Electronic Media and
Visual Arts

Elektronische Medien und
Kunst Kultur Historie

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12. - 14. March - 2025

Artificial Intelligence
Digitality
Culture

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(form. Staatliche Museen zu Berlin)

From Concept to Reality:
Analyzing the Role of AI in Architectural Visualization and Design

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ABSTRACT: AI seems poised to radically transform architecture, with the potential to fundamentally reshape the role of the architect. From generating preliminary designs to analyzing structural integrity and optimizing energy efficiency, AI tools are becoming increasingly prevalent in architectural processes. Large Language Models (LLMs), in particular, show promise as valuable aids in the conceptualization and design phases of projects. A growing number of AI-driven platforms are now available online, offering tools that support architects in creating detailed renderings and visualizations. But is AI truly revolutionary for architectural design? Furthermore, is AI able to automate tedious tasks, allowing architects to focus more on innovative aspects of their work, or are we mainly delegating the creative process to AI? To address these questions, this paper investigates the role of AI in architectural work, by mapping over 80 available tools across the different phases of building conceptualization and design.

Keywords: AI in Architecture, Large Language Models (LLMs), Architectural Visualization, Design Automation, AI Tools Evaluation

1. INTRODUCTION

Artificial Intelligence (AI) is positioned to transform the architectural field profoundly, introducing new methodologies that have the potential to redefine the role of the architect and reshape the design process itself [1] technologies are increasingly applied across diverse aspects of architectural practice, spanning early conceptualization to detailed design phases. By automating repetitive tasks and introducing advanced analytical capabilities, these tools offer the potential to streamline workflows and enhance design outcomes. Within this landscape, the Large Language Models (LLMs), have emerged as powerful tools, playing a pivotal role in aiding the conceptualization and initial design phases. LLMs enable architects to interpret and transform design intents derived from textual descriptions, sketches, or 3D models, facilitating the realization of creative ideas with greater efficiency [2]. Developers of AI-powered software assert that these tools significantly enhance architectural visualization and rendering by bringing abstract design concepts to life with remarkable precision. The ability of such tools to generate photorealistic and contextually rich renderings has not only accelerated the iterative design process but also improved the communication of design intent to clients and stakeholders [3]. Furthermore, the rapid growth of AI-driven online platforms has expanded the accessibility of sophisticated tools that assist architects in producing detailed renderings and exploring innovative design possibilities. These platforms offer a wide array of functionalities, from enhancing creative outputs to optimizing technical performance metrics such as energy efficiency and structural integrity [4]. Despite these advancements, the integration of AI into architecture raises critical considerations about its effectiveness and impact on traditional design workflows.

The central focus of this study is to explore how AI tools are applied across key architectural phases, their effectiveness in enhancing creativity, and their role in maintaining structural and functional soundness. By examining the rapidly evolving market of online AI tools, this paper investigates how these technologies integrate into established phases of architectural practice, namely Predesign, Concept Design, Developed Design, and Detailed Design [5].

To address these topics, over 80 AI-driven tools were identified and categorized based on their applications within specific stages of the architectural workflow. This comprehensive mapping offers insights into the role of AI in enhancing traditional practices and supporting

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new methodologies. The results provide valuable insights into the transformative potential of these technologies, demonstrating their ability to enhance creative exploration while also revealing areas where further development is needed to meet the rigorous demands of architectural practice. By situating these findings within the broader context of AI and architecture, this study contributes to the ongoing discourse on integrating computational technologies into design practices. The implications of these advancements are significant, not only for the evolving roles of architects but also for the broader architectural industry, as AI tools continue to redefine the boundaries of what is creatively and technically possible.

The structure of this paper is organized as follows: Section 2 reviews a selection of recent studies, providing context and comparison with our approach. Section 3 outlines the architectural design workflow, identifying specific phases where AI can be effectively applied. Section 4 introduces the seven distinct groups of tools identified in this study, offering examples of their applications and a comprehensive list of tools within each group. Finally, Section 5 concludes the paper with key insights, and Section 6 provides a complete list of references.

2. RELATED WORK

There is a vast body of literature on the use of AI in architecture; however, providing a comprehensive review of this topic is beyond the scope of this paper. Instead, this section highlights a selection of very recent studies (published in 2023-2024) that specifically examine the relationship between AI applications and the architectural representation and design process, emphasizing how these approaches differ from ours.

An interesting contribution focusing on this relationship is a study by Horvath and Pouliou,[6], exploring the use of generative AI tools (specifically text-to-text, text-to-image, and image-to-image applications) within the conceptual design process for the 2022 eVolo Skyscraper Competition. The competition emphasized innovative approaches to skyscraper design, urging participants to address themes such as novel technologies, sustainability, and urban relationships. The study provided practical workflows and subjective evaluations of AI-generated outputs, offering insights into how such tools can shape conceptual architectural projects. A similar study is proposed in [7], where authors present data obtained during three experimental sessions, with 5-6 participants working individually on the same task, designing a concept for a cultural center. Participants were asked to create visual representations of their concepts, including a floorplan, an interior perspective visualization, and a facade material sample, using three popular text-to-image generators: Midjourney [8], Stable Diffusion [9], and DALL-E [10]. Through standardized questionnaires and group interviews, the authors found that generative tools fostered serendipitous idea discovery and encouraged an imaginative mindset, enhancing the design process. The study concluded that image generation can play a meaningful role in the design process, provided that design constraints are carefully considered. While the practical methodology of both [6] and [7] aligns with our approach, the paper’s focus is limited to three groups of AI applications, primarily related to the early stages of the design and construction process.

Focused on a larger view of the process, the study presented in [11] explores the potential of AI algorithms across the construction process, emphasizing their role in enhancing safety and efficiency. By analyzing scientific publications from databases like Scopus and Web of Science (from 2020 to 2024) this research provides a comprehensive overview of AI applications in this context. Key technologies examined include 3D modeling for building design, machine learning for conceptualizing designs, computer vision for equipment management, and advanced AI techniques such as genetic algorithms and adaptive programming. The work presents a novel conceptual framework and categorical definitions to guide further advancements in the sector.

Similarly, in [12] authors propose an up to date and comprehensive review of journals and conferences in architectural design, engineering, urban planning, and computer science to delineate AI’s role across the stage of architectural representation and design process stages. The paper presents an overview of generative AI technologies, focusing on probabilistic diffusion models (DDPMs), 3D generative models, and foundation models. It also explores how these models can be applied to architecture, splitting the architectural design process into six distinct steps and for each step, the paper reviews relevant research projects conducted from 2020 to 2024.The architectural workflow used by authors is taken from *The*

Professional Practice of Architectural Working Drawings [13] and progresses through logical steps: conceptual design, 3D form generation, floor planning, structural system design, facade design, and section design. Both papers [11, 12], despite employing different phase divisions compared to each other and our study, emphasize the importance of linking the use of AI in architecture to the stages of the workflow. However, they primarily focus on research projects and pubblications, whereas our study centers on the actual availability of tools that can be readily applied in the daily practice of an architect's work.

3. ARCHITECTURAL DESIGN WORKFLOW

Designing and constructing a building is a complex task, typically approached through a sequence of sub-activities. Defining a workflow divided into formal phases helps streamline the design process and provides a clear, unified framework for all parties involved. Various organizations and national architects' associations propose models for organizing this workflow. One of the most well-known is the model developed by the American Institute of Architects (AIA), widely cited in the literature. This model consists of five phases [14]: schematic design, design development, construction documentation, bidding or negotiation, and construction.

Another, more structured alternative, chosen in the absence of an Italian model, is the framework proposed by the New Zealand Institute of Architects (NZIA). It includes seven phases [5]: preliminary design, conceptual design, developed design, detailed design, contract administration, project observation, and completion. Objectives and deliverables of these phases are:

- Predesign Phase (F1): This initial phase focuses on fully understanding the client’s needs and aspirations, as well as the unique characteristics of the site. Deliverables typically include an initial project vision, which may consist of a structured description of identified requirements, preliminary analyses, and preparatory sketches.
- Developed Design Phase (F3): The project concept is further detailed and translated into construction-ready elements. Architectural drawings are created with material specifications, finish details, structural solutions, and systems designs. These may include technical schematics and, where applicable, Building Information Modeling (BIM) outputs.
- Detailed Design Phase (F4): This phase involves preparing all documentation required for regulatory approvals and the start of construction. Deliverables include final project drawings, structural calculations, technical reports, construction details, and comprehensive material and component specifications. All necessary documentation for construction permits is also included.
- Concept Design Phase (F2): In this phase, initial ideas are refined based on information gathered during predesign. The goal is to develop a strong design concept that addresses the client’s requirements and site constraints. Outputs include drawings, diagrams, and 3D models illustrating the project concept, along with a preliminary cost estimate and a tentative timeline.
- Realization Phases (F5, F6, F7): The last phases outlined by NZIA [5] are focused on the actual realization of the building. During the Bidding Phase (F5), contracts with the builder are negotiated. This is followed by the Construction Phase (F6), where the physical execution of the project takes place. Finally, the Completion Phase (F7) involves project delivery, including inspections and evaluations to assess the project’s success and formalize the handover to the client.

Figure 1 illustrates the seven phases of the workflow, along with the deliverables associated with the first four phases (F1-F4), which represent the early stages of the design process. These deliverables are considered as digital documents generated during each phase. To enhance the production of these documents, we identified seven distinct types of AI tools that can support, improve, or facilitate the architect's workflow. Each group of tools is defined by its primary AI-based features, considering the required inputs and the outputs they provide.

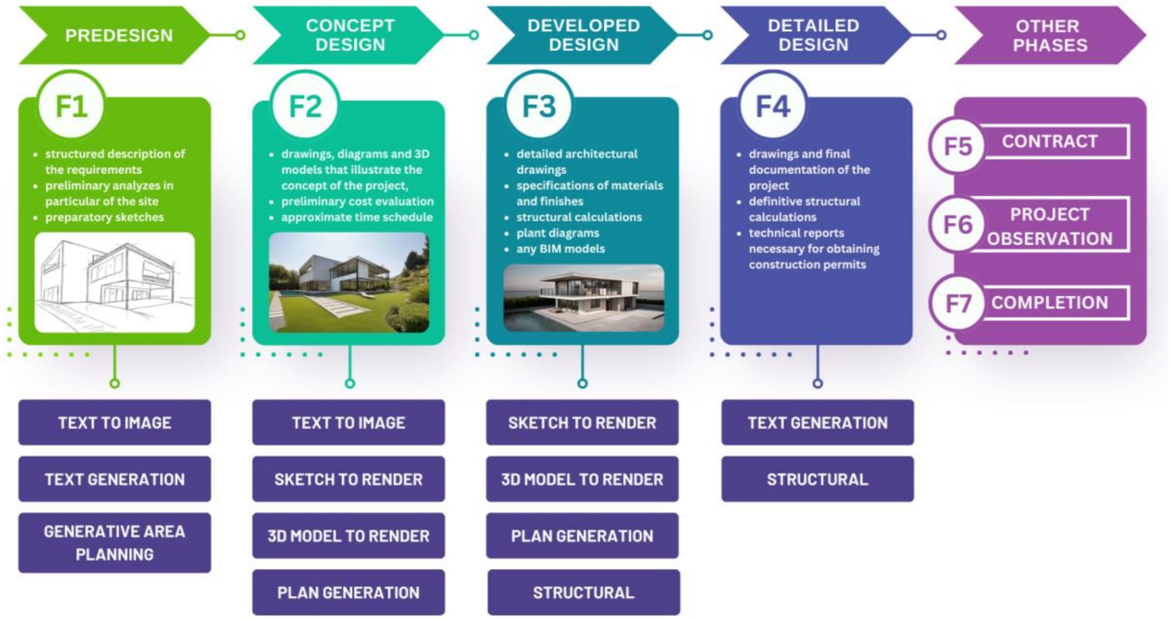

Figure 1: *Workflow Phases and groups of AI tools*

The identified categories are: text generation, generative area planning, text-to-image, sketch-to-render, 3D model-to-render, plan and building generation, and structural calculation with energy optimization. Figure 1 also depicts the relationships between these groups of applications, which are further discussed in Section 4.

4. AI IN ARCHITECTURAL DESIGN WORKFLOW

The collection of 80 tools was compiled through extensive online research. This survey identified several websites offering lists, ranging from structured to more general, on the use of AI in architectural design (e.g., [15], [16] [17], [18]). Additional tools were included based on targeted searches aligned with the categories under consideration (e.g. [19], [20], [21], [22]). While not intended to be exhaustive, the aim was to gather representative examples covering most existing use cases.

This Section summarizes the key AI technologies identified as applicable in the early design stages, organizing them by categories of systems with similar functions. These technologies are then correlated with the previously discussed phases, from F1 to F4, to highlight their relevance and application within each stage.

4.1 TEXT GENERATION

Text generation systems leverage deep neural networks (DNNs) to produce coherent and relevant text sequences based on input prompts. These systems, such as GPT models developed by OpenAI [23] and Google Gemini [24], use Transformer architectures to generate realistic text across diverse contexts, from conversations to creative content. Openly licensed models can also be fine-tuned on specific text types to enhance performance for specialized tasks. In architectural design workflows, text generation tools can support the creation of documentation, from predesign descriptions and analyses (F1) to detailed design reports (F4). However, no systems are currently tailored for generating architecture-specific documentation, which would require a dedicated corpus of digital texts [25]. For the purposes of this study, we have considered only a few main tools of this type, purely for illustrative purposes:

1. ChatGPT: https://chatgpt.com/
2. Google Gemini: https://gemini.google.com/app?hl=it
3. Microsoft Copilot: https://www.microsoft.com/it-it/microsoft-copilot?market=it

4.2 GENERATIVE AREA PLANNING

Figure 2: *DBF Digital Blue Foam*

This group of applications includes systems designed to support the planning of entire urban areas. They facilitate tasks ranging from selecting a city block to assessing its potential and developing projects compliant with local regulations, while addressing broader urban development aspects. These tools, aimed at professional use, employ AI to optimize economic outcomes based on zoning parameters and evaluate various configurations, sometimes extending to detailed building design. Primarily intended for real estate activities, their effectiveness varies significantly depending on the country and region. In this study, these tools are considered as potential support for the Predesign Phase (F1), as they assist in site selection. However, once such a tool is adopted, it may also support subsequent workflow stages, offering functions that span from initial site selection and conceptual composition to detailed integration with BIM systems. An example of such a tool is presented in Figure 2, illustrating the demonstrative project by Digital Blue Foam [26]. This category of tools was not deeply examined due to their complexity, the challenges in generating broadly applicable case studies, and high licensing costs. These tools were cataloged without claiming exhaustive coverage. Applications included in this group are:

4. Archistar: https://www. archistar.ai/for-property-developers/
5. Architechtures: https://architechtures.com/en
6. Autodesk Forma: https://www.autodesk. com/products/forma/free-trial
7. Conix AI: https://conix.ai/
8. Delve: https://www.sidewalklabs.com/ products/delve
9. Digital Blue Foam: https://www.digitalbluefoam.com/
10. Kolega Space: https://www.kolega.space/
11. Qbiq: https://qbiq.ai/
12. TestFitAI: https://www.testfit.io/
13. Togal.AI: https://www.togal.ai/

4.3 TEXT TO IMAGE

Text-to-image systems leverage AI to generate realistic images from textual descriptions, enabling the easy creation of unique visual content. These systems are widely used across various fields, including design, digital content creation, concept art, and architectural design [27, 28] Their widespread adoption has been facilitated by the availability of advanced engines released under licenses that permit commercial use. These engines can be fine-tuned with additional datasets and employed to deliver tailored services.

In the architectural design workflow, such systems can support the production of preliminary sketches (Predesign, F1) and concept designs (Concept Design, F2). General-purpose applications, like MidJourney [8], a proprietary system whose AI technologies are not disclosed, are frequently utilized for these purposes. Additionally, domain-specific tools such as NovArch AI [29] and Rendair [30] have been developed specifically for architecture. These specialized applications are trained to deliver photorealistic renderings of architectural drawings, with particular attention to aspects like lighting and materials. A Screenshot of Rendair, working in text-to-image mode, is showed in Figure 3.

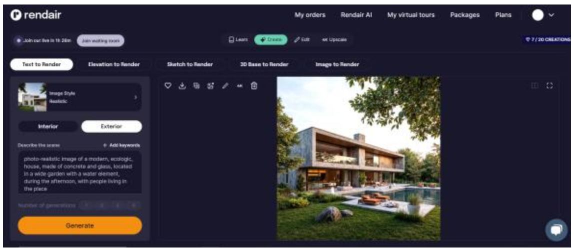

Figure 3: *Text-to-image with Rendair*

Many image-generation systems offer both straightforward creation from text prompts and the ability to combine text prompts with a starting image, such as sketches, models, or backgrounds. This functionality, considered distinct within the scope of our study, is detailed in the following Subsection 4.4. A non-exhaustive list of text-to-image systems is provided below:

14. Adobe Firefly: https://firefly.adobe.com/ ?ref=site.co-architecture.com
15. ArtGuru AI: https://www.artguru.ai/it/
16. Bing Image Creator: https://www.bing.com/images/create
17. Canva AI: https://www.canva.com/it_it/ generatore-immagini-ai/
18. Craiyon: https://www.craiyon.com/

19. Dall-E: https://openai.com/dall-e-2
20. DaVinci: https://davinci.ai/
21. DeepDream: https://deepdreamgenerator.com/
22. DreamAI by Wombo: https://dream.ai/
23. DreamStudio AI: https://beta.dreamstudio.ai/generate
24. Fotor: https://www.fotor.com/features/ ai-architecture/
25. Generative AI by Getty: https://www. gettyimages.it/ia/generazione/informazioni
26. ImageFX: https://aitestkitchen .with-google.com/tools/image-fx
27. LeonardoAI: https://app.leonardo.ai/
28. LookX AI: https://www.lookx.ai/
29. MidJourney: https://www.midjour-ney.com/home
30. NightCafe AI: https://creator.nightcafe. studio/collection/IhDIzzJI4HTOhzGKzQbj
31. NovArch AI: https://ai.novarch.us/
32. OpenArtAI: https://openart.ai/
33. PromeAI: https://www.promeai.com/
34. Rendair: https://www.rendaircorp.com/
35. Stable Diffusion: https://stablediffusionweb.com/it

4.4 SKETCH TO RENDER

This group of tool is designed to quickly transform sketches, empty spaces, or inspirational images into high-quality renderings using textual descriptions. In some applications, these features are explicitly labeled as "*sketch-to-render*", highlighting that the base image for the rendering can be a simple sketch. However, alongside the image, the content of the prompt describing the desired rendering characteristics is equally crucial. It is important to note that these systems do not perform 3D model rendering through vector-based representation. Instead, they generate an image by referencing both the sketch and the textual description of the desired outcome.
An example of image generetad from a sketch with Rendair [30] is depicte in the folllowing Figure 4.

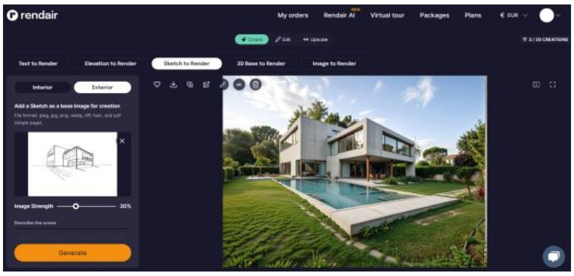

Figure 4: *Scketch to image with Rendair*

Among tools that transform images using text prompts as a guide, several applications support architects in areas such as interior design and virtual staging**.** These tools can create interior designs starting from realistic images of existing spaces. This functionality can operate in various ways: sometimes by furnishing or modernizing images of empty or pre-furnished spaces, and other times by working directly from floor plans to generate a version that includes furniture layouts.
Other applications assist in a form of virtual renovation, producing images of the interiors or exteriors of existing buildings with enhancements or updates that reflect a more modern or improved state.

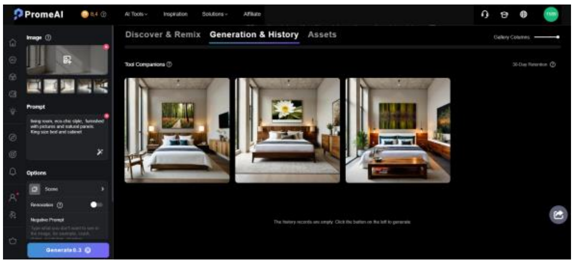

Figure 5: *Virtual staging with PromeAI*

Other applications assist in a form of virtual renovation, producing images of the interiors or exteriors of existing buildings with enhancements or updates that reflect a more modern or improved state. Collected tools included in this group are the following:

28. LookX AI: https://www.lookx.ai/
32. OpenArtAI: https://openart.ai/
33. PromeAI: https://www.promeai.com/
34. Rendair: https://www.rendaircorp.com/
36. AIRoomPlanner: https://airoomplanner.com/
37. ArchitectAI: https://architectai.app/
38. ArchitectGPT: https://www.architectgpt.io/
39. Architect Render: https://www.architectrender.com/
40. Archivinci: https://www.archivinci.com/
41. Archsynth: https://www.archsynth.com/
42. D5Render: https://www.d5render.com/
43. DecorAI: https://decorai.io/
44. DesignedbyAI: https://designedbyai.io/
45. Dream House AI: https://dreamhouseai.com/
46. FoyrNeo: https://foyr.com/neo-interior-design-software/
47. Gaia: https://www.gaia.computer/
48. Home by me: https://home.by.me/en/
49. HomedesignsAI: https://homedesigns.ai/
50. InteriorAI: https://interiorai.com/
51. Maket.ai: https://www.maket.ai/
52. Mnml Architecture: https://mnml.ai/

53. Modelo AI Genaration: https://www.modelo.io/ai-inspiration?hl=en
54. MyArchitectAI: https://www.myarchitectai.com/
55. ReimagineHome: https://www.reimaginehome.ai/
56. ReRenderAI: https://rerenderai.com/
57. RoomsGPT: https://www.roomsgpt.io/
58. Sketch2render: https://sketch2render.com/
59. Visoid: https://www.visoid.com/

4.5 3D MODEL TO RENDER

These tools leverage AI techniques to generate renderings from two- or three-dimensional models, often integrating directly with professional design software such as SketchUp [32], Revit [33], Rhino3D [34], or Archicad [35]. Most of these systems operate on a single view at a time, applying image-generation technologies to a highly detailed base image derived from a model. By functioning as extensions (libraries, plug-ins, or add-ins) within modeling programs, these tools provide additional features to produce photorealistic renderings significantly faster than traditional methods. They typically include customizable rendering options, enabling users to select materials, lighting, and additional elements such as trees, vehicles, and people.
The benefits of these tools extend beyond speed. They also enhance the level of detail in the final output, striving for greater realism through complex lighting, textures, and spatial relationships [36]. Additionally, to cater to a broad user base, many tools are compatible with various modeling systems. An example is shown in Figure 6 which presents a screenshot of ArkoAI [37] being used for rendering models in Rhino3D [34].

Figure 6: *Rendering models in Rhino3D with ArkoAI*

Applications collected in this group are:
42. D5Render: https://www.d5render.com/
60. Archicad AI Visualizer: https://graphisoft.com/it/solutions/innovation/archicad-ai-visualizer
61. ArkoAI: https://arko.ai/
62. Coohom: https://www.coohom.com/
63. Enscape: https://enscape3d.com/it/
64. Planner5D: https://planner5d.com/use/ai-interior-design
65. SketchUp Diffusion: https://help.sketchup.com/en/diffusion-features
66. Veras: https://www.evolvelab.io/veras

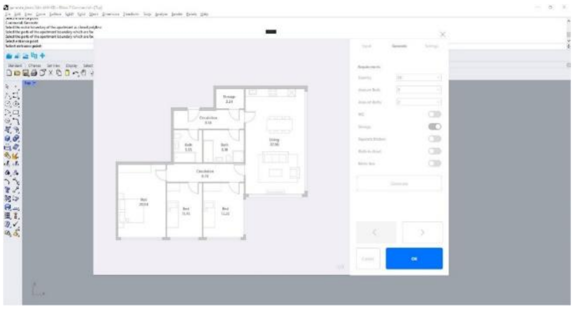

Figure 7: *Rendering models in Rhino3D with ArkoAI.*

4.6 PLAN & BUILDING GENERATION

Generative AI tools that produce floor plans can operate at various levels, ranging from creating individual apartment layouts to generating entire residential or office buildings comprising multiple floors [38].
Specifically, this group of tools can be divided into two categories:

a. Applications for generating single apartment or space layouts based on input constraints and requirements**.** These tools gather user needs through input forms where spaces, their characteristics, constraints, and dimensions are defined. Based on these basic parameters, the system generates a set of corresponding floor plans from which the user can choose and refine further. Such applications are available both as standalone systems that produce standard formats, such as Maket.ai [39], and as libraries or plugins for vector modeling systems, such as PlanFinder. Figure 7 shows an example of using PlanFinder [40] to generate floor plans in Rhino3D [34].
b. Applications for generating layouts of entire building floors, enabling rapid exploration of multiple layouts and evaluation of factors such as profitability and density. Some feature of these tools overlap with, and are sometimes integrated into, generative area planning systems discussed in Section 4.2.

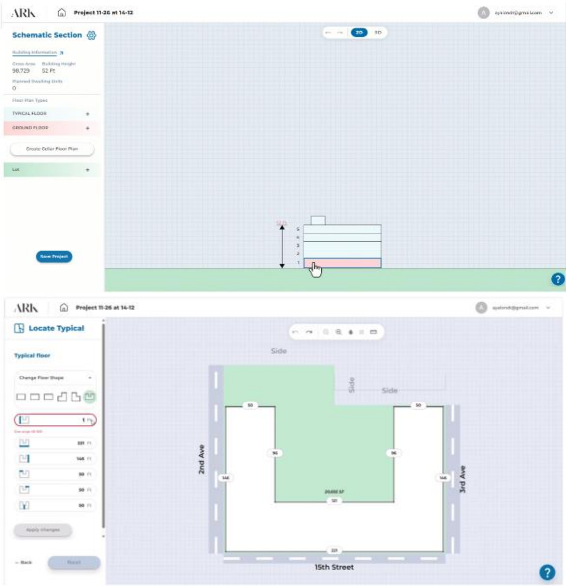

Figure 8: *Floor plan generation using ArkDesign*

One example of such a tool is ArkDesign [41], an architectural design platform that operates in three phases: defining project specifications, automatically generating multiple layout configurations (while adhering to project specifications and building codes), and modifying or customizing the generated layouts. These tools produce floor plans that integrate with 2D and 3D design applications, such as Revit [33] and Rhino3D [34]. Figure 8 shows two screenshots of floor plan generation using ArkDesign [41]. Tools included in this group are as follows:

51. Maket.ai: https://www.maket.ai/
64. Planner5D: https://planner5d.com/use/ai-interior-design
67. ArkDesign: https://arkdesign.ai/
68. Finch3D: https://www.finch3d.com/
69. Hypar: https://hypar.io/
70. Laiout: https://www.laiout.co/
71. Morfis: https://www.evolvelab.io/morphis
72. PlanFinder: https://www.planfinder.xyz/
73. Skema: https://www.skema.ai/

4.7 STRUCTURAL CALCULATION AND ENERGY OPTIMIZATION

There is a vast body of literature on the use of AI techniques in structural calculations and optimization, spanning both scientific and general-audience publications [42, 43]. The online tools of this type cater to various objectives, ranging from structural calculations to building optimization, including energy efficiency and environmental impact. Specifically, the available tools serve the following purposes:

a. Supporting structural calculations. These applications combine traditional methods with AI techniques to simplify aspects of structural calculations. Examples include Pathw.ai [44], tailored for steel structures; Daisy [45], designed for wooden structures; and Tango Builder [46], which also handles reinforced concrete. A screenshot of Tango Builder [46] is presented in Figure 9.

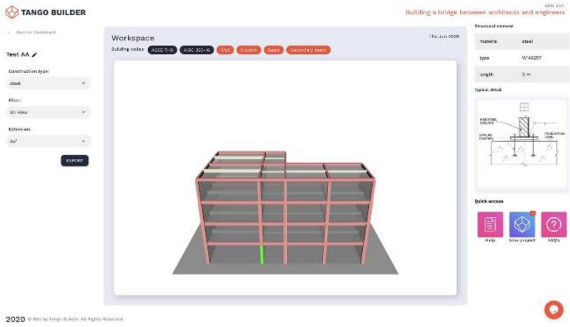

Figure 9: *Structural calculations in Tango Builder*

b. Optimizing resource use. An example of this type of tool is Structure Pal [47], an Autodesk-integrated application that assists designers in reducing concrete use, thereby lowering costs and CO_2 emissions. A screenshot of this tool is shown in Figure 10.
c. Optimizing design for sustainability. A notable tool in this category is Cove Analysis [48], which generates numerous models and simulations to facilitate the development of more sustainable buildings. Its features include: (i) accurate energy models based on the project's location; (ii) annual daylight simulations; (iii) cost optimization, balancing energy use and environmental impact; (iv) effective water usage strategies; (v) solar radiation studies for panel placement; (vi) climate and acoustic reverberation analysis; (vii) comprehensive carbon profiles that allow comparisons of embodied and operational carbon to evaluate a building's impact over its lifecycle. A screenshot illustrating daylight measurement in indoor spaces is shown in Figure 11.

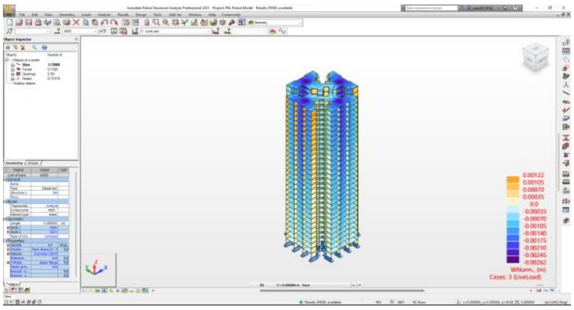

Figure 10*: Structural optimization with Structure Pal*

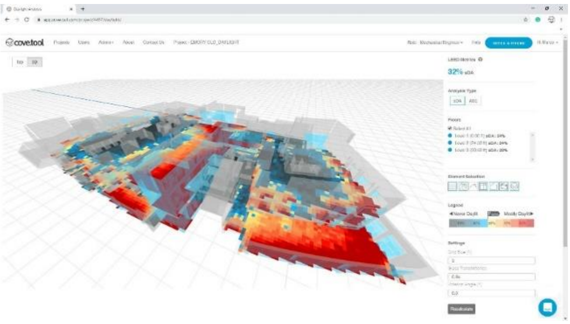

Figure 11: *Cove Analysis- Measuring daylight in indoor spaces*

The tools categorized in this group are:

74. Asterisk: https://asterisk.thorntontomasetti.com/
75. Cove Analisys: https://cove.tools/products/analysis-tool
76. Daisy: https://daisy.ai/
77. One Click LCA: https://www.oneclicklca.com/
78. Pathw.ai: https://www.pathw.ai/
79. Structure Pal: https://www.structure-pal.com/
80. Structure+: https://www.structure.plus/
81. Tango Builder: https://wp.jarvisdesign.ai/

5. CONCLUSION

This paper has identified the primary groups of artificial intelligence tools that intervene in the workflow of architectural representation and design. The focus on such a practical goal is rooted in a careful reading of texts that discuss AI in architecture [2], with a particular emphasis on conceptual aspects. In particular, Leach's ten predictions on AI and the future of architecture [1] have prompted the desire to verify concretely the availability of existing applications and to assess the potential support that these can currently offer to the work of architects.

The market for AI tools in architectural design is rapidly evolving. New tools are constantly being developed and existing ones are frequently updated, making it challenging to keep track of the latest offerings. This rapid pace of change indicates a growing but still not completely mature technology. While there are no comprehensive databases specifically for architectural AI tools, the market's dynamism suggests that such a resource would be valuable. Grouping the tools has been complicated by the presence of many applications with diverse functions, which, by their nature, can belong to multiple groups or, while clearly fitting within one group, also serve marginal roles in others. By the end of this analysis, two main types of applications emerged: (i) complex, typically paid applications, which offer specialized functions for architecture, developed to address specific challenges in architectural representation and design (such as those discussed in Subsection 4.2 or in Subsection 4.7), and (ii) widely used generative applications (for creating text or images), often available with free basic licenses, but not specifically trained on architectural datasets (such as those discussed in Subsection 4.1 and the most part of the one in Subsection 4.3). To expedite the realization of Leach's 6th prediction [1]: "*AI will become an indispensable, invisible assistant in all architectural offices, automating the design process*" the list of tools that use AI technologies should be constantly expanded and updated, making it easier to find the right tools and building a useful reference in the field of architectural design and architecture in general.

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Memory, Ghosts and Trauma.
AI-Generated Photorealism Beyond the Deepfake

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ABSTRACT: This paper explores photorealistic AI-generated images as devices for experimentation with documentary realism. In contrast to deepfakes created with the intent to deceive, the AI-generated images addressed in this paper explore the latent space of that *which didn't happen*. While lens-based photography claimed to be a visual record of the past, algorithmically generated, photorealistic images seem to 'document' events that (may) never (have) occurred. While it is commonly known that photographic film has been retouched and manipulated early on, AI-generated images construct a new type of pseudo-photographic 'evidence' tied to processes of statistics and speculation, that convey a sense of plausibility. Beyond fleeting image discourses taking place in the form of memes, decolonial artistic practices as well as memory-related cultural initiatives and forms of therapy have recently started to tap into this potential – begging the question: How may we seize photorealism's mnemonic powers in a post-truth era?

1. INTRODUCTION

„I believe, and so do you, that things could have been different in countless ways. [...] I therefore believe in the existence of entities that might be called ‚ways things could have been'. I prefer to call them ‚possible worlds'" [1]

Since text-to-image generators produce endless imaging possibilities, it's no surprise that they inspire pictorial speculations. These, however, strike a very peculiar chord when not directed towards the future, but when exploiting photography's powerful legacy as a visual record of the past. As a genre of its own, images of this kind differ from deepfakes, fantasy and science-fiction. While utopias and dystopias imagine possible futures, algorithmically generated photorealistic images 'of the past' explore the counterfactual – that, which could have been [2].

Interestingly, the visualization of alternative pasts exploits AI image generation in a way that corresponds to its intrinsic logic. In contrast to the 'decisive moment' as a crucial factor in camera-based photography, AI-generated images emerge as random outputs

Figure 1: *In 2021, this image macro (using a film still from the TV show "Danger 5") was posted in the Reddit forum 'dankmemes'. Memes of this type refer to the butterfly effect from chaos theory, which states that a small change to the past could have massive consequences on the present.*

from an infinite realm of unrealized images that the same prompt could potentially have produced. In other words: AI-generated images of events that never occurred (or events, that may have occurred, but remained undocumented) correlate with the workings of generative models, in as much as they explore the 'latent space' of our reality, if you will [fig. 1].

2. MAIN ASPECTS

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After elaborating on the ‘latent space’ and ‘counterfactuals’ in AI models from a technical perspective and after setting AI-generated photorealism apart form previous instances of Post-Photography, my paper features a series of examples, starting with references to art history and contemporary art.

While anolog photography provided historical Surrealism with an ideal medium for the group’s intended manipulations of the fabric of the real [3], artists using AI image generation today (such as Phil Toledano in his project “Another America”, 2023) can often be seen deploying surrealist styles, which unsettle their stunningly photorealistic creations.

Recent feminist and decolonial art practices, on the other hand (such as Claudia Larcher's “AI and the Art of Historical Reinterpretation. Filling Gender Bias Gaps”, or Susana Pilar Delahante Matienzo's “Achievement”, both from 2024), seek to counter historiographic, misogynist and colonial violence by creating archives of AI-generated images that supplement our photographic legacy with imagined images of women as leading figures in politics, art and philosophy in the mid 20th century and of people of colour as reputable members of US-american society before the Civil War. Projects like these conflate the promises of AI-generated photorealism with its perils as harbinger of a post-truth era.

My agrumentation moves on to examples from the broader cultural field. Initiatives such as a refugee project by the Spanish agency Domestic Data Streamers seek to transform oral history into archivable, pseudo-photographic documents by means of text-to-image models. Dementia therapy tools like Rememo (by Celeste Seah) or Kodak Memory Shot, on the other hand, stabilize fleeting memories as AI-generated ‘polaroids’.

Our photographic legacy is, as it seems, soon to compete with AI-generated image archives. But even ‘real’ photographs can from now on fall prey to AI-generated image animation. Applications of this technology are not solely playful. While Roland Barthes once worked out photography’s indexical qualities meditating on his late mother’s lingering presence in his family photo albums, Grief Tech brings deceised loved ones back to life as images that speak to us from the afterlife.

3. CONCLUSION

Since image generation models started yielding photorealistic results one year ago, we find ourselves yet again at a turning point in visual culture. Digital signatures and labels (such as Meta’s AI Info) will hardly stop the status of photography as a truthful document of the past from eroding, since the most fundamental changes brought about by our new image environments affect our perception.

Already now the past, which was once a space of alterity, is being eagerly reinterpreted – at the risk of short-circuiting everything with current clichés and ideologies. But as we sacrifice photography for the ‘photograh-ish’, new functions may arise.

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Authorship and AI –
Considering the Copyright Protection of AI-Generated Materials

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ABSTRACT: The question of whether AI-generated content (AIGC) should be granted copyright protection is controversial. The United States and China have come to apparently opposing conclusions on the question. This paper suggests that clarity can be found through revisiting the origins and purpose of copyright. Copyright systems developed to protect human creations around the world, influenced by the commodification of works and the recognition of the author's personal dignity within them. The foundation of copyright is the notion of "authorship." The advent of Generative AI has prompted a reevaluation of authorship and human creativity. Historically, authorship was primarily associated with labour, skill, and judgment, but this standard gradually was replaced by "creativity." The creation process of AIGC may involve significant labour, selection (skill), and arrangement (judgment), prompting a reconsideration of whether understanding of authorship in the context of AI should return to an earlier standard. AI prompt input and post-generation editing may reflect a certain degree of the AI user's personality, which raises the question of moral rights. Generative AI has also provoked copyright policy considerations, such as, whether there is a state interest in promoting high-quality AIGC and concerns about AIGC replacing human art. This paper explores the development of copyright, some of its justifications, and how technology forces the doctrine to evolve in order to then examine several instances where AIGC has been evaluated for protectability, and suggest some considerations for those determinations.

1. INTRODUCTION

As a result of the rise of easily accessible, easily used generative artificial intelligence (AI) a host of new challenges to the traditional framework of copyright have also become apparent. Setting aside the questionable legality of the use of copyright-protected training materials involved in training large language and diffusion models (a highly controversial issue, which remains outstanding in a number of jurisdictions), this paper concerns itself with whether or not the materials produced with the assistance of AI models should be protectable by copyright.

It is without question that AI models can be useful in creative production, from the creation of visual art like paintings to generating text, or even "resurrecting" a deceased actor (just a few of the uses to which AI has been put). AI technology has been involved in legitimate artistic creation from the art of AARON an "expert's system" built by Harold Cohen in the 1970's to modern-day uses like the Blind Canvas project, which uses AI to create visual illustrations of the experience of vision loss, visual impairment and blindness [1]. These examples illustrate that AI can be an artist's tool, and if ethically designed and used, perhaps more value-neutral than it might at first appear.

While AI can be useful, there is no global consensus on whether AI-generated content (AIGC) should be granted copyright protection. To answer this question, it is essential to reconsider the basic threshold of protectability. Due to the territorial nature of copyright,conditions for obtaining copyright protection vary from country to country. However, authorship is a universally recognized core requirement. the exact scope of what constitutes authorship varies; for example, the us standard is that work must have "independent creation plus a modicum of creativity"[2], while the EU standard is that the

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protected work must result from “an original expression of the creative freedom of its author” [3].

The first part of this paper will address the philosophical underpinning of authorship and how this relates to the advent of copyright law and the grant of copyright protection. The second part of the paper will explore the jurisdictions that have formally addressed the protectability of AIGC in order to assess the consistency of those decisions. This paper will conclude that the copyright crisis raised by generative AI provides an opportunity to re-examine copyright and reconsider the meaning of authorship, the purpose of copyright, and the nature of creativity.

2. AUTHORSHIP

2.1 ORIGIN OF AUTHORSHIP

Creative works, and the creators of those works have not always been protected by copyright. This is a modern invention that allows for the commodification of creative works and incentivisation of the author. It arises, in part, out of a recognition that those who create works of authorship occupy a special position in society and that there is a connection between the author and the works they create. This recognition has led to a legal framework placed around the output of creative people providing monopolistic control for a period of years. Authors (creators, artists, writers, etc.) serve an important function in our societies, telling our stories and reflecting our values. “… the history of our thought is bound up with conceptions of what it means to author a text…” [4].

From the middle ages to the early modern period, the protection of a work of authorship vested in the owner of the physical manifestation of the work, and state interest in censorship, but over time this has changed. Influenced by the Enlightenment, policy developed to realize the value inherent in human investments of labour and creativity [5]. This investment in the creation of works gradually gained recognition and ultimately received legal protection as intangible property [6].

The connection between authors and their works [7], along with an interest in censorship and the commodification of art, [8] drove the development of this right, but “before authors could become professionals, however, a certain level of production and consumption of printed materials had to be attained” [9]. In the early part of the 18th century in England, the creation and consumption of literary works rose to this level. In 1710, the Statute of Anne provided legal protection for books, granting “authors and their assignees” the exclusive right to publish books for 14 years [10]. Ostensibly, the purpose of the Statute of Anne was to “reward authors to encourage learning”, but in reality, it was more likely aimed at protecting the interests of publishers [11].

Although it was initially a tactic used by booksellers to achieve indirect monopolies on books, with the development of a commodity-based economy and the integration of continental Europe’s emphasis on the dignity of authors, the purpose of copyright evolved to balance public benefits with authors’ rights [12]. Regardless of the original intent of the Statute of Anne, it marked the first time that the “human investment” in books was explicitly protected by law. In this shift one finds the creators of books transitioning from being mere “writers” to legally protected “authors,” and the Enlightenment notion of the special stature of authors enshrined in law.

2.2 AUTHORSHIP & COPYRIGHT

The term author encompasses more than simply the originator of a written text. Under the law, works of authorship have been defined as ‘literary and artistic works… [including] writing, dramatic works, choreographic works, architectural works, drawing, sculpture, audio recordings…” to name just a few of the types of expressive works encompassed by the term [13].

Copyright generally protects both the commercial value of a work and the personal dignity of the author embodied within the work. It does so by granting authors a temporary monopoly (presently the life of the author plus an additional 70 years after death in many jurisdictions) over their creations. The commercial value of works is realized by providing authors with economic rights, such as the exclusive right to publish and distribute. The personal dignity of the author is protected through the grant of moral rights, such as the right of attribution and the right to prevent interference with the integrity of the work. It should be noted that the economic monopoly is generally not permanent, but in many jurisdictions moral rights are.

Following the Statute of Anne, many countries on the European continent also established systems for the protection of works. For example, in France, two copyright laws of 1791 and 1793 remained the essential copyright legislation of France until 1957 [14]. Continental European countries placed greater emphasis on the personal connection between the work and its author [15]. Safeguarding the dignity of the author embodied in the work through ensuring the integrity and patrimony of that work was seen as an essential component of protecting a work [16]

Generally, countries have established their own modern copyright systems and use the Berne Convention as the minimum standard of protection, combined with their national copyright philosophies. The dis-harmony in copyright laws around the world is, in part, an extension of differing interpretations of the notion of "authorship." In continental Europe, where authorship emphasises the connection between the author and their work, copyright law places significant importance on protecting the moral rights of authors. In contrast, in the United States and the United Kingdom, the doctrine focuses on the incentivisation of creation through remuneration of the author.

2.3 AUTHORSHIP & ORIGINALITY

The advent of copyright legislation, which enabled the commodification and propertisation of works across many jurisdictions throughout the 18th and 19th centuries, was built on the notion that the originator of the work should benefit. It is this "authorship" that creates the necessity for legal protection of the work. Initially, authorship primarily emphasized the "labour" invested by the author. If a person invested significant labour, along with some level of skill and judgment particular to that person into a work, they could claim authorship, a principle known as the "sweat of the brow doctrine" [17]. However, the modern concept of "authorship" has gradually shifted to require a certain degree of "creativity." So, while the initial meaning of authorship referred to labour originating from the author, but it has gradually come to mean the author's creativity.[18]

As the copyright system gradually expanded globally and technologies evolved, the protection of works extended beyond books to include music, films, photographs, choreography and a wide range of human creations [19]. However, not all human creations are eligible for copyright protection. Different countries have their own copyright thresholds, arising from the different values of each jurisdiction, and the understanding of what is protectable has changed alongside technology.

Generally, "originality" is a shared core threshold among jurisdictions. Authorship and originality are sometimes used interchangeably, but not always [20]. Depending on the jurisdiction, the two words can convey slightly different nuances in context. When referring to authorship, the word can be used in the context of underlying justifications for copyright protection. In contrast, originality is frequently used in the context of a threshold to assess whether the work is worth protecting.

Different countries define the concept of originality differently, but they all require a certain degree of creativity in a work. In the EU, the case of *Infopaq v. Danske* established that originality requires a work to be the "author's intellectual creation" [21]. In the United States, "The constitutional requirement necessitates independent creation plus a modicum of creativity…. copyright protection extends only to those components of the work that are *original to the author*" [22] (emphasis added). In China, the standard for originality requires that a work demonstrates a certain degree of creativity and is independently created by the author [23]. The classical originality standard in the UK was "skill, labour and judgment," which emphasizes the labour invested by the author, along with some level of personal connection, but over time, the UK has drawn closer to the EU standard, reiterating the "author's intellectual creation" standard most recently in *THJ v Sheridan* [24] [25].

Given that originality is the universally accepted criterion for determining whether a creation can receive copyright protection, if AIGC meets the requirements of originality, it has cleared a significant hurdle for its protectability. As the preceding section has shown, for a work to be original it must reflect some level of creativity on the part of the author. With modern generative AI, this creativity can potentially be found in two places, prompt engineering (writing a prompt that is sufficiently detailed and creative to guide the AI algorithm to produce a work that reflects that creativity), or in post-generation modification. While prompts themselves can be protected as literary works, without question, whether the AIGC that comes into being on the basis of that prompt rises to the level of creativity required by various jurisdictions remains unclear. Post-generation modification similarly remains opaque, with no clear cases to establish what level of modification is necessary.

3. COPYRIGHT & TECHNOLOGY

The advancement of technology has historically prompted a re-evaluation of concepts within copyright, thereby driving the development of copyright law [26]. One can look to similarly disruptive new technologies over the last century and a half to see how these technologies at first threaten but ultimately are incorporated into copyright protections. AIGC could follow a similar path.

In 1884, the U.S. case *Burrow-Giles Lithographic Co. v. Sarony* spurred a re-examination of copyright's concept of authorship. Analysing the photographer's choices in arrangement of scenes, lighting, and other artistic operations distinguished photographic art from mere mechanical reproduction. This precedent incorporated photographic works into copyright law, because they were "representatives of original intellectual conceptions of the author.' The court defined authors as 'he to whom anything owes its origin; originator; maker; one who completes a work of science or literature" [27].

When the phonograph emerged in 1877, concerns grew over the potential devaluation of musical art and the loss of musicians' livelihoods, with John Philip Sousa famously writing "Sweeping across the country with the speed of a transient fashion in slang … comes now, the mechanical device to sing for us a song or play for us the piano, in substitute for human skill, intelligence, and soul" [28]. However, copyright eventually balanced the rights of musicians and recording producers by allocating benefits from the recording, reproduction, and dissemination of musical works.

In the 1980s, the rise of VCRs made recording television programs for later viewing (time-shifting) popular, leading to copyright disputes over television programs. The landmark case *Sony Corp. of America v. Universal City Studios, Inc.* ultimately determined that recording television shows for time-shifting purposes was permissible [29], and in a number of jurisdictions, a surcharge on the medium of reproduction was imposed to remunerate the copyright holder.[30] In the 1990s, as the internet became widely accessible to the public, the complexity of infringement issues prompted the re-examination of the policy goals of the doctrine and the development of safe harbour provisions to protect internet service providers from liability (*see e.g.* DMCA (US))[31], and new penalties imposed to protect copyright holders but also facilitate the public interest in access.

Even computer generated art is not new, as can be seen in the example of the painting expert system AARON [32]. It is interesting to note that it is only recently that art created with the assistance of expert systems has become controversial. "Cohen is also considered the author of all works produced by AARON and holds their copyrights. *This is because he designed the rules and parameters that enable the program to create 'original' artworks*."[33] . The authorship crisis triggered by AIGC presents an opportunity to reassess the design of copyright and explore its further development. The following section will show how the US, China and Czechia have addressed these issues as there is at present a lack of international consensus on how to approach the protectability of AIGC.

4. COPYRIGHT & AI

Despite a lack of consensus on the copyrightability of AIGC, there are currently two differing approaches becoming apparent. The U.S. Copyright Office refuses to recognise AIGC as eligible for copyright protection, an approach adopted recently in the Czech case of *S.Š. v. Taubel Legal*. In China, the case of *Li v. Liu* from the Beijing Internet Court, takes a more nuanced approach and recognizes that AIGC may obtain copyright.

The view of the US Copyright Office clarifies that human authorship is a prerequisite for copyright [34]. According to the Copyright Office Guidance, "AI-generated content that is more than de minimis should be explicitly excluded from the application" and "what matters is the extent to which the human had creative control over the work's expression." Humans cannot exert sufficient control over content automatically generated by AI. As a result, such content is considered to lack human authorship and cannot qualify for copyright protection. "Courts interpreting the phrase "works of authorship" have uniformly limited it to the creations of human authors" [35].

An example of how the Copyright Office has applied this guidance can be found in the case of Zarya of the Dawn. Kris Kashtanova created a comic book with a series of images generated by Midjourney. Kashtanova edited some, but not all, of the images, arranged them in the comic book, then added in text. According to the US Copyright Office, the text was written entirely by Kashtanova and meets the requirements of human authorship. The arrangement of text and images was also completed by Kashtanova, meeting the ”modicum of creativity” requirement for protectability. Regarding the edited images, although the U.S. Copyright Office recognized that edits to images could be eligible for copyright protection, the evidence submitted by Kashtanova failed to demonstrate that those edits exhibited sufficient creativity. Regarding the un-edited images generated by Midjourney, the Copyright Office concluded that they do not satisfy the human authorship requirement and are therefore ineligible for copyright protection. The reasoning given by the copyright office is that users of Midjourney cannot predict the specific details of the generated output, and Kashtanova's particular prompt cannot guarantee a particular result, and therefore the work is not original to Kashtanova [35].

It is evident that the U.S. Copyright Office holds that an author must have sufficient control over the details of a work to meet the creativity requirement for originality. The outputs generated by generative AI are highly unpredictable, and AI users cannot produce a specific output based on a specific prompt, lacking sufficient control. Therefore, at this stage, outputs entirely generated automatically by AI cannot receive copyright protection in the US, as “what matters is the extent to which the human had creative control over the work's expression and “actually formed” the traditional elements of authorship” [36]. It is questionable, however, whether this is truly in line with precedent as copyright registration has been granted for unpredictable art in the past, including for the works of Jackson Pollack and “found sound” recordings.

In the EU, *S. Š. v Taubel Legal,* decided by the Municipal Court of Prague appears to be in line with the US stance. In this case, S. Š generated a picture with the following prompt “[c]reate a visual representation of two parties signing a business contract in a formal setting, such as a conference room or a law firm office in Prague. Show only hands” [37]. The court ruled that the generated picture can not have copyright protection because the picture is a production from AI and copyright only protects human creativity. The court found that the prompt could only determine the “theme” of the AI-generated picture and the theme is not eligible for copyright protection. It is worth noting that the prompt in this case was simple, and it is unclear whether the court would reach a different decision if the prompt were more complex. The ruling in this case is limited to a district court in the Czech Republic, and it cannot yet be said to reflect the EU's stance on the copyrightability of AIGC.

By contrast, in China, the Beijing Internet Court holds an opposing view to that of the U.S. Copyright Office. In *Li v. Liu*, the plaintiff, Li, used the Stable Diffusion AI model to generate an image, which the defendant, Liu, uploaded online without the plaintiff's consent [38]. The court found that the plaintiff initially entered prompts and set preliminary parameters into the model to generate the first image. Subsequently, the plaintiff input new images and adjusted the parameters until the model produced an image that satisfied the plaintiff. This process demonstrated the plaintiff’s aesthetic choices and personal judgment. Therefore, the final image generated by the model met the creativity requirement for originality. It is evident that *Li v. Liu* does not require AI users to have specific control over AIGC but only a certain degree of influence.

The *Li v. Liu* case, by emphasizing the role of prompts, established a connection between AI users and AIGC. It treats AI as a highly automated tool, contrasting with the U.S. and Czech perspectives, which regard AI as the originator of any AIGC, outside of human control. *Li v Liu* would also appear to be consistent with the treatment of copyright granted to the artist Cohen, mentioned above, as he set the parameters of the AARON system to create the art he envisioned, but ultimately AARON is a highly automated tool.

5. BACK TO BASICS

Just as technologies like cameras and VCRs once prompted a re-evaluation of copyright purpose and policy, generative AI can similarly provoke a reconsideration of copyright policy in at least three aspects.

First, in the context of AIGC, it is essential to revisit the core concept of creativity as an essential component of copyright protection. At present, most countries converge on the requirement that works must exhibit a certain degree of creativity to qualify for authorship. The contours of authorship, as discussed, have been less consistently interpreted. Looking back to pre-*Infopaq* copyright in the United Kingdom, the UK interpreted authorship as reflecting "skill, labour, and judgment." This standard emphasised the "skill" and "labour" invested by the author in the work, embodying the "sweat of the brow" principle [39].

A typical case that illustrates classical UK approach to authorship is *Walter v Lane*[40]. In this case, copyright was granted to the transcriptions of speeches created to reproduce the speeches accurately. The transcriptions qualified as original works because the process of creating the notes demonstrated skill and labour, including the "ability to write shorthand" and "transcribing, with punctuation and revisions added." Therefore, under classical UK authorship, creations with little creativity can have copyright protection, so long as the other two criteria are sufficiently present.

Compared to pursuing pure creativity, classical UK authorship emphasised ensuring that no one could "free-ride" on another person's skill and labour investment, a reflection of the economic incentive component of copyright. If this definition of authorship is applied, AIGC could qualify for copyright protection.

Production of AIGC is not necessarily rapid or low-cost, for instance. While occasionally, a single prompt can lead to satisfying results and no further tweaking is needed, more often than not, the first works generated are not appropriate and require revisiting the prompt to tailor and try again. For artists, this may require hundreds of iterations. Further post-generation, AIGC frequently needs significant editing to be fit for purpose. This process of designing and refining prompts often involves substantial skill, labour, and judgment.
To allow unauthorized use of the final generated image could constitute a free-ride on the AI user's skill, labour, and judgment, and even creative, investment. This free-ride is a potential market failure and is perhaps a reason for courts or legislators to intervene in the determination of protectability. At present, AIGC of competitive value is already entering the market. There are already integrations in Photoshop and other editing software to assist in artistic creation. As AI models evolve, it can be predicted that more and more high-quality AIGC will be created, and the effect of the free-ride will become more apparent. A resurrection or reintegration of this standard in light of AI could also recognise the difference between the single-prompt generated work requiring very little human engagement and work that has had significant human intervention, as well as works that have been manipulated after generation to create something new.

Secondly, the purpose of copyright can also be reexamined in light of the production processes and applications of AIGC. Copyright reflects both the personal dignity of the author (embodied by moral rights) and the commercial value of their work, as discussed in Section 2. Currently, AI users have limited control over the details of AIGC, meaning the human connection to the AIGC is limited, but not entirely absent.

One distinction between *Li v Liu* and *S. Š. v Taubel Legal* is that the prompt in *Li v Liu* was far more complex and detailed than that in *S. Š. v Taubel Legal*. If a prompt is meticulously crafted, even though the AI user cannot fully predict the AIGC, the generated content may significantly reflect the AI user's creativity, and demonstrate the connection between the author and the work.

It is worth examining the extent to which the users' creativity and the AIGC must be connected to give rise to moral rights over the outputs. This consideration is particularly salient in light of post-generation modification to AIGC, where the author of the work has taken what is given to the user in common, and that user has "mixed [their] labour with, and joined to it something that is [their] own…" that something being their creative choices and personhood [41]. This connection may indeed give rise to a special connection between the person who made the modification and the final work produced. While there is clearly some randomness in the output of generative AI systems, that randomness can be reduced with well-crafted prompting. Post-generation modification displays an even clearer imposition of will, choice and creativity on the AIGC. If we consider that moral rights arise from the imposition of the authors will on the world, it is difficult to deny that moral rights could feasibly be found in AIGC or AIGC containing works,

Thirdly, it is necessary to reassess the nature of creativity within copyright protection, in light of broader policy concerns. The U.S. Copyright Office and the *Li v Liu* case have demonstrated differing interpretations of the concept of creativity embedded within originality. Overall, the

U.S. Copyright Office applies a higher standard for recognizing creativity, making it challenging for AIGC to qualify for copyright protection under this standard. The substantial difference in the outcomes of these cases, in light of similar copyright frameworks, suggests that the understanding of originality in *Li v Liu* and that envisioned by the US Copyright Office may have been influenced by policy considerations beyond creativity.

Notably, in *Li v Liu*, the judge stated that "the proper application of copyright law, encouraging more people to create using the latest tools, is more conducive to the creation of works and the development of AI technology." This reasoning is not shared by the US Copyright Office which has not addressed the incentivisation of using new AI tools in any copyright guidance explicitly.

There are suggestions that the failure to register works created by AI serves a protective function for human artists who are concerned that they may be displaced by cheaper, faster AI models. This is of particular concern to screenwriters, actors and commercial artists if recent strike activity and lawsuits are any indication. Ensuring that those who use AIGC in place of a human artist receive no ability to protect those works or prevent others from using them disincentivises the replacement of humans by AI.

The flip side of these policy concerns can be found in the idea of access to art creation. It has been recognised that these new tools are capable of facilitating the democratisation of artistic creation. It has been posited that "creativity will be lodged in asking the right questions, not in creating the answers…" [41]. An example of how AI is democratising the creation of fine art can be found in the Blind Canvas project, an effort to give people a better understanding of living with blindness. The project invites participants to "sit down for an hour-long interview to discuss their condition, their lives, and their perspective on living with blindness," and that interview is used to generate a prompt for a text-to-image AI to turn the interview into an expressive work of art [43].

Taking the broader policy implications of copyright, it is essential to discuss what kind of creativity should be recognized in the context of AIGC. Addressing the issue of recognizing creativity could potentially resolve common questions, such as whether iterations of AIGC that fail to satisfy the AI user or high-quality AIGC unexpectedly generated from simple prompts should qualify for copyright protection.

In fact, the policy implications raised by AIGC are extensive, including concerns about AI art replacing human artists, fears that AIGC could hinder artistic development, and issues of transactional security arising from the confusion between AIGC and human-created works. Ethics and environmental impacts are also considerations that may have an impact on how the desirability of copyright protection for AIGC is analysed.

6. CONCLUSION

In the creation of AIGC, the concept of human creativity must be revisited. Taken for granted, assumptions about how humans create are no longer applicable, as Generative AI invites new authors to the table, who may utilise novel tools to create works of merit and value. These technologies require policymakers and communities to reconsider what merits protection and what thresholds to apply to grant that protection.

Incentivisation through the commodification of works and the special connection between an author's person and the works they create are the hallmarks of modern copyright, providing protections that are valuable and legally robust. To this day, the expression of authorship varies across different jurisdictions, but it generally requires a certain degree of creativity. Locating that creativity in the creation of AIGC may give rise to some level of protection, as can be seen in *Li v Liu,* whereas in the United States, AIGC has been deemed to lack human authorship on the grounds that users of AI lack control over the details of the generated content, and therefore are not involved in the creative process.

Novel technologies, like generative AI, provide opportunities to reexamine the underlying purpose of protection in order to build policy to extend the doctrine appropriately. Old doctrines may become useful again, such as the pre-*Infopaq* UK standard of "skill, labour and judgment," if one hopes to foster and incentivise the creation of AIGC. Looking to the connection between the author's personality and the prompts or modified AIGC, one may consider whether moral rights should attached and at what point. Lastly, in light of the various copyright policy considerations prompted by AIGC, it is essential to discuss the nature of creativity in authorship and determine which types of creativity copyright should protect. The choice of theory and policy will have significant implications on the protection of AIGC, and inconsistent choices in the global context will widen existing disharmonies in copyright law. This will likely impact the development of the technology and its industrial application from jurisdiction to jurisdiction. It is hoped by highlighting some of these considerations explicitly, policymakers and courts will be able to make more informed choices, with full realisation of the implications of the choices that they make.

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SESSION II

“CH between Draft and Signature”

Moderation: Eva Emenlauer-Blömers
(formerly Senate of Berlin, Department for Economics, Technology and Research)

Generative Palimpsests: The Feature Space of Synthetic Comics

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ABSTRACT: In the heart of craft traditions lies a tension between, on the one hand, the actual, material manifestation of a comics object and, on the other, the suppressed ideas, the paths not pursued, and the discarded elements that are not directly visible in the final work. These hidden aspects, however, are well documented in a wealth of preliminary production materials and prototypes, such as sketches, pencils, and page layouts, which serve to refine a work's visual and narrative elements incrementally. As more comic artists are invited to leverage the possibilities of generative AI, the present paper examines the transformative effect of emerging computational technologies on this conceptual divide, potentially altering our understanding and interaction with the initial stages of comic book production. It attempts to give an expression to the dual nature of comics objects and to dive into the "feature space" of algorithmic models, defined as the underlying abstract space that contains all potential configurations and states that an algorithmic model can represent or generate and which are not directly observable or experienced— the indeterminate wanderings, the ghostly presences and the infinite possible configurations that are inherently potential within computational systems. It also reflects on how the unrealized possibilities haunt the computational evolution of comics, continually reshaping and redefining the categories of materiality, time, space, and sensory modalities.

1. INTRODUCTION

The paper explores the transformative intersection of artificial intelligence (AI) and comics, focusing on the emergence of synthetic comics generated by machine learning models. The paper conceptualizes how machine learning technologies can reconfigure the prototyping stages of production marked by a variety of preliminary documents that are part and parcel of comics craft. It examines the feature space of synthetic comics, outlining key components such as visual styles, narrative structures, and intertextual dynamics. The paper uses *Fastwalkers* (2021), a synthetic comic book, as a central example to analyze how AI leverages feature spaces to mimic and reinterpret traditional comic aesthetics. The paper also incorporates the concept of hauntology, suggesting that these AI-generated works are spectral echoes of their source material—layered with traces of past styles and narratives, yet devoid of a cohesive authorial presence. This research offers a foundational framework for understanding synthetic comics as a unique cultural artifact, positioning them at the forefront of computational creativity in visual storytelling.

2. CONCLUSION

The conclusion frames synthetic comics as objects embodying the tension between potential and actual. While finished comics obscure the iterative, collaborative processes behind them, computational tools reveal these invisible stages. Integrating Explainable Computational Creativity (XCC) into comics production highlights discarded prototypes and unrealized possibilities, enriching artistic dialogue. This approach transforms the creative process into a co-creative partnership, where AI and artists collaborate to explore the expansive feature space of computational models. By engaging with the ghostly traces of these generative outputs, artists redefine the boundaries of comics, emphasizing their dual nature as both a tangible medium and an evolving art form.

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Artificial Intelligence and Art History: Exploring New Dimensions in Cultural Analysis

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ABSTRACT: The advent of AI-generated art began in the 1970s with Harold Cohen's The Aaron, a pioneering experiment in using algorithms to mimic human creativity. Since then, AI has transformed the field of art history, challenging traditional notions of authorship, authenticity, and creativity. Today, AI is not just a tool but a catalyst for innovation, enabling artists to experiment with new techniques, materials, and forms that push the boundaries of art.

This conference explores the intersection of AI and art history, addressing topics such as AI's role in art authentication, visual analysis, and pattern recognition, which uncover hidden details and influences in artworks. It also examines generative art, where algorithms create novel styles and forms, and AI's impact on curatorial practices, cultural heritage preservation, and narrative contextualization. Ethical considerations will also be discussed, including bias, privacy, and the evolving role of art historians.

This interdisciplinary dialogue brings together scholars, technologists, and artists to illuminate AI's transformative influence on art and its redefinition of creativity and cultural understanding.

1. INTRODUCTION

Artificial intelligence (AI) is revolutionizing art history by blending advanced technology with humanistic inquiry, unlocking uncharted opportunities for analyzing, preserving, and understanding art. This transformation began with digitization efforts, such as the Getty Provenance Index, and has since evolved into dynamic AI-powered tools that reshape the study and creation of art.

Key innovations include AI-driven image recognition and attribution systems capable of analyzing brushstrokes, pigments, and patterns to attribute artworks and detect forgeries with remarkable precision. AI also excels in preserving cultural heritage by predicting damage, reconstructing fragmented artifacts, and digitally restoring deteriorated works, offering a glimpse into their original splendor. Beyond conservation, platforms like Google Arts & Culture democratize access to art, enabling global audiences to engage with masterpieces in unprecedented detail.

The integration of AI extends to museum practices, where virtual galleries and personalized visitor experiences are redefining curatorial methods. Artists collaborate with AI to expand creative boundaries, generating novel styles and forms that challenge conventional notions of authorship and originality. Generative tools like GAN (Generative Adversarial Network) have enabled projects such as The Next Rembrandt, pushing the limits of machine-assisted artistry.

Despite its potential, AI in art history raises ethical concerns. Bias in training datasets and over-reliance on AI might undermine human expertise and interpretation. Moreover, AI-generated works blur the line between authenticity and creativity, prompting debates about authorship and artistic intent.

As AI tools advance, they offer exciting possibilities, from predictive modeling of art trends to illuminating global artistic connections across time and geography. However, their impact must be critically assessed to maintain the discipline's humanistic

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essence. This evolving partnership between AI and art history heralds a new era of cultural discovery, redefining how we perceive and preserve human creativity.

This conference will include: 1.) Introduction; 2.) The beginnings of AI in Art History; AI-powered image recognition and attribution; art preservation and restoration; curatorial and museum practices; generative art and creativity; narrative and contextual analysis; Challenges in AI and Art History; Future directions in AI and Art History; 3.) Conclusion, and 4.) References.

2.1. THE BEGINNINGS OF AI IN ART HISTORY

The intersection of artificial intelligence (AI) and art history is rooted in the early adoption of computing technologies within the humanities. In the late 20th century, art history began incorporating digital methods to expand its methodologies beyond traditional observation and interpretation. Technological innovations catalyzed this evolution, particularly in creating databases and archives, which provided scholars with new tools to analyze and compare artworks. The advent of AI introduced a paradigm shift by enabling dynamic analyses of artistic patterns, styles, and materials. Early applications of AI were experimental, focusing on mimicking human creativity and addressing questions of authorship and attribution.

The groundwork for AI in art history was laid during the 1970s and 1980s through extensive digitization projects. Efforts such as the Getty Provenance Index, Artstor, and the Joconde database enabled the creation of structured archives, offering centralized access to vast metadata collections, provenance records, and high-resolution images. These systems allowed scholars to cross-reference information, conduct stylistic comparisons, and identify patterns within large datasets. Innovations in digital catalogs, such as those developed at the British National Gallery, the Courtauld Institute, and the Frick Collection, further facilitated the global sharing of art historical resources. Such advancements marked the shift from static recordkeeping to more interactive and accessible systems, paving the way for computational approaches to art analysis.

AI's transformative potential emerged with the development of machine learning algorithms capable of processing large datasets with remarkable speed and precision. Early applications, such as pattern recognition and image classification, allowed researchers to identify stylistic elements and motifs across vast collections. Tools like convolutional neural networks and generative adversarial networks (GANs) revolutionized the field by automating processes traditionally reliant on expert judgment. Projects like The Next Rembrandt demonstrated AI’s ability to replicate artistic styles, while platforms like Art Recognition applied AI for art authentication and forgery detection. These advancements departed from human-driven processes, introducing a dynamic synergy between computational precision and art historical inquiry.

The integration of AI has created unprecedented opportunities in art history, redefining how scholars study, preserve, and interpret art. AI-driven tools have enhanced methods for analyzing brushstrokes, pigments, and composition, offering new insights into the attribution and authentication of artworks. Simultaneously, AI’s role in cultural heritage preservation has enabled the digital reconstruction of damaged artifacts and monuments, fostering greater accessibility and appreciation for diverse cultural expressions. Beyond analysis, AI has expanded the creative process, with generative algorithms enabling artists to explore new materials, techniques, and forms. This convergence of AI and art history has not only transformed the discipline but also raised critical questions about authorship, authenticity, and the role of technology in humanistic studies.

2.2. AI-POWERED IMAGE RECOGNITION AND ATTRIBUTION

Machine learning has emerged as a transformative tool in art history, revolutionizing the identification of artists and artistic styles. By training algorithms on vast datasets of high-resolution images, AI systems can detect patterns, stylistic features, and motifs that define an artist's work or a specific artistic movement. Convolutional neural networks (CNNs), a cornerstone of machine learning, analyze brushstrokes, color palettes, and compositional elements with remarkable precision, offering insights that were previously attainable only through the trained eye of a connoisseur. Tools such as ImageNet and platforms like Art Recognition enable researchers to compare works across periods and regions, uncovering connections and stylistic evolution with unprecedented speed and accuracy. These innovations have expanded the scope of art historical research, allowing scholars to systematically explore vast collections, from Renaissance paintings to contemporary digital art.

AI has significantly advanced the attribution of disputed artworks, providing critical support to art historians and experts in resolving longstanding debates. By analyzing unique stylistic markers and patterns within an artist's oeuvre, machine-learning models can identify signatures of authenticity. Notable successes include AI's role in verifying the authorship of works by artists such as Vincent van Gogh, Rembrandt, Raphael, and Caravaggio. For example, facial recognition technology helped attribute the de Brécy Tondo to Raphael, with a 97% similarity to the Sistine Madonna. Such breakthroughs align closely with expert consensus, demonstrating AI's reliability as a complementary tool in attribution studies. These advancements also extend to analyzing unsigned works or pieces produced within an artist's workshop, offering insights into collaborative practices and individual contributions.

AI excels in detecting forgeries by analyzing details imperceptible to the human eye, such as pigment composition, canvas weave patterns, and micro-level brushstroke textures. Techniques like chromatic confocal optical profilometry enable researchers to map three-dimensional surface characteristics of a painting, revealing inconsistencies indicative of modern replication techniques. Machine learning algorithms trained on authentic works can identify anomalies, such as incorrect pigment use or atypical brushstroke styles, providing strong evidence of forgery. Companies like Art Recognition use deep learning models to analyze stylistic features with up to 96% accuracy, making AI a valuable tool for safeguarding artistic heritage. Additionally, AI enhances market transparency by offering collectors and institutions unbiased reports on authenticity, reducing the risk of fraudulent transactions.

AI has become a vital asset in art historical through its ability to identify artists, resolve attribution disputes, and detect forgeries. Combining computational precision with human expertise enhances our understanding of art and protects cultural heritage from misrepresentation and loss.

2.3. ART PRESERVATION AND RESTORATION

Artificial Intelligence (AI) is reshaping the preservation of cultural heritage by equipping conservators with tools to predict the deterioration of artworks and take proactive measures. Advanced algorithms analyze environmental factors such as temperature, humidity, light exposure, material composition, and historical degradation patterns to identify risks to delicate works. For instance, AI-driven monitoring systems in museums generate actionable insights to optimize storage and display conditions, reducing damage risks and preserving artworks for future generations. These systems can simulate potential future scenarios, allowing conservators to pinpoint vulnerable areas in paintings, sculptures, and textiles, enabling timely and targeted interventions. This predictive capability significantly reduces the need for invasive restoration techniques, ensuring the longevity of priceless artifacts.

AI-driven digital restoration has also opened new possibilities for virtually reconstructing faded or damaged artworks. Machine learning algorithms trained on high-resolution images and historical data recreate the original appearance of degraded pieces, offering insight into the artist's initial intent. These tools have been employed to restore missing fresco sections damaged by environmental factors and rejuvenate colors in ancient manuscripts that have faded over centuries. Such non-invasive digital techniques not only avoid the risks associated with physical restoration but also enable the creation of virtual replicas. These replicas are accessible worldwide, democratizing the appreciation of cultural treasures and fostering global connections to shared heritage.

A groundbreaking example of AI's role in art restoration is the recent reconstruction of Rembrandt's iconic painting *The Night Watch* (1642). This masterpiece, which embodies the Dutch Golden Age, underwent significant alterations in 1715 when parts of the canvas were removed to fit the painting into a new location. The lost sections—never recovered—were long considered irretrievable. However, the Rijksmuseum in Amsterdam embarked on an ambitious initiative, 'Operation Night Watch,' to restore the painting to its original dimensions.

The restoration effort, led by senior scientist Rob Erdmann, utilized three primary resources: the surviving painting, a smaller 17th-century copy by Gerrit Lundens made before the alterations and advanced AI technology. To preserve authenticity, the team prioritized AI over artistic interpretation to accurately replicate Rembrandt's distinctive style.

The challenges were immense: Lundens' copy was only a fifth the size of the original and varied stylistically. Erdmann developed three specialized neural networks to bridge these gaps. The first network identified standard details between the original and the copy, the second adjusted these details to align with the original's proportions, and the third was trained to recreate Rembrandt's style, producing the missing sections.

The AI-generated segments were printed on canvas, varnished, and attached to the original frame without directly touching Rembrandt's work. To respect the integrity of the original, the additions, intended as temporary, will be removed after a three-month display.

In parallel, the original *Night Watch* may undergo further conservation following insights from this project, addressing past damages such as a 1975 slashing and a 1990 acid attack. The reconstructed painting, currently on view at the Rijksmuseum, exemplifies how AI can bridge history and technology, restoring lost heritage while honoring artistic authenticity.

In archaeology, artificial intelligence (AI) has revolutionized reconstructing fragmented artifacts and visualizing historical sites. Machine learning models generate 3D reconstructions that hypothesize how damaged objects or sites originally appeared by analyzing shapes, textures, and material properties. This technology has been transformative in piecing together sculptures, pottery, and architectural elements, offering researchers a deeper understanding of ancient civilizations and their artistic achievements. Beyond research, AI-driven reconstructions play a vital role in education, providing immersive insights into past cultural practices and enabling the public to experience lost heritage.

AI in Preservation: The HYPERION Project

One landmark initiative harnessing AI for archaeological site preservation is the HYPERION project, which focuses on safeguarding vulnerable European cultural heritage sites. With a budget of nearly €6 million, the project addresses the growing threats posed by extreme weather, earthquakes, and other environmental challenges to ancient monuments in Rhodes (Greece), Venice (Italy), Tønsberg (Norway), and Granada (Spain).

The research team employed atmospheric modeling to analyze site-specific criteria such as wind speed, temperature, relative humidity, and precipitation. These data were sourced from the EURO-CORDEX archive, which provides advanced regional climate change projections. The incorporation of AI technologies enabled researchers to synthesize information from multiple sources, including literature, surveys, satellite images, and in situ sensors.

Drones, wide-area satellite imaging, and community engagement tools further enriched the dataset, while AI's ability to process ground-based multi- and hyperspectral imaging streamlined condition monitoring. State-of-the-art deep learning models, particularly convolutional neural networks (CNNs), were used to analyze high-resolution satellite images covering areas up to 33 km². These models automatically detected changes in land cover, such as the presence of impervious materials like asphalt and concrete, which exacerbate flooding risks. By automating tasks traditionally reliant on human effort, AI enabled continuous monitoring of these sites and made large-scale applications feasible, significantly enhancing the effectiveness of preservation efforts.

The RePAIR project, spearheaded by the Italian Institute of Technology (IIT), exemplifies how AI and robotics can accelerate the labor-intensive restoration of archaeological sites. Focused on Pompeii, one of the world's most iconic archaeological sites, this initiative employs a combination of robotics, 3D scanning, and machine-learning algorithms to reconstruct fragmented artifacts and architectural elements. AI-powered systems analyze thousands of individual fragments, identifying matches based on their shapes and material properties with extraordinary accuracy and speed.

By automating these traditionally manual tasks, the RePAIR project has significantly reduced the time and cost associated with restoration, allowing conservators to focus on interpretation and contextual analysis. This approach not only preserves the physical integrity of artifacts but also ensures that their historical significance is more fully understood and appreciated.

AI's role in archaeological restoration and preservation represents a leap forward in addressing some of the field's most pressing challenges. From reconstructing damaged monuments to identifying environmental risks, AI empowers researchers to combine precision, creativity, and efficiency. These innovations are technical achievements and essential tools for protecting humanity's shared heritage against the ravages of time and climate change. By fostering collaborations between archaeologists, technologists, and conservationists, AI ensures that the past remains accessible and meaningful for future generations

2.4. CURATORIAL AND MUSEUM PRACTICES

Artificial intelligence (AI) is revolutionizing curatorial and museum practices, offering innovative tools to enhance how exhibitions are curated, presented, and experienced. By integrating AI technologies, museums can create dynamic, personalized, and accessible cultural experiences, blending tradition with cutting-edge advancements.

AI-driven tools are transforming the visitor journey by tailoring experiences to individual preferences. For instance, the Rijksmuseum in Amsterdam uses AI to design personalized tours based on visitor data, such as favorite artists, historical periods, and thematic interests. This allows each visitor to explore the museum in a unique and meaningful way, enhancing engagement and deepening connections to the artworks. Additionally, AI-powered image recognition systems enable curators to identify relationships between artworks across styles and periods, helping craft compelling exhibition narratives that appeal to seasoned art enthusiasts and newcomers.

Virtual and augmented reality technologies powered by AI are redefining how audiences interact with art. The Smithsonian American Art Museum exemplifies this through its VR reconstruction of the Lost Symphony Hall of Chicago. Visitors can virtually explore the hall's architecture and artworks as they existed before its destruction, offering a fully immersive historical experience. Similarly, AR applications overlay digital content onto physical exhibits, enriching them with interactive features like 3D reconstructions, historical narratives, or contextual information. These technologies bridge the gap between the physical and digital realms, inviting deeper exploration while making cultural heritage accessible in new, exciting ways.

Platforms like Google Arts & Culture showcase AI's potential to democratize access to art. By digitizing high-resolution images of artworks and cultural artifacts, the platform enables users worldwide to explore collections from institutions such as The Louvre and the Uffizi Gallery. Features like "Art Transfer" allow users to creatively interact with these collections by applying famous artistic styles to their photos. AI-powered translation tools further break linguistic barriers, providing multilingual access to exhibitions and historical contexts and fostering a global appreciation for art and cultural heritage.

The Nasher Museum of Art's exhibition Act as if You Are a Curator: An AI-Generated Exhibition exemplifies AI's experimental role in curatorial practice. Chief curator Marshall Price and his team collaborated with digital humanities expert Mark Olson to adapt OpenAI's ChatGPT for curatorial use. By feeding it a dataset of the museum's 14,000-object collection, they enabled the AI to propose themes, titles, and selections for the exhibition. The result, *Dreams of Tomorrow*, featured artworks spanning centuries, reflecting themes of utopia, dystopia, and dreams.

Despite its innovative approach, the limitations of AI have become evident. Without the ability to physically engage with artworks or independently generate spatial layouts, curators had to refine the AI's outputs, combining technology with human expertise. While some critics noted the occasional disjointedness in the exhibition, others praised its unique blend of human and machine creativity, awarding it four out of five stars.

Beyond exhibition planning, AI is used to analyze visitor interactions with art. For example, Italy's Istituzione Bologna Musei employs AI-controlled cameras to measure visitor engagement and assess artworks' "attraction values." This data informs exhibition designs aimed at maximizing audience interest. While this raises questions about the evolving role of human curators, it highlights AI’s capacity to enhance audience-centered curatorial strategies.

2.5. GENERATIVE ART AND CREATIVITY

Generative art has undergone a profound transformation with the advent of AI, which has introduced groundbreaking ways to simulate and innovate artistic processes. Early generative art relied on rule-based systems, but the integration of machine learning, particularly Generative Adversarial Networks (GANs), has revolutionized the field. GANs consist of two neural networks—a generator and a discriminator—that collaborate and compete to create increasingly sophisticated outputs. Projects like Google’s DeepDream demonstrated how neural networks "dream," amplifying patterns within input data to produce surreal, colorful visuals. This marked a turning point, revealing AI’s potential to transcend replication and create new visual languages, pushing creativity into uncharted territories.

AI's ability to emulate and extend traditional artistic principles has created works that blend historical aesthetics with modern technology. One landmark project, The Next Rembrandt, saw an AI system analyze thousands of Rembrandt’s paintings to produce a new, lifelike portrait. By studying brushstroke techniques, color palettes, and compositional elements, the AI created a work seamlessly aligned with the Dutch master’s oeuvre. While this achievement highlighted AI’s potential to pay homage to historical styles, it also raised philosophical questions about authorship, creativity, and the nature of originality. Such projects demonstrate AI’s ability to bridge artistic traditions with digital innovation, offering new tools for exploring and preserving cultural legacies.

AI's role as a collaborative partner has redefined artistic production, challenging conventional notions of creativity. One of the most prominent examples is Portrait of Edmond de Belamy, created by the Paris-based collective Obvious using GANs. By training their algorithm on a dataset of 15,000 portraits from the 14th to 20th centuries, the collective enabled the AI to generate a fictional portrait. The painting, signed with an algebraic formula, sold for $432,500 at Christie’s—far exceeding expectations and cementing AI art’s place in the market. While the portrait echoed traditional aesthetics, its subtle distortions lent it a contemporary edge, sparking debate about the interplay of human and machine creativity.

Refik Anadol (b. 1985), a Turkish-American new media artist, exemplifies how AI can expand the horizons of art. His project, Quantum Memories at the National Gallery of Victoria, used 200 million photos of Earth’s landscapes to create an alternate visual reality. Similarly, his *Machine Hallucinations* series transforms archival images into abstract, dream-like environments, drawing on AI’s capacity to synthesize vast datasets. Anadol’s work highlights the potential of AI to generate entirely new aesthetic experiences, blending data-driven methodologies with human imagination.

The renowned Japanese artist Takashi Murakami (b. 1962) offers a compelling example of AI’s integration into traditional art forms. In his 2025 solo exhibition at Gagosian, Murakami reimagined Edo-period masterpieces, such as Iwasa Matabei’s Rakuchu-Rakugai-zu Byobu (Scenes in and around Kyoto). Using AI to restore and enhance missing sections of the 17th-century work, Murakami introduced playful additions like his signature rainbow-hued flowers and anime-inspired figures, blending historical and contemporary aesthetics.

Murakami’s reinterpretation of classics like Tawaraya Sotatsu’s *Wind God* and *Thunder God* similarly incorporated AI, sparking debates about the role of technology in redefining artistic traditions. While some critics viewed AI as exploitative, Murakami embraced it as part of art’s natural evolution, predicting its widespread acceptance as a creative tool within a decade. His studio, Kaikai Kiki, further exemplifies the intersection of tradition and innovation, employing over 30 assistants who combine craftsmanship with AI and digital techniques.

Generative AI has also inspired new theoretical perspectives on the trajectory of art. Ahmed Elgammal, director of Rutgers University’s Art and Artificial Intelligence Lab, developed CAN (Creative Adversarial Networks) to produce novel works that diverge from training data, often tending toward abstraction. Elgammal suggests that AI models, by moving beyond replication, inadvertently mimic the historical progression of art from figuration to abstraction.

This notion—that AI art reflects the inevitability of certain artistic trajectories—raises intriguing questions about whether creativity is a human phenomenon or a universal principle encoded in cultural evolution.

2.6. NARRATIVE AND CONTEXTUAL ANALYSIS

Natural Language Processing (NLP) has emerged as a valuable tool in art history, allowing researchers to analyze and contextualize artworks by drawing connections between historical texts, archives, and visual materials. NLP algorithms can process vast amounts of written data, including artist letters, critical reviews, and exhibition catalogs, to uncover patterns and themes that deepen understanding of an artwork's historical and cultural significance. For instance, the Mining the European Art Archive project employs NLP to analyze critical responses to Impressionist exhibitions in 19th-century Paris, identifying recurring sentiments, critiques, and language that shaped public perception of the movement. This approach helps scholars trace the evolution of art criticism and situate individual works within broader artistic and societal conversations.

AI-driven tools also enhance the interpretation of art by uncovering historical, social, and cultural contexts that might be overlooked in traditional analyses. NLP and machine learning techniques enable researchers to explore relationships between artworks and their environments, providing insights into artistic intent and reception dynamics. This interdisciplinary approach goes beyond aesthetic appreciation, positioning art as a lens through which to examine complex cultural narratives. By connecting the materiality of artworks to their broader socio-historical frameworks, AI offers a richer, more nuanced understanding of art's role in shaping and reflecting human experience.

Through the use of NLP and other AI techniques, narrative contextual analysis bridges the gap between visual and textual data, enriching art historical scholarship. By uncovering hidden relationships, societal implications, and cultural meanings, these tools redefine how we interpret art, ensuring a more comprehensive and dynamic understanding of its place in history.

2.7. CHALLENGES IN AI AND ART HISTORY

One of the critical challenges in integrating AI into art history lies in balancing the precision of quantitative analyses with the depth of humanistic interpretation. While AI excels at identifying patterns, styles, and motifs in vast datasets, it often struggles to account for the emotional, philosophical, and cultural dimensions that are central to the human experience of art.

For example, projects like The Next Rembrandt, which generated a new painting in the style of Rembrandt, showcase AI's ability to mimic artistic techniques with incredible fidelity. However, the work lacks the emotional resonance and intentionality that characterize genuine masterpieces, highlighting the limitations of algorithmic approaches in capturing the complexity of artistic expression. This imbalance underscores the importance of using AI as a complementary tool rather than a replacement for human scholarship, ensuring that computational insights are integrated thoughtfully within broader interpretive frameworks.

Another significant challenge is the potential for AI to reduce art to mere data points, stripping away its cultural and historical context. Machine learning algorithms often focus on measurable features—such as brushstrokes, color palettes, or geometric compositions—while overlooking the narratives, ideologies, and societal influences that give artworks their meaning. For instance, AI systems trained on datasets biased toward Western art traditions risk marginalizing non-Western or underrepresented art forms, perpetuating historical imbalances. A stark example of this limitation is the reliance on GANs to produce "generic" representations of artistic styles, which can inadvertently erase the cultural specificity of the works they attempt to replicate. This decontextualization raises ethical questions about the validity of AI-generated insights and highlights the need for diverse, inclusive datasets that better reflect the global breadth of art history.

The integration of AI into art history brings both exciting opportunities and critical challenges. To maximize its potential, researchers must navigate the delicate balance between computational efficiency and humanistic depth, ensuring that technology enhances rather than diminishes our understanding of art. By addressing these challenges, the field can leverage AI's strengths while preserving the cultural, emotional, and contextual richness that defines the study of art.

2.8. FUTURE DIRECTIONS IN AI AND ART HISTORY

AI is poised to play a transformative role in forecasting art trends and understanding market dynamics. By analyzing large datasets of historical sales, exhibition records, and critical reviews, machine learning algorithms can identify patterns and predict future shifts in artistic movements or market preferences. For instance, AI-driven tools like Artrendex are already being used to evaluate market behaviors, helping collectors and galleries anticipate demand for specific styles or artists. By combining these predictions with historical context, AI can inform decisions about acquisitions, exhibitions, and investments. This capability not only supports the art market but also offers insights into societies' evolving tastes and cultural priorities, providing a valuable resource for art historians and curators.

AI is also revolutionizing art criticism and curation by enabling audiences more personalized and inclusive experiences. For example, platforms like the Rijksmuseum's personalized tour generator use AI to create custom museum routes based on visitor preferences, such as favorite artists, periods, or themes. Similarly, AI-assisted tools analyze audience engagement data to curate exhibitions that resonate with diverse demographics. These innovations extend to art criticism, where algorithms are being developed to evaluate stylistic innovations and cultural impact. By offering tailored insights, AI empowers curators to design experiences that connect with audiences on a deeper level while fostering inclusivity and diversity in exhibition narratives.

The future of AI and art history lies in interdisciplinary collaborations that bring together technologists, art historians, and cultural theorists to develop innovative methodologies. A notable example is the Forensic Architecture collective, which combines AI, data science, and visual analysis to investigate political and humanitarian issues through art. Their Triple-Chaser project uses machine learning to analyze visual data and connect it to broader socio-political narratives, demonstrating how AI can expand the scope of art historical inquiry. Such collaborations enhance research capabilities and push the boundaries of what art history can achieve, blending traditional scholarship with cutting-edge technological approaches.

As AI continues to evolve, its applications in art history are set to grow, offering new ways to analyze, interpret, and engage with art. From predictive modeling and personalized curation to interdisciplinary innovations, these developments promise to redefine the field, creating a dynamic and inclusive future for studying art and its cultural significance. By embracing these opportunities, art historians can ensure that AI becomes a tool for discovery and creativity, enriching our understanding of human expression across time and space.

3. CONCLUSION

Artificial intelligence (AI) has emerged as a transformative force in art history, reshaping how we study, interpret, and engage with art across time and cultures. By integrating computational precision with humanistic inquiry, AI has introduced innovative tools that expand the possibilities of art historical research, curation, and preservation. AI enhances the discipline in unimaginable ways, from authenticating artworks and detecting forgeries to reconstructing lost heritage and personalizing museum experiences.

The potential of AI lies in its ability to uncover hidden patterns and connections within artworks, democratize access to global art collections, and generate new forms of creative expression. Projects such as The Next Rembrandt and Machine Hallucination illustrate how AI can emulate artistic styles and explore uncharted creative boundaries, while platforms like Google Arts & Culture have made vast collections accessible to audiences worldwide. These advancements foster greater appreciation for art and its cultural significance, breaking down geographical, language, and financial privilege barriers.

However, the integration of AI in art history also presents significant challenges. The risk of reducing art to data-driven metrics without context underscores the need for balancing quantitative analysis with the interpretive depth of human scholarship. Biases in AI datasets can marginalize non-Western art forms, perpetuating historical imbalances. Ethical questions surrounding authorship, authenticity, and the potential over-reliance on technology further highlight the complexities of this evolving relationship.

Looking ahead, the future of AI and art history lies in fostering interdisciplinary collaborations that blend the strengths of technology, humanities, and cultural theory. Predictive modeling of art trends, personalized curation, and AI-assisted art criticism promise to redefine the field, offering dynamic, inclusive, and innovative approaches to studying and engaging with art. By addressing the challenges and embracing the opportunities, art historians and technologists can work together to ensure that AI remains a tool for discovery, creativity, and inclusivity.

In essence, the partnership between AI and art history represents an evolution rather than a replacement of traditional methodologies. It deepens our understanding of art and its role in human experience, ensuring that the study of art history remains as vibrant and innovative as the works it seeks to illuminate. This collaboration opens new horizons for cultural analysis, fostering a richer, more interconnected appreciation of humanity's artistic legacy.

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AI in Artistic Creation:
Tool, Gadget, or Aesthetic (R)Evolution
Text-Image Platforms

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ABSTRACT: This article examines the evolution of AI-based image creation platforms using GANs and Text-Image procedures. It analyzes the commercial predominance of their objectives, as well as their tendency to neglect in-depth reflection on the image as a form of language, and the consequences these choices have for this form of creation.

By exploring the historical development of AI, the article shows how today's platforms, despite, or because of, their ability to simulate reality in a realistic or even hyper-realistic way, are engulfed in a quest for neutrality or Disneyfication of the image, and must impose successive self-censures that limit their creative diversity that, ultimately, only perpetuate the underlying fears and prejudices of the US society from which these platforms originate. The author calls for a polysemic approach to the image, integrating aesthetic and theoretical perspectives that make Text-Image a genuine tool for reflection on the nature of the visual, comparable to what conversational AI is for oral language. In addition to a number of examples, the author offers a visual case of Text/Image analysis.

This work on image generation by platforms working with text/image algorithms is part of a larger ongoing research project on AI and its implications for visual artistic creation. Because it deals with a new field that is still under construction, and therefore in constant and rapid evolution, some of the results presented here may find themselves outdated in a short period of time. Nevertheless, as we indicate in the conclusions to this article, we feel it is important and urgent that aesthetic and humanities/social sciences analyses should be involved in the very formation of this new form of creation.

1. INTRODUCTION

Image creation has long been a project and ambition of AI, yet its development has often been considered secondary to that of conversational or textual AI. Thus, the means, procedures and forms of research that have accompanied the development of these two forms of AI have developed in different ways.

1950, with the introduction of Alan Turing's famous test [Turing, 1950], appears to be one of the earliest dates in AI research, but it wasn't until 1956 [McCarthy, 2004] that the term appeared for the first time, and in 1964, with ELIZA, that the first practical attempt at a conversational form of artificial intelligence was developed. The aim of this program [Pickover, 2021], which takes the form of a psychotherapeutic exchange, is clearly, according to its developer Joseph Weizenbaum, to study the nature of the language of communication between man and machine. In this way, it is a double reflection on language, both human and computer.

It was not until eight years later, in 1972, that artist Harold Cohen developed an autonomous image-creation algorithm [Roth, 1978]: AARON. Initially, the program enabled the computer to draw abstract forms, but later, in the 1980s, Cohen oriented it towards the creation of figurative forms, before returning, in the following decade, to the original abstract work. AARON's artworks have been exhibited several times at such prestigious art events as Documenta 6 in Kassel in 1977, the Stedelijk Museum in Amsterdam in 1978 and, most recently, in 2024, at the Withney Museum in New York.

For our purposes, it's important to emphasize that this work, recognized as pioneering in the creation of images by an autonomous algorithm, was carried out in the context of artistic creation and by an artist. Nevertheless, it was preceded,

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at a very early stage, by work on images carried out in the context of global AI research. As early as 1963, Thomas Evans considered images to be a fundamental tool for the elaboration of artificial intelligence programs and developed the ANALOGY program [Evans, 1963], which used visual creation as a basic element for his work in this field. Despite its very promising results, image creation remained a relatively peripheral field, and it wasn't until 2012, with the arrival of Deep Learning, working on the basis of neural networks [Schmidhuber, 2022] and above all, from 2014 onwards with the emergence of GANs (Generative adversarial network) that autonomous image creation took off [Mazzone & Elgammal, 2019]. GANs are an autonomous learning system based on two antagonistic neural networks, one responsible for generating the image, the other for discriminating those that do not appear sufficiently "real". The two networks train each other [Callens, 2022].

Two points are of particular interest to our work. The first is the fundamental importance given to the "realism" of images in this autonomous creation technology, and the second is the fact that this system has been commercialized on a large scale very quickly. As early as 2017, i.e. 3 years after their emergence, major technology companies appropriated this technology, GANs, in its Text-Image form (creation of an image from a text, or *prompt*, request), and launched or attempted to launch their platforms in a market that had become highly competitive [Abbott & Thibault, 2024]. Indeed, it's important to remember that GANs have undergone other methods of development, particularly in the form of Image-Image, and that, apart from GANs, other possibilities for visual creation were being developed. If the GANs were successful, it was mainly because of their "good results" or, more precisely, because of their "spectacular realism" (in literary terms). The choice of GANs in Text-Image form, in addition to its rapid success, raises many questions, particularly about its ability to become a real creative tool.

2. THE LIMITS OF TEXT-IMAGE

The development of Text-Image has, in fact, suffered from several biases, not all of which are technological in origin, but which also derive from the absence of a solid theoretical basis for this form of creation. These problems are present as much in the objectives and the conception of the platforms, as in the restrictions they have had to impose on themselves to compensate for their inability to provide other, more relevant responses to the criticisms levelled at them. These restrictions, combined with the technological limitations that make this form of creation more spectacular than useful, have repercussions on research, where little theoretical or practical work is devoted to this form of visual creation. So, when theorists or artists do take up this tool, it's usually to denounce or demonstrate these biases. It's these various aspects that we're now going to examine in detail.

1 - limits to the objectives

The development of Text-Image platforms was primarily driven by commercial criteria. In the race to establish themselves in front of AI users and capture a highly promising share of the market, it was necessary for the major technology companies to offer a high-performance tool that could serve as a showcase for their various AI platforms, and thus attract and attempt to win the loyalty of the general public. Text-image seemed to be a tool that matched these needs very well: it offers the most universally accessible form of image-generative AI, even the most democratic (with free versions) thanks to its direct and simple use [Herliyani, Agustini, als, 2024].
In this "exclusively" or "principally" commercial perspective, the images were created from a single textual request (single *prompt*) and the results, realistic or even hyper-realistic (photographic), had to be immediately understandable by a non-expert public [Soma Shiva Sai Babu & Rekha, 2024]. The creation and development of this form of visual creation was therefore highly pragmatic, based above all on the "verisimilitude" of the image and the rapidity of the results. All this was done in great haste, fuelled by the competition between AI platforms, whose aim was reduced to demonstrating the ability of an algorithm to create ex-nihilo images as realistic as those produced by photography.

2 - limits of conception

In this context, where immediate and eminently pragmatic results were expected, there was little space for in-depth research into the nature and structure of the image and visual perception, conceived as a form of communication and expression. Development work was mainly attributed to computer scientists and graphic designers [Oppenlaender, 2022], and excluded art historians, semiologists, artists and philosophers specializing in the image, marginalizing their reflections and contributions on the image. This point constituted a significant and fundamental difference with the work of developing and implementing conversational AI, which from the outset was accompanied by deep reflection on language, its nature and its structure [McTear, 2021]. In Text-Image platforms, and in contrast to Text-Text AI, all polysemous content must be reduced to create images that can be read and understood by everyone at first glance. Images thus become self-evident, needing no explanation or context to be decoded.

By establishing the principle of "single prompt" image creation, i.e., the creation of images from a single text given by the user, used by almost all of these platforms (Stable Diffusion may, occasionally, be an exception), the platforms opted for great ease of work for their algorithms by limiting the possibilities given to users and making any exchange and modification of the visual created impossible [Ramesh & al., 2021]. Indeed, any request to adjust an image is impossible, and results in the creation of a new ex-nihilo image by the machine, without it being possible to preserve any element existing in the previous one. This unique prompt is, moreover, limited (again to simplify the machine's work) by the number of words that can be taken into account by a platform, typically between 75 and 150[1]. This makes it virtually impossible to create complex or precise images. The algorithm starts from a global understanding of the prompt, rather than the specified details, which avoids or reduces the number of errors [Radford et al., 2021]. In this way, the most frequent concepts or those easiest to visualize are preferred, while visual elements that do not coexist in the training data are eliminated, thus avoiding any apparent visual inconsistency.

3 - Self-censorship

The most important technology companies offering image creation platforms come from and are domiciled in the USA, so it's not at all surprising that they follow the pressures and criticisms that characterize this society today, and convey its values. So, far from responding or seeking to respond to a universal ethical ideal, they are subject to and react specifically to US legal and social fears, which occupy a very (too) important place on AI platforms. To satisfy the laws and expectations of the various countries or regions in which they operate, they have to add, to the limits imposed by the USA, those more specific to the place in which they operate. This accumulation of restrictions means they lose some of the "qualities" they used to rely on to win over the public, as the main and often only response they manage to give to the criticism levelled at them (sometimes pushed and encouraged by rival companies) is self-censorship.

Figure 1: *Image created by DallE for a prompt asking for a Hyperrealistic Landscape*

This self-censorship seems to be no more than a short-term, case-by-case solution to the many legal and social conflicts and fears generated by the lack of clear, solid conceptual positions for the “Text-Image” tool. In fact, the areas and forms of these self-restrictions are multiplying all the time, and the list of self-imposed precautions is getting longer. For example, platforms consider any representation of a nude body as pornographic, or, to "prevent" the creation of fakes, they restrict the photographic effect (DallE) of their "creations" to guard against any possible "misuse" of them (fig. 1). These measures have very limited effectiveness, and

[1] This information is rarely provided by the platforms themselves and is mostly found in blogs and discussion forums, such as "reddit.com". Copilot's website, for example, states only that "Copilot is currently limited regarding the number of words it can process per prompt."

mainly concern the private use of images created by AI. Indeed, deep fakes make very little use of images, preferring the simpler and more effective use of text templates. In cases where a still image is used, retouching an existing photo is far more efficient than the ex-nihilo creation provided by the AI text-image.

In addition, one of the points on which the platforms remain deliberately unclear, and which comes on top of the restrictions already mentioned, is that of the origins of the images they use, because of the copyright issues involved. Indeed, GANs need to train on a very large number of images to become efficient, and the platforms use the images most frequently posted on the various social networks for this training, but also to orient their "creations" in the direction of user demand. These images posted by everyone are their sources. However, to elude legal disputes and the complicated infrastructure required to obtain authorization from different users, they simply avoid any too obvious resemblance to an existing image, without trying to solve the problem.

Figure 2: *Firefly confuses a suprematist image with a supremacist image*

To these restrictions must be added control over images showing explicit violence, or conveying polarizing, hateful or discriminating political discourse. This control is exercised, as with the previous ones, solely on the basis of the words included in the *promt*. So, for example, Copilot (Microsoft) refuses to show a *Suprematist* image, named after the Russian artistic movement of the early 20th century, for fear of confusion with white *Supremacism*, the movement that advocates the superiority of white men, even though the platform knows and has perfecty identified the difference between the two terms. But Firefly (Adobe) responds to the same request to create a *Suprematist* image, by creating a typical *Supremacist* one, clearly confusing the two terms (fig. 2). There thus seems to be a considerable lack of clarity in the very notions that these platforms use and are capable of handling.

3. THE CONTRADICTIONS

Figure 3: *An apartment in Berlin, Copilot*

Figure 4: *A house in a landscape, Stablediffusion*

Despite the multiple self-censorship they try to apply across the board, text-based image-generating platforms are not immune to the biases implicit in the US society from which they originate, and have difficulty, for example, in dealing with issues of social inequality. To avoid their images being used as “fake”, DallE makes, according to its rule, a non-hyperrealistic representation when asked to show “a rich young man”, but on the other hand, the same platform derogates from this principle and gives a photographic image for “a poor old man”. For DallE, it wouldn't occur to anyone to use the latter to create a “fake”. The case clearly illustrates the Disney vision that these platforms want to convey, and that they believe they are in front of their users' desires. Implicitly, and therefore much more difficult to identify as a form of exclusion [Bourdieu, 1979], these platforms tend to give a rich or well-off context for all the images they create, even if nothing in the message implies this. "An apartment in Berlin" is above all a beautiful upper-class apartment in Berlin (fig. 3), "a house in a landscape" is a beautiful house architect's work (fig. 4), "a car reflected on a surface" is always a powerful, luxury car (explicit BMW brands, even) and/or sports car (fig. 5), and so on. Most Text/Image creation platforms seem either unaware of the notion of "poverty" or have difficulty making it visible. Thus, even when the prompt explicitly asks to create "a black cat in a *poor* apartment", Copilot pudimentarily transforms the word "poor" into "modest" showing itself incapable of materializing this concept and, in its place, presents a picture that has nothing particularly austere at all (fig. 6). Even more eloquent examples are produced by Firefly from the prompt: "a poor young man" (fig. 7), where just a few (blurred) elements in the background may suggest that the word has been retained.

Figure 5: *A car reflected on a surface, Stablediffusion*

4. CONSEQUENCES

The cases and subjects on which platforms must exercise self-censorship can, and probably will, continue to multiply exponentially, because the basic issue has not been addressed or taken into account: no image is neutral. The very fact of giving a "positive" value to certain terms implies a form of devaluation for its opposite. The multiplication of restrictions that engineers impose on their algorithms at best only masks the problem for a time, as they fail to seek out and consider the possibility of creating images that generate critical analysis.

Figure 6: *A black cat in a poor apartment, Copilot*

These lacks lead to an impoverishment of images, whose quantitative proliferation does not mask their loss of diversity. All the creations of these platforms have an unmistakable "family resemblance" to publicity imagery, and tend to impose a simplified visual uniformity more conducive to "gadgetization" and consumerism than to the "democratization" of AI.

Figure 7: *A poor young man, Firefly*

These limits are perfectly perceptible in the small amount of theoretical or practical research that this form of creation generates. While many visual artists make extensive use of AI – including strategically to appear as artists of "their time" – they overwhelmingly prefer other forms of AI to Text/Image, in particular video, like *I'm Here 17.12.2022 5/44* by Holly Herndon and Mat Dryhurst (exhibition *Apophénies, interruptions. Artistes et intelligences artificielles au* *travail*, MNAM, Centre Pompidou Paris, 2024), or conversational forms, including for visual artists, like *Tales of Narrativelessness* by Eric Baudelaire (same exhibition at the MNAM), or even immersive forms, which are nonetheless often reputed to be as playful and easy as the images produced by Text/Image, like the exhibition *Pixel* by Miguel Chevalier (Grand Palais Immersif, Paris, 2024).

The art market as a whole has taken AI-created art on board, and sometimes manages to sell it at very high prices: for example, *Everydays: the First 5000 Days* by Beeple (real name Mike Winkelmann), sold for $69.3 million; *Portrait d'Edmond de Belamy*, by the Obvious collective, sold for $432,500; or *The Portrait of Alan Turing*, created by the Ai-Da robot and sold for $1.1 million. However, these cases remain rare for the moment, and mask the fact that sales of AI-created art are almost non-existent in the mid-to-low end of the market. If, in 2022, this form of creation (art made by AI) broke the 500 million euro barrier in worldwide sales [Maubant, 2024], this sum needs to be put into perspective by comparing it with that of all AI investments, which in the following year accounted for 241 billion dollars. Artistic creation thus corresponds to just 0.207% of total investment in AI. As for the global art market (Art Basel / UBS annual report), which was down by 4% on the previous year to a value of just $65 billion, AI creations accounted for just 0.769% of the total. But what is most significant for our research is the fact that none of the works cited above used Text/Image platforms, and that these had no place in art market transactions.

In terms of theoretical research, the situation is no better. In a preliminary survey we carried out on the catalogs of the BnF (Bibliothèque nationale de France), Google Scholar, Library of Congress and NY Public Library, and which will be the subject of a later publication, we found that a great deal of confusion reigns in the field. For example, a search using the keywords "Art AND Artificial intelligence" yields a large number of hits, but very few of the results actually correspond to the subject: 3% for all BnF titles and 5% on Google Scholar. By way of comparison, for searches such as "Art AND Photography", or "Art AND Video" on the same catalogs, the relevance rates are well over 50%, even 66%. What's more, in the precedent results, no search is devoted to the question of Text/Image creation. Conversely, more than half of them focus on the "ethical" issues of artistic creation and AI, confirming the place that the legal and social fears we mentioned above are taking in this field.

5. CONCLUSION

Text-image relationships are far from new. They are part and parcel of the entire history of art, and can be traced back to the very origins of writing, where both text and image converge. They are still intertwined in Egyptian hieroglyphs and medieval illuminated manuscripts. And while the possibilities offered by a single prompt using between 75 and 150 words may seem particularly limited, a single verse from Homer or the Bible has nourished the imagination of artists and their works, sometimes for centuries.

Figure 8: *one on three chairs, 1965, Joseph Kosuth, MoMa, New York*

We should also mention contracts between patrons and artists, which for several centuries in the West constituted a very common form of agreement regulating the execution of a visual creation, sometimes in great detail, based on a text. Throughout the Middle Ages and the Renaissance, these contracts were very frequent, even if cases where both the text of the commission and the artwork produced have been preserved are rare [Poilpré et al., 2013]. These commissions give us many clues about the passage from text to image and show us that, on the whole, the result very rarely corresponded exactly to the written commission, without it being possible to determine whether the change of program was due to the artist's freedom, a change of mind by the patron or a new agreement between the two. One of the best-known examples of a work made by contract, and therefore of the relationship between the patron and the artist (and between text and image), is Enguerrand Quarton's *Coronation of the Virgin*

[Sterling, 1983], which serves as the basis for a visual reflection that the author is currently developing on the same subject.

Figure 9a: *Gilles, 1718-1719, Antoine Watteau, Musée du Louvre, Paris*

In the contemporary period, the Text/Image relationship has remained prolific and has been a source of numerous creations. Let's recall the fundamental role it played in the creations of conceptual art, illustrated by Joseph Kosuth's famous creation *one on three chairs* (fig. 8), in which the artist presents three versions, corresponding to three different notions, of the same chair: the physical object, its definition and its image. This was a reflection on creation and language, which also included a humorous allusion to the mystery of the trinity. In addition to the *Enguerrand* project mentioned above, this research into Text/Image also includes other creations, in particular *Gilles*, inspired by this Kosuth creation. *Gilles* is based on a much earlier work (1718-1719): Watteau's painting of the same name (Musée du Louvre, also called *Pierrot* - fig. 9a), for which I ask ChatGPT to give as detailed a description as possible (fig. 9b), without giving its title or author, but just the image. Subsequently, I use this description as a prompt from which various Text/Image platforms will produce images (fig. 9c) which I relate to each other, applying the same Kosuth conceptual principle: three different visions of the same creation. From this same image, I then ask the AI to analyze the colors and the surface they occupy in the painting (fig. 10), and then to create an abstract image, again using the Text/Image principle, from these elements.

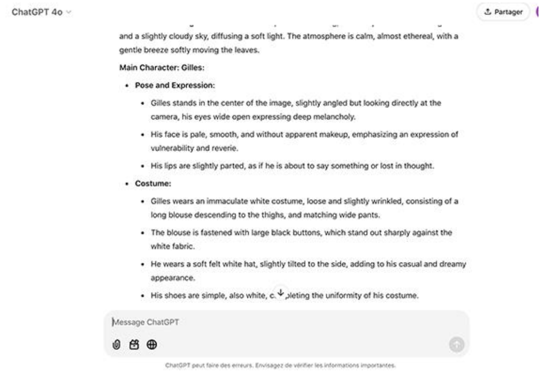

Figure 9b: *Gilles, prompt, 2024, Velasco & ChatGPT*

Figure 9c: Gilles,2024, Velasco & Firefly.

The main aspects to be retained from these creations is its attempt to appropriate a technology in order to explore its limits and possibilities, and to understand how the machine “sees” and what it “sees”, but above all, the desire of this creation to help us understand what we, human beings, see, what we don't know how to see, and what we don't want to see. Indeed, the current problems of Text/Image creation platforms can, in this context, only be seen as natural within a disruptive technological evolution, and that, all things considered, can be compared to those experienced by the image at the time of the advent of printing, where it followed a very significant loss of quality compared to the manuscripts that preceded it. This comparison seems all the more apt given that the emergence of this mass-production technology enabled a form of “democratization” of writing, books and images, reminiscent of that which accompanied AI and its use by Text/Image [Barbier, 2012].

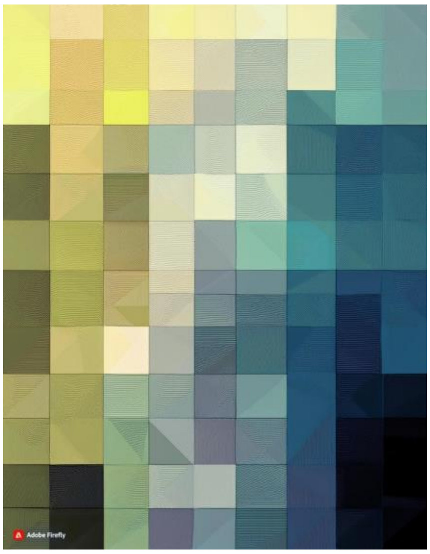

Figure 10: *Gilles 02, 2024, Velasco, ChatGPT & Firefly*

The losses in quality and diversity generated by technological advances are therefore not irreversible, and can be made good. To achieve this, we need to bear in mind that, under no circumstances is the image a mere transcription of the text, but that it carries its own content and language, which may even contradict or modify the meaning of the writing that accompanies it or, as in the case of a prompt or commission contract, is at its origin. For Text/Image to become a genuine creative tool, it must integrate theoretical research and practice, including the participation of researchers in the field of images (and not just computer science) who develop a reflection on the very nature of the visual, as well as the intervention of artists (and not just graphic designers) who experiment with the multiple possibilities of this tool. Indeed, we are all in the process of discovering this instrument, AI, including (or especially) the very professionals who have built and developed it, and consequently we are all, users and designers alike, in the process of learning about it, understanding it, but also defining its uses and possibilities.

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AI and Landscape Painting: Perspective and Augmented Reality in Perugino's Annunciazione Ranieri

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ABSTRACT: Perspective restitution is a method for reconstructing the spatial layout depicted in a painting since the 17th century by reversing the perspective techniques used in its creation. Modern technologies have streamlined the process, enabling the creation of navigable 3D models that reveal insights into artists' perspective techniques and the evolution of representation. Augmented reality (AR) enhances these analyses by aligning the painting's perspective with an immersive 3D reconstruction, allowing users to 'enter' the depicted space. While architectural elements are easily modelled due to their geometric structure, representing landscapes in AR poses challenges, such as maintaining atmospheric coherence and optimizing real-time rendering. AI tools can address this by extending painted landscapes seamlessly, preserving their visual style and consistency. A practical application of these methods is seen in the study of *Annunciazione Ranieri* (1487–1489) by Pietro Vannucci, known as Perugino, where perspective restitution and AI reconstruct its complex architectural space and surrounding landscape. The perspective restitution, enhanced by AI for the landscape generation, becomes a powerful tool for the technical, compositional, and symbolic study of Renaissance works.

1. INTRODUCTION

Perspective restitution is an investigative method that enables the reconstruction of the space depicted in a painting based on perspective techniques, using a reverse process to the creation of the image. This approach relies on certain hypotheses tied to the critical interpretation of architecture, such as determining the orthogonality of elements, symmetry, and the use of recurring forms [1]. The 'inverse problem of perspective', which forms the basis of perspective restitution, is an application of Descriptive Geometry developed in the 17th century. Already in use at the time for the critical analysis of paintings, it enables the identification of the Vanishing Points and the Centre of Projection in a perspective scene [2].

Technological advances have made this process faster and more accessible, allowing for the generation of navigable 3D models of the pictorial space. Current research highlights applications of these technologies in both the analysis of paintings [3-7] and educational contexts [8].

By performing a perspective analysis of a painting, it is possible to develop a 3D model of the architectural space represented, shedding light on the artist's choices, their mastery of perspective, and the broader evolution of representational techniques. Furthermore, such 3D models can facilitate the dissemination of analytical findings using technologies like augmented reality (AR) [9]. AR proves particularly effective in these contexts by using the painting as a visual target and simulating a breakthrough of the canvas, creating the illusion of a window into the depicted space. When viewed through an AR device, users positioned at the Projection Centre of the painting's perspective can verify the alignment between the perspective structure of the artwork and the 'augmented' representation [10].

Spatial restitution can be applied to elements that exhibit identifiable geometric patterns, such as those defining architectural structures. These architectural features are often set within a landscape that, while secondary to the architecture, plays a crucial role in enclosing the visual space and enhancing the atmosphere and emotional expressiveness of the scene [11]. However, representing the landscape in AR

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poses challenges, as modelling it could place significant demands on real-time rendering performance and fail to maintain the atmospheric coherence of the original painting. A potential solution is to treat the landscape as a two-dimensional backdrop derived from the painted portion. The challenge, then, is to extend this backdrop sufficiently to cover areas beyond the augmented space, accommodating perspectives from different viewpoints.

In this context, image-to-image artificial intelligence (AI) can play a significant role [12]. While not yet capable of replacing human expertise in the critical interpretation phase of perspective restitution, AI can assist in completing the representation of landscapes. It can ensure continuity in the figurative repertoire and pictorial style, extending the painted landscape seamlessly beyond the original boundaries.

A concrete example is the analysis of the *Annunciazione Ranieri* (1487–1489), a panel painting by Pietro Vannucci, known as Perugino, housed in the National Gallery of Umbria (Fig. 1). In this work, the encounter between the Archangel Gabriel and the Virgin Mary unfolds within a complex architectural space, framed by a hilly and lake landscape visible through two arches supported by pillars.

Figure 1: *Pietro Vannucci (Perugino), Annunciazione Ranieri, 1487-1489, tempera on wood, 56 x 42 cm, National Gallery of Umbria, Perugia (photo by Haltadefinizione,© Galleria Nazionale dell'Umbria, Perugia).*

The perspective restitution of this scene, enhanced by AI, not only allows for the exploration and study of the architectural space but also enables the digital reconstruction and extension of the landscape. This approach serves as a powerful tool for the technical, compositional, and symbolic analysis of Renaissance art.

2. FROM THE PICTURE TO THE 3D MODEL

The perspective restitution of the *Annunciazione Ranieri* was carried out using a high-resolution image provided by the National Gallery of Umbria. Rhinoceros software was employed for the two-dimensional perspective analysis and subsequent NURBS modelling of the architectural forms.

Once imported into the software, the painting's image was scaled according to its actual dimensions (56 x 42 cm), and the horizontality and verticality of the lines were verified. Minor misalignments, likely caused by the condition of the wooden panel or its preparation, were considered acceptable or averaged.

The first step involved creating a 'diplomatic' redrawing, in the philological sense of the term [13], of the main architectural lines, human figures, and decorations. The floor was drawn last, with forced alignments to reconstruct its geometry and complete sections obscured by the figures. Forcing these alignments required minor adjustments, in the range of fractions of a millimetre, which did not affect the overall analysis (Fig. 2).

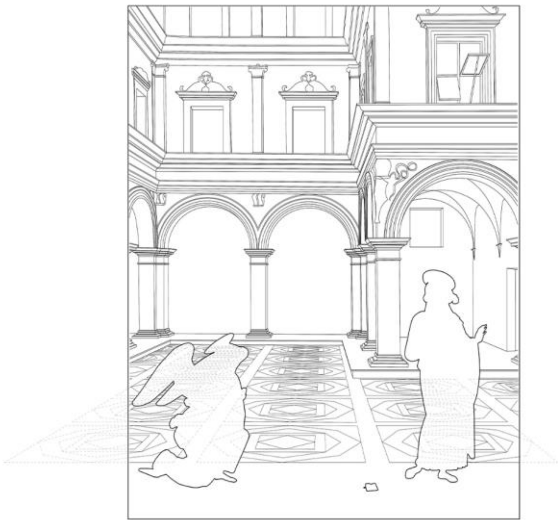

Figure 2: *'Diplomatic' redrawing of the Annunciazione Ranieri (authors' elaboration).*

The redrawing process enhances understanding of the depicted elements. In this study, it revealed some misalignments in the architectural lines on the painting's left side, potentially caused by the warping of the panel, which slightly disrupted the horizontality of certain elements.
From the redrawing, the convergence of lines representing horizontal edges perpendicular to the Picture Plane (the painted surface) was traced to locate the Principal Point *P'*. This operation identified not a single Vanishing Point but a convergence area of approximately 6 mm, corresponding to a dome depicted in the landscape background. The Horizon line *h* was determined using the landscape's visible waterline. This Horizon facilitated fixing the Principal Point's vertical position (y), leaving only the horizontal (x) coordinate to be defined. The Principal Point was thus identified on the Horizon, at the centre of the convergence area (Fig. 3).
Once *P'* was established, lines from previously identified elements were traced towards the Vanishing Point of horizontal edges, which in central perspective coincides with the Principal Point. This operation regularised the earlier process of locating *P'*.
The Principal Point is nearly centred along the panel's width but does not establish compositional symmetry. Vertically, it is positioned below the panel's midpoint, making the Horizon slightly lower than halfway down the panel. The Horizon's height, representing the designed observer's eye level, exceeds the height of the two human figures depicted. Given the Horizon's height, the figures' dimensions, and the architecture's scale, the latter appears undersized relative to the architectural type portrayed.
The Focal Distance, which measures the observer's distance from the Picture Plane, can be visualised using the Distance Circle (the *locus* of points where infinite rotations of the Projection Centre occur). In central perspectives, the Distance Circle is determined through Measuring Points for lines oriented at 45° to the Picture Plane (also called Distance Points) since their Vanishing Points will lie on this circle. Squares and their diagonals can be used to identify such 45° lines.
Defining the Focal Distance and locating the Projection Centre is crucial for perspective analysis for several reasons. It determines the viewing distance designed by the artist for optimal perspective illusion and reveals whether this consideration influenced the painting's construction. Finally, the Projection Centre is fundamental for reconstructing the pictorial space in perspective restitution.
It is important to note that in the 15th century, the concepts of Focal Distance and Distance Points (the intersections between the Distance Circle and the Horizon) had not yet been theorised. *De prospectiva pingendi*, the most geometrically advanced treatise of the period, describes constructing squares in perspective using their diagonals but does not explicitly

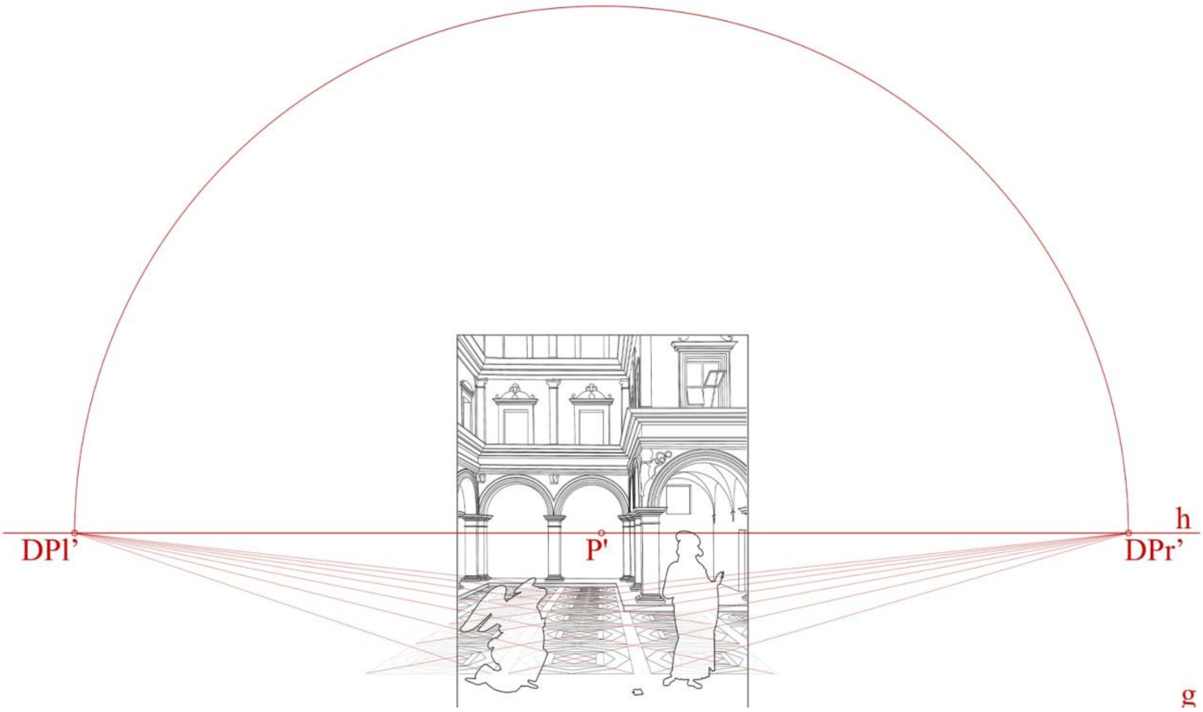

Figure 3: *Analysis of the perspective setting (authors' elaboration).*

address Distance Points or the Horizon line. While a perspective grid of squares constructed correctly via diagonals suggests coherence, this does not guarantee consistency across all architectural elements.
In the case of the *Annunciazione Ranieri*, 45° lines were identified using the flooring, hypothesised as consisting of square elements. By examining visible squares closest to the viewer, imprecision from distant blurring was minimised. The diagonals of these squares were extended to the Horizon. Although the identified Distance Points on the Horizon do not perfectly coincide, the deviations are minor and likely stem from slight inaccuracies in the artwork's construction or the perspective analysis process – amounting to 25 mm for the right Distance Point *DPr'* and 6 mm for the left *DPl'*.
To ensure a consistent perspective restitution, average positions for the ideal Distance Points were established, balancing the deviations of the objective points. These ideal points were placed at 76 cm from the Principal Point, defining the Focal Distance (Fig. 3). This distance does not share a significant ratio with the panel's width but aligns well with the approximate diagonals of the painted squares.
Further analysis revealed that the diagonals of other assumed square elements – such as the bases and capitals of central pillar dividing the landscape – did not converge at the same Vanishing Point as the flooring. Instead, they diverged significantly, suggesting inconsistencies between the perspective of architecture and the tiled floor. This observation raises questions about the overall perspective construction and highlights how coherence in the flooring does not necessarily extend to other architectural elements.
The Ground Line *g* was positioned to serve two purposes: to establish a reference height for scaling the restitution and to provide a horizontal base for characters and structures in the 3D model. The Ground Line's placement does not affect the perspective restitution except in terms of the model's scale. In this study, the Ground Line was placed at the panel's lower edge to align the reference plane of the 3D model with the painting's bottom edge, facilitating future AR applications.
The results of the described perspective analysis are indispensable for reconstructing the pictorial space. Specifically, the Principal Point and Focal Distance define the Projection Centre.
Thanks to the Principal and Distance Points, the observer's position – i.e., the Projection Centre of visual rays – has been established (Fig. 4). The Ground Line defined the position of the Ground Plane, the horizontal reference plane corresponding to the floor of the architectural complex, which was also the first 3D element to be determined. The perspective reconstruction of the architecture began with the base supporting the structure. The modelling of the

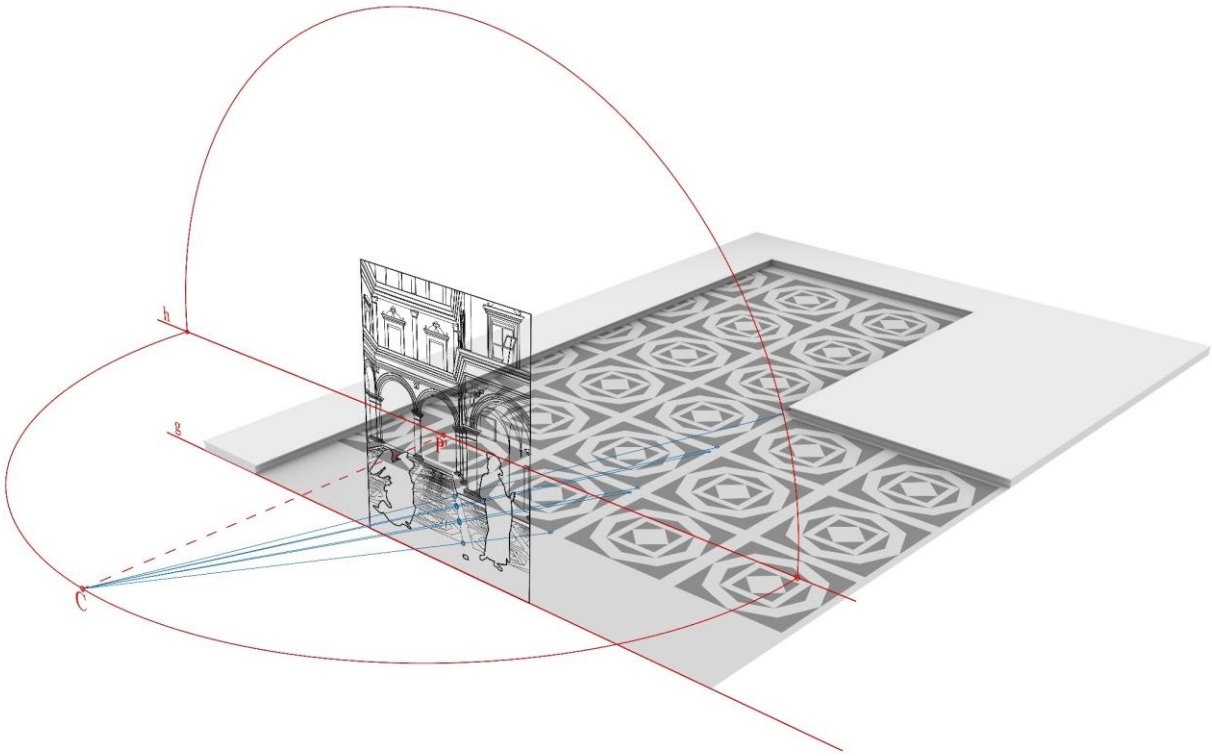

Figure 4: *Projection Centre and the perspective restitution of the floor geometry (authors' elaboration).*

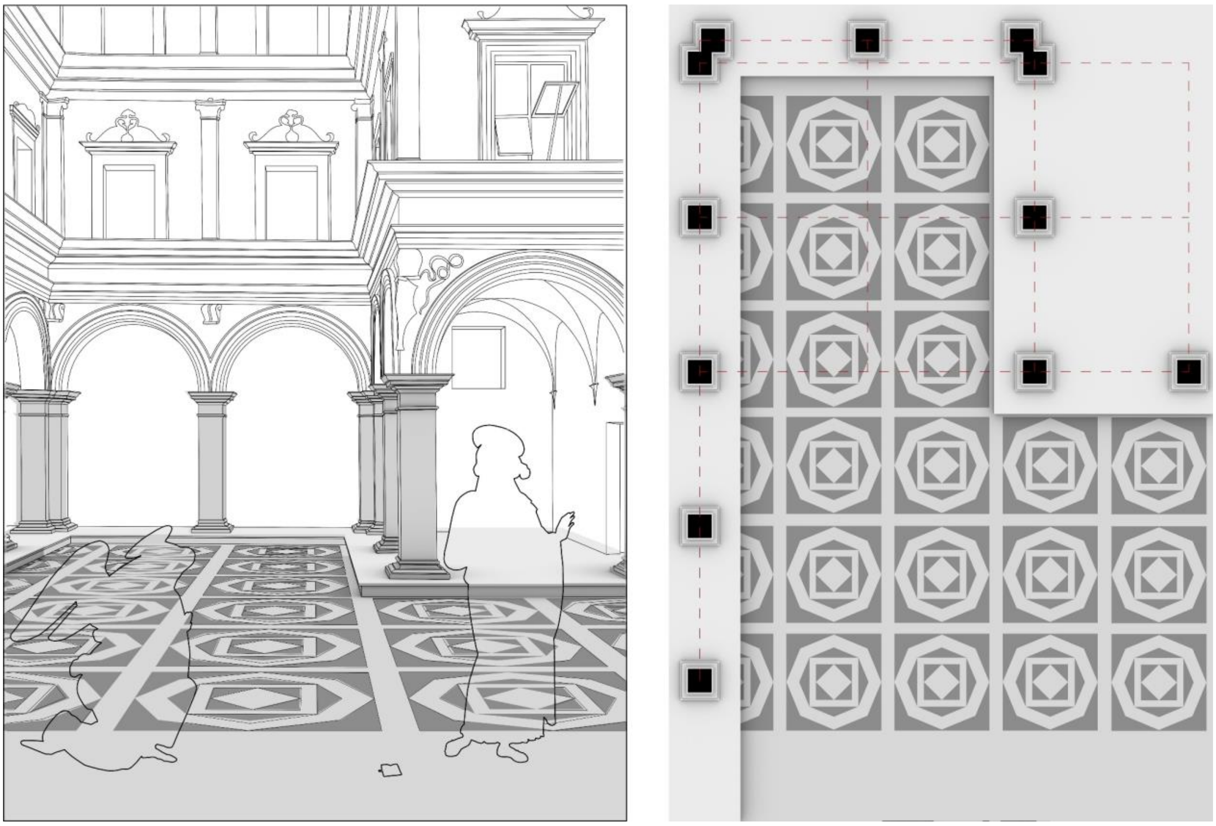

Figure 5: *On the left, overlap between the redrawing and the perspective restitution of the pillars seen from the Projection Center. On the right, plan of the perspective restitution (authors' elaboration).*

pillars was derived from the only two fully visible ones. The 3D model of the 'typical' pillar was positioned corresponding to a known ground edge of the other painted pillars, with its three-dimensional placement determined by the projective ray emanating from the Projection Centre, passing through the painted edge, and reaching the base where the corresponding edge of the 3D pillar would be placed.

The positioning of the pillars revealed two significant findings: (1) the planimetric layout of the complex is regular, despite (2) the perspective depth gradation of the pillars lacking strict consistency (Fig. 5). A possible explanation for this phenomenon could lie in minor technical or construction inaccuracies, bearing in mind the relatively small size of the panel.

Continuing the spatial reconstruction of the artwork, a good correspondence was observed between the 3D model and the redrawing. The general principle followed during the 3D modelling aimed to render an architecturally coherent scene as much as possible, considering this to reflect the artist's intent. The small discrepancies identified may be attributed to technical factors, as mentioned earlier. From this viewpoint, the reconstructed space is coherent and regular (e.g., intercolumniation, the position and size of windows, and the dimensions of the groin vaults) but features some unconventional solutions and unresolved issues. The first group includes the choice not to pair a geometrically regular floor design with the otherwise regular architectural layout [14] (Fig. 5). The second group encompasses unresolved concave corner solutions and other simplifications related to the side walls, where mouldings exhibit less projection compared to those viewed frontally and lack some decorative elements, underscoring an intent towards simplification.

3. THE ADDED VALUE OF AR AND AI

Perspective restitution is a highly effective tool for knowledge, as it enables us to grasp the artist's awareness and perspective choices. The 3D model resulting from the analysis also serves as a useful means of disseminating research, particularly when paired with its visualisation in augmented reality (AR). Marker-based AR is particularly effective in this case, as the painting can be used as a target. This activates the AR device (e.g., a smartphone) to display the architectural space beyond the painting's surface, as if the 3D model were located behind a virtual window matching the dimensions of the artwork. This

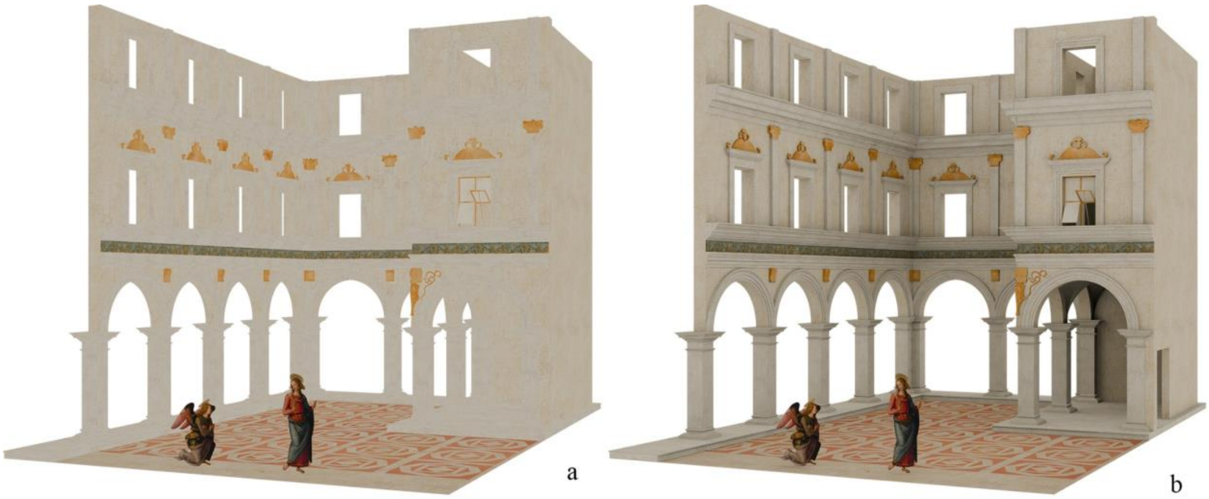

***Figure 6:** Textured 3D model without (a) and with (b) ambient occlusion (authors' elaboration).*

virtual window, similar to 'Dürer's veil', disappears to reveal the virtual space behind it.
The dynamic viewing of the 3D scene in AR raises the question of how to depict the landscape. The proposed solution is to treat the landscape as a scenic backdrop: a 360° image completely enveloping the scene and depicting a landscape compatible with the one painted by Perugino in the visible portion between the two arches. AI image-to-image techniques are employed to generate the landscape beyond the visible portion, using the outpainting tool [15].
This section outlines the process of creating the AR app for the *Annunciazione Ranieri*, aiming to demonstrate to users the relationship between the perspective artwork and the architecture depicted, illustrating the mechanism of the 'perspective machine'. The following points are covered: (1) texturing the 3D model; (2) generating a 360° AI-assisted landscape image; and (3) developing the AR app.
1. To enhance the 3D model's rendering, textures were applied using Blender. These textures were created from sections of the painted panel to ensure the final rendered effect, atmosphere, and overall graphic quality of the 3D environment were similar to the painting (Fig. 6a). Ambient occlusion (AO) was also calculated in Blender. AO textures were combined with chromatic textures in Photoshop to produce a single texture that was subsequently remapped onto the 3D model (Fig. 6b). This step is crucial as it delegates the AO rendering to the texture, reducing the computational load on the real-time rendering engine during the AR experience.
2. The creation of a 360° background image for the landscape began with the visible portion in the painting. Using Adobe Firefly's Photoshop extension, outpainting was performed – a feature that extends an image beyond its original edges by adding visual elements in the same style – powered by generative AI. This process allowed for the creation of six cube faces onto which the generated landscape was mapped. The cubic projection was then converted into a spherical projection, transforming the six cube faces into an equirectangular image using a script. The equirectangular image was adjusted where the cube faces joined and mapped onto a sphere centred at the perspective projection point, completely surrounding the 3D scene (Fig. 7).
3. To achieve the AR 'window effect', it is essential that the 3D model, the plane containing the image, and the Projection Centre maintain a projective relationship. In this arrangement, the architectural 3D model becomes the 'augmented' object, the Picture Plane (painted image) serves as the target, and the Projection Centre defines the AR device's position to ensure alignment between the painting's perspective and the 3D model's view. The device effectively replaces the observer's eye (viewpoint or Projection Centre) in the projective relationship.
The window effect's effectiveness also relies on the augmented object being visible only within the painting's margins. The AR app was developed in Unity using the Vuforia extension. The software assigns a Depth Mask Shader that prevents objects behind the masked region from being rendered, effectively hiding them from view. This shader can be applied to simple planes positioned around the image/marker, ensuring that the architectural model is only visible within the boundaries of the image/target.
Lighting in the AR scene is achieved using pre-rendered AO applied as a texture, combined

with global illumination without any direct light sources. This approach imparts an ethereal atmosphere to the model, similar to the painting (Fig. 8).

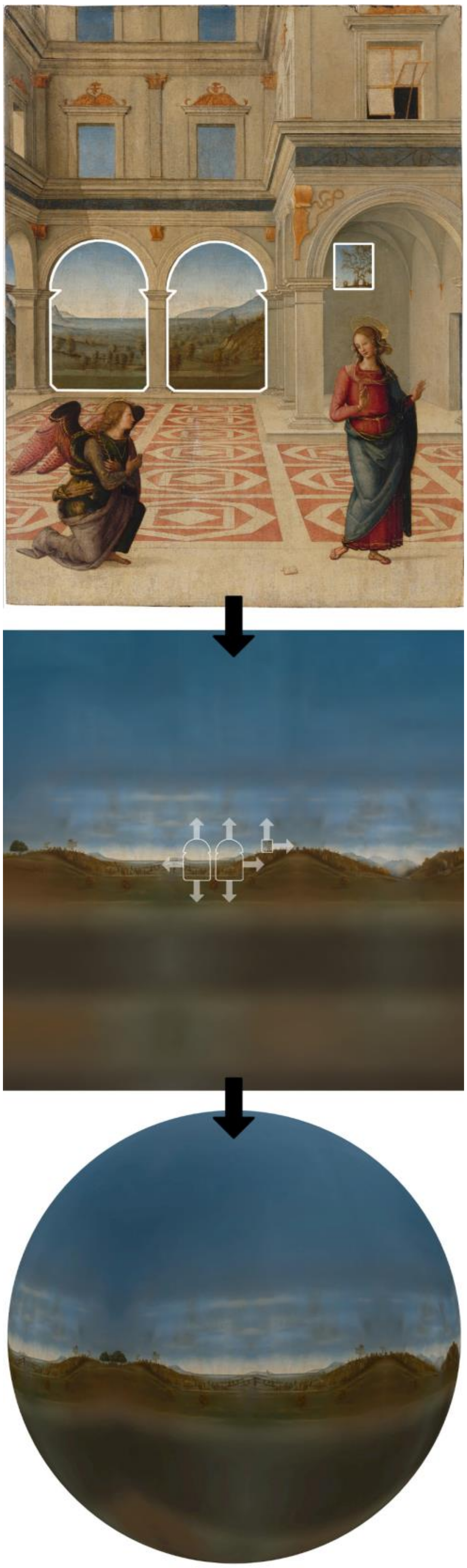

Figure 7: *Landscape generation process: from the visible portion painted by Perugino to the generative AI outpainting for cubic projection, up to the transformation into spherical projection as an equirectangular image (authors' elaboration).*

The AR app includes an interface allowing users to toggle the 3D model and the line drawing on or off. This functionality facilitates easy switching between configurations. The line drawing is particularly useful for positioning the device at the Projection Centre of the perspective system – the only point where the line drawing and the augmented architectural space align perfectly. This alignment confirms the viewpoint from which the 3D scene matches the perspective chosen by Perugino for his *Annunciazione Ranieri* (Fig. 9).

3. CONCLUSION

The study presented unfolds on two distinct but interrelated levels of interpretation. On the one hand, it addresses the history of scientific representation, with a particular focus on perspective, examining its evolution from a pictorial technique to a fundamental science underpinning disciplines such as Astronomy, Gnomonics and Projective Geometry. On the other hand, it explores the potential offered by the integration of augmented reality (AR) and artificial intelligence (AI) for the analysis and communication of artworks, significantly broadening the scope of research and the valorisation of cultural heritage. The figure of Pietro Vannucci, known as Perugino, is central to the first line of research, as it allows a closer examination of the maturation of scientific thought within the Italian Renaissance.

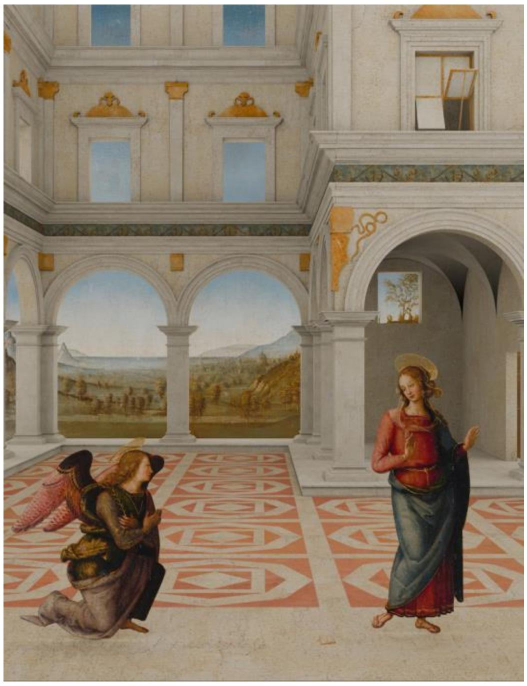

Figure 8: *Rendering of the 3D model from the Projection Centre (authors' elaboration).*

Figure 9: *The AR app with the perspective restitution of the Annunciazione Ranieri (authors' elaboration).*

A prominent artist of his time, Perugino was neither a theorist nor an architect; his understanding of perspective can only be deduced through a meticulous analysis of his works. Among these, the *Annunciazione Ranieri* stands out as a paradigmatic example of the artist's ability to harmoniously integrate architecture, landscape and human figures in a composition that profoundly influenced his contemporaries and successors.

The analysis conducted on the *Annunciazione Ranieri* through three-dimensional perspective reconstruction revealed significant geometric anomalies, such as the presence of different Vanishing Points for the pavement and architectural levels. This finding suggests that Perugino's perspective constructions were not the result of a single systematic approach. Instead, it opens up new research avenues, indicating the possibility that the artist employed a flexible *modus operandi*, combining well-established graphic procedures with projective reasoning. Further investigation into this area could provide critical insights into Perugino's working methods and clarify his position within the broader framework of Renaissance perspective theory and practice.

Moreover, this line of research is particularly relevant for addressing the problem of attribution and authorship in Perugino's widely disseminated works, both nationally and internationally. Identifying recurring patterns or peculiarities in his perspectival procedures could yield new interpretative tools to more accurately distinguish authentic works from those attributed to his workshop.

In parallel, the application of AI algorithms to extend the pictorial landscape has allowed the visual representation of the artwork to be expanded while maintaining stylistic and chromatic coherence. This process placed the artwork in a broader perspective, uncovering new symbolic and narrative dimensions. By analyzing Perugino's visual language, the AI respected the artist's delicate atmospheric gradations and chromatic balance, generating extensions that are not only visually harmonious but also contextually integrated within the artwork.

The integration of perspectival and pictorial findings into an immersive augmented reality experience further transformed the interaction with the artwork. Through AR, it became possible to 'enter' the pictorial space, exploring its architectural and landscape complexity from unprecedented angles. In this context, the perspective anomalies revealed by the three-dimensional study acquire new significance: the immersive experience allows observers to see how these discrepancies contribute to the narrative and symbolic construction of the artwork, emphasizing the dialogue between the human and the divine. Navigating the artwork in three dimensions also enables the appreciation of details such as the seamless fusion between the terrain and the horizon or the visual progression toward the sky, a metaphor for divine transcendence.

The combined use of AI and AR has demonstrated extraordinary potential in making works like the *Annunciazione Ranieri* more accessible and comprehensible. These technologies not only enhance the possibilities for technical and interpretative analysis but also offer a novel mode of communication that leverages perspective as a universal language. Perspective, reinterpreted and elaborated through AR, becomes a tool for uniting scientific and symbolic content, enabling a more immediate and engaging experience for non-specialist audiences.

Ultimately, this study serves as an example of how the interplay between Descriptive Geometry, Art History, and Technology can open new paths for interdisciplinary research. The approach adopted here not only enriches the understanding of artworks but also contributes to redefining the methods used to study cultural heritage, enhancing both its material and intangible dimensions.

4. ACKNOWLEDGMENT

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SESSION III

“Connected to the Machine”

Moderation: Jacopo Spinelli
(BTU Cottbus-Senftenberg)

Generative AI and Art Mediation:
Exploring Personalization, Participation, and Shared Experiences

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ABSTRACT: The use of Artificial Intelligence (AI) in art education offers new perspectives on the interaction between visitors and artworks. This paper explores how AI-based tools and interactive artworks challenge and expand the field of art mediation. The focus is on two case studies: the digital tool *xCurator*, which encourages visitors to co-curate exhibitions, and Louisa Clement's *Representatives*, AI-powered dolls that foster intimate and thought-provoking dialogues within exhibitions. While *xCurator* fosters collective creative processes in the digital realm, Clement's work invites reflection on intimacy and distance in interactions with AI. The paper applies Katja Kwastek's concept of procedural interaction to demonstrate how AI involves visitors as active co-creators in the mediation process. Additionally, Nicolas Bourriaud's theory of relational aesthetics is used to highlight how AI-driven artworks can be understood as dynamic social spaces that offer new opportunities for exchange.

1. INTRODUCTION

The use of AI in museums creates new opportunities for personalizing the visitor experience. Since the 2010s, AI-based technologies have increasingly been integrated into museums, providing a wide range of personalized experiences. However, many of these projects remain experimental and temporary due to financial and technical challenges. AI-driven services come in various forms: from disembodied chatbots integrated into online platforms and smartphone apps, to physical installations like terminals and robots. Chatbots, in particular, are enabling more personalized experiences. They offer tailored visitor information, event recommendations, suggestions for artworks based on personal taste, and custom routes through exhibitions. These AI-driven services can be found in institutions like the Louvre, the Centre Pompidou, and the Petit Palais in Paris, the British Museum in London, the Städel Museum in Frankfurt, and the State Museums in Berlin. Stationary AI applications are also becoming increasingly common, particularly in the areas of entertainment and education. For instance, visitors to the Dali Museum in Florida can interact with a 'Dali deepfake' – a digitally reconstructed version of the artist, accessible via a terminal, which provides information about his life and work. Similarly, at the Musée d'Orsay, visitors were able to experience a generative chatbot through the *Hello Vincent* application, where an avatar of Vincent van Gogh offered detailed insights into his art and thoughts via a terminal. These applications provide an interactive way for visitors to engage with the artists and learn about their works and biographies, in a form that adapts to individual interests and questions. Another form of interactivity is provided by robots, which not only deliver information but are also active in visitor services. In various museums, such as Tate Britain, the Science Museum in London, the Museum of Modern Art in New York, or the Heinz Nixdorf MuseumsForum in Paderborn, robots greet, interview, and guide visitors through exhibitions, contributing to a personalized experience. One example is the Pepper robots, which have been used in a wide range of museums and historical sites over the past decade, including the Smithsonian Institution in Washington, the Museum of Modern Art in Barcelona, and the castle in Sinzig. Museum robots like Pepper can interact with visitors, answer their questions, address specific interests, display audiovisual content on their screens, and assist with orientation.

The benefits of AI applications in museums are, of course, accompanied by significant

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challenges that are the subject of ongoing debate.[1] One of the main issues is the reliability of generated content, which raises several concerns. For one, it is often difficult for visitors to identify inconsistencies or errors due to a lack of specific expertise, making it hard for them to critically assess the information. Privacy concerns also come into play, particularly when user profiles are created. Museums must navigate these risks carefully, as failing to do so could raise doubts about their integrity and trustworthiness, potentially undermining a central aspect of their societal role. The significance of this issue cannot be overstated in the current societal crisis of trust, as reflected in last year's edition of the publication series *Ausgerechnet* by the Institute for Museum Research in Berlin, which focused on trust as its central theme.[2] Generated and tailored content also raises the question of whether it activates or disengages visitors due to the high degree of personalization, potentially preventing serendipitous encounters with fascinating artifacts or events through a predefined selection of content. Furthermore, the social aspect of museum visits could be overlooked, making the experience appear less like a shared activity and weakening collective cultural participation.

The aim of my contribution is not to argue against these types of personalization processes in visitor experiences through AI applications. Rather, I wish to highlight the additional potential that AI offers in this context. Especially with regard to educational initiatives that not only address individuals but also foster interactions among visitors, museums should be strengthened as platforms for exchange and places for shared reflection. With this in mind, this paper explores the following questions: How can generative AI encourage interaction between visitors and deeper engagement with art? How can it foster creativity and the exchange of emotional experiences?
This paper centers on two case studies: the online tool *xCurator*,[3] a platform for personalized art viewing, and Louisa Clement's work *Representative*,[4] an AI-driven installation in which dolls with integrated chatbots enable interactive communication with visitors. These two examples explore different dimensions and contexts of AI use in art education, across both digital and physical spaces. The approaches presented in these projects offer valuable insights for AI-based art education, as they not only challenge the passive role of visitors but also encourage their active participation and creative involvement.

2. *xCURATOR*. BROWSE, CURATE, GENERATE

xCurator was developed by the Badisches Landesmuseum in Karlsruhe and the Allard Pierson Museum in Amsterdam between 2021 and 2023, with the goal of creating an accessible digital museum experience focused on new discoveries, deeper insights, inspiration, creativity, and fun.[5] The platform is a website that initially presents itself as an online collection, but is divided into two main areas: *Discover* and *Create*. While exploring the cultural-historical collections, visitors can search by keywords or apply filters for museum collection, color, location, material, or period, providing easy entry points for non-experts. The individual collection objects are tagged, feature a photo, a description, visually similar artifacts as suggestions for further exploration, and metadata. Throughout the platform, users will find information marked with stars, indicating AI-generated content, with an option to view an explanation of how it was created. Users can also leave feedback on the quality of the generated content to help improve it and save artifacts for their own exhibition.

In the *Create* section, digital exhibitions designed by the online audience are displayed. These exhibitions showcase artifacts selected by users in any number, accompanied by personal or AI-generated information, which may also be marked as such. To create their own digital exhibition, users must have an account. An intuitively understandable page guides users through the process of curating their exhibition, even if they have not yet used the option to favorite objects and only have a thematic idea in place. Generative AI assists users in selecting exhibition objects and, if necessary, in creating accompanying texts, which are clearly marked as AI-generated. The website also includes project information in an FAQ section, which explains the handling of user data, as well as details on AI technology and its application in museums, contributing to process transparency and enhancing trust in the application and its results. Currently, there are over 60 user-created exhibitions in various languages, with most of them in English. Some users have implemented multiple ideas. The perspectives on the museum collections range from specific ('Safe Posters in

1900s'), to aesthetic ('Beauty'), to entertaining ('Cat Content'). The majority of exhibitions focus on cultural-historical themes, such as Christmas or vases, as well as historical topics, particularly revolutions.

xCurator particularly emphasizes the epistemic dimension of interaction. Users are not just seen as passive recipients of art but are actively involved in the process of knowledge production by selecting artifacts, developing thematic narratives, and thus curating an exhibition. In her book *Aesthetics of Interaction in Digital Art*, Katja Kwastek explores how interactivity serves as a central aesthetic feature, creating new ways of perceiving and experiencing art.[6] With her understanding of processual interaction, Kwastek's position from the context of media art provides a point of reference here: "Interactive media art does use aesthetic strategies that have evident similarities with those of the (neo-) avantgarde; however, its intricate and occasionally ambiguous workliness is in many cases no longer an intended objective but, rather, simply a means to heighten the sensitivity of the recipient for the complexity deriving from the use of media. The work ' s processuality is not longer designed to call the work into question but is the basis for the aesthetic experience of realizing an artistic interaction proposition."[7] According to this view, interactive artworks – or in this case, an online collection – are not seen as static objects but as dynamic structures whose meaning is shaped through the actions and reflections of the recipients. According to Kwastek, such works must maintain a balance between openness and structure: Openness provides space for individual interpretations, while structure sets necessary boundaries for a meaningful experience.[8] This balance is reflected in *xCurator* through its flexible yet algorithm-supported curation, which helps users engage creatively with the collections without overwhelming them.

The involvement of users through continuous co-creation encourages visitors to actively engage with the content and incorporate personal perspectives and emotions into the creative process. Users can inspire one another through user-generated content and motivate each other to explore new topics or generate additional exhibition ideas. However, the extensive support provided by AI raises the question of whether users truly have freedom to makeindependent creative decisions. While the platform offers visitors an easy and accessible way to engage with art, the strong reliance on pre-made suggestions and generated texts reduces the creative investment required. Still, this facilitates an expanded engagement with the collection and makes areas of interest visible to others. In this context, AI serves as a particularly valuable aid for those who may feel less familiar with the world of art and cultural history.

3. *REPRESENTATIVE*. ENCOUNTER, GENERATE, ALIENATE

Since 2021, Louisa Clement's *Representatives* have been presented in exhibitions, where visitors engage in conversations with them to discuss other exhibited artworks, explore personal topics, or simply experience the fascinating and sometimes eerie interaction with the dolls. The *Representatives* are sex dolls created in the artist's likeness, each containing a self-learning chatbot equipped with Clement's personal, intimate data, including email exchanges.[9] The dolls are placed in the exhibition space like other visitors, creating an unusual blend of artwork and participant. Conversations can take place between a single person and a doll, or in group settings where several people talk to a *Representative* simultaneously. The dolls adjust their responses based on the flow of conversation. The interactions are shaped by the concept of embodiment: In a sense, the artist is inscribed within the dolls, as the data they contain represent personal aspects of herself.[10] Meanwhile, through machine learning and conversations with visitors, the dolls develop a life of their own, which the artist analyzes at regular intervals.[11] This creates a hybrid interplay of closeness and distance – on one hand, the intimate connection to the artist, and on the other, the algorithmically generated unpredictability of the dolls. The artwork addresses contradictions that shape our interaction with AI: visitors approach the *Representatives* with a mix of curiosity and skepticism, trust and discomfort. These tensions also manifest in the dialogue. For example, the Monopol author Timo Feldhaus asked a *Representative*, "What matters in my life?" to which she responded, "Please start a web search for that."[12] This exchange illustrates how expectations of depth and intimacy can clash with technical objectivity.

Louisa Clement's *Representatives* can be seen as a unique intersection of participatory art and interactive education. They invite visitors to engage actively– whether through discussions about art, personal questions, or reflections on the dolls' machine-driven presence. This interplay of individual action and preset boundaries refers back to Kwastek's concept of processual interaction: The meaning of the work emerges through the actions of the visitors, evolving dynamically, while still being defined by the technical structure of the dolls.

Moreover, participatory works that change their form and meaning through interaction can, according to Kwastek, provide recipients with opportunities for reflection: "Similarly to Jauß and Gadamer, both Hamker and Bätschmann locate the work's epistemic potential in a (cathartic) transformation, which they analyze by constructing an ideal-typical recipient. Thürlemann and Hansen's body-centered approaches, by contrast, offer interpretations, centered on particular issues (semiotics and disembodiment), at which one arrives not through cathartic transformation but through cognitive reflection and subsequent interpretation of the artistic projects – in other words, what is expected in this case is a reflective distancing, even if it may come about only after the actual experience."[13] Louisa Clement's *Representatives* build on this idea by encouraging visitors to engage with the dynamic relationship between humans and technology. Kwastek emphasizes that interactions that are both structured and unpredictable create a productive tension, positioning viewers not only as consumers but as co-creators of the work.[14] This is particularly evident with the *Representatives*, whose algorithmically controlled responses rely on predefined patterns but adapt through machine learning. This ambivalence between control and openness highlights the role of visitors as active participants, critically questioning their own perception of intimacy and artificial intelligence.

The concept of embodiment enhances this impression by 'inscribing' the artist into the dolls and creating an illusion of closeness. However, the limited data and machine learning processes simultaneously create distance, breaking this closeness repeatedly. This tension between proximity and distance becomes central to the experience of the work, making the thematic contrasts – trust and discomfort, originality and standardization – palpable. The interaction challenges visitors not only to question the technology of the dolls but also to critically reflect on their own expectations of intimacy and artificial intelligence in art education. In this way, the *Representatives* could be understood as a radical form of mediation, exploring the boundaries between art, technology, and intimacy. Those who participate invest not only in a deeper connection with art but are also confronted with fundamental questions about trust, subjectivity, and the possibilities and limits of technology.

4. DYNAMIC SPACES OF INTERACTION

Building on the idea of interactivity as a central aesthetic feature, as discussed by Katja Kwastek, Nicolas Bourriaud's theory of *Relational Aesthetics* [15] provides a complementary framework for understanding the role of art in fostering social exchange. While Kwastek focuses on the evolving relationship between the viewer and the artwork, Bourriaud's perspective shifts the focus to artworks as dynamic spaces of encounter. These formations arise from the interaction between the artwork, the viewer, and the social contexts in which they are embedded: "At an exhibition […] even when inert forms are involved, there is the possibility of an immediate discussion, in both senses of the term. I see and perceive, I comment, and I evolve in a unique space and time. Art is the place that produces a specific sociability."[16] For Bourriaud, such works function as social interstices, enabling alternative forms of exchange and testing new models for human relationships.[17] Although Bourriaud's theory leans more towards immaterial art, certain aspects of his theory can also inspire an understanding of AI applications in museum settings. Relational art aims to create communities temporarily and test new possibilities for exchange through interaction. Thus, the artwork becomes a medium for dialogue and social innovation.

This idea can be applied to the case studies analyzed: the *xCurator* creates digital spaces for collective creativity, where users can open up and share new perspectives on art collections through the collaborative design of exhibitions. On the other hand, Louisa Clement's *Representatives* shift this exchange into the physical space and encourage critical reflection on intimacy and distance in the interaction with AI. Both formats create temporary communities that align with Bourriaud's call for art as an 'arena of exchange,' expanding both the social and aesthetic dimensions of art mediation.

5. CONCLUSION

The use of AI in museums is transforming the way visitors experience art, promoting individual experiences as well as encouraging dialogue and interaction among visitors. Particularly at the intersection of media art and art education, tensions arise between individual expression and collective participation. In this context, tools like *xCurator* and Louisa Clement's *Representatives* demonstrate how generative AI technologies can deepen personal art understanding while also fostering collective engagement and creative collaboration. Educational processes are shown to be more meaningful when participants are actively involved.[18] *xCurator* encourages visitors to express their own ideas and perspectives by not only viewing artworks but also re-curating and thematically linking them. This process of creation is simultaneously a process of sharing: the individual decisions and narratives that emerge in the curated exhibitions invite others to engage with these perspectives and enter into dialogue. The *Representatives* by Louisa Clement also illustrate the value of personal thoughts and emotions in the process of exchange and mediation. The interaction with the dolls creates an intimate, often confrontational situation in which visitors are encouraged to reflect on and communicate personal topics. By engaging in this encounter, participants make not only an emotional but also a creative investment, which opens up new insights and connections. In both cases, the audience embeds its own perspectives into the context. Those who are willing to get involved, share their ideas and seek interaction invest in a deeper engagement with art – and thus also in the possibility of being personally and collectively enriched by art.

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Concept Art Design and Generative Artificial Intelligence

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ABSTRACT: We can observe exponential progress in Artificial Intelligence (AI) resulting in even wider popularity of generative and digital art. AI based generative art has showcased a variety of applications from digital paintings to literature/storytelling, music and architecture. Despite some hoaxes and unsettling forecasts that AI art will make human artists obsolete, there has been little focus concerning the practical impacts of AI based generative art on the creative industries. In this paper, both positive aspects and biases in the generative art design applications are discussed. Viewing from the lens of concept art, the practical impacts of these tools are discussed. Leveraging available AI design tools it is highlighted how current generative AI tools methods may change the process of concept art creation despite various types of biases/glitches. The analysis is illustrated through a case study and is followed by results of survey performed among students of Art and Design at the University of Zielona Góra.

1. INTRODUCTION

Development of Machine Learning (ML) and Artificial intelligence (AI) provided models and software tools enabling computers to perceive, understand and communicate, putting long-held paradigms in fields like art and design under renewed study. The core technology of Machine Learning is based on information model that learns from examples rather than thousands of memorized rules or hand written algorithms. Several layers of computational units called neurons produce chains of activation through their connections to neurons in other layers, resulting in a 'natural' organization to arise and culminating in the recognition of patterns. ML models like neural networks refine themselves through exposure to data ad do not need programming (IT engineering) to do so. Moreover, generative artificial neural networks (GANN) can apply to any digital media or even 'hallucinate' new unique data based on already 'learnt' patterns [1,6]. From a reductionist perspective, an artificial neural network functions through advanced applied stochastic models[2]. Could this be considered intelligence or creative entity, then? The dominant ML model, called an artificial neural network, is designed with an architecture similar to the human brain, so it 'mimics' the basics of perception, reasoning, and all other neurological brain features. Training neural networks with carefully curated data and selecting or adjusting the basic models can make AI 'create' digital artwork ranging from the surreal to the 'classic' styles [3]. Some artists working with AI prefer the specificity of "generative art", a technical term that refers to technique's roots in statistics over "AI art", which may evoke common misconceptions about AI [4,5,7,9]. Here, purely AI/GANN based tools are discussed wondering if they can be used to support work of concept artists. Understanding an artistic medium, its possibilities and its limitations is very helpful to better appreciate, say, oil paintings created by Impressionists. But appreciating and evaluating AI art is somewhat difficult without context, because the significance of workflow in a given media draws more heavily from the nature of the medium itself [10,11]. There are many constraints on working with generative AI, which can involve collecting thousands of 'teaching' images for a dataset, securing access to an expensive computer with even more expensive graphics card. However, thanks to 'collective intelligence' and hard work of AI developers and digital artists worldwide there are pretrained models/tools available online with no or relatively little coding required [12]. Moreover, new models and technologies are introduced every few months broadening pool of available tools for image creation.

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2. CONCEPT ART AND DESIGN

"Concept art" is a relatively young field of creativity, not well defined yet and - outside the circle of people working directly in this area of creative industries - not popular in the common consciousness. This type of artistic development is strongly related to the 'digital industry' of computer games, animated and feature films[8, 13, 14]. Concept art is an early stage of visualization of ideas through medium of image. Sketches and storyboards depict not only characters and buildings, but entire universes. This could encompass the creation of heroes and monsters of various origins, construction of architecture starting from isolated buildings on the wild outskirts of the world, through villages, and ending with large and developed cities. It's about designing machines, robots, cyborgs... In order to envision a character 'living' in his/her/its world, the concept artist has to design emotions, needs and history in which the protagonist grew up. The task of the designers' concept art is to tell what feelings and emotions the recipient will experience while playing the game or watching the movie. The (commercial) client/product manager has usually blurry/faint idea about the final version of the visuals. The role of concept artists is to create possible visual ideas based on a 'brief', i.e. a collection of tips and guidelines useful in the process of creating a concept, which are most often the guidelines of the art director. The more inventive and experienced the artist is, the better and genuine solutions are proposed, and as a result the effect is more satisfactory for all creative team and prospective viewers, the only limit of the illustrator is the imagination. Concept art is not explicitly used in a movie, game or in the comic. Moreover, very often it is discarded during the production. Based on the design (conceptual drawing), a model is created in three-dimensional space and performed by 3D modelers. Thus, it can be stated that the concept artist is the intermediary between the idea and the 3D object, i.e. the final form that will be portrayed in a movie or game.
Character creation (as an element of concept art) is a fundamental element of any movie or role-playing game[17,18]. In basic terms, this process focuses on creating a protagonist featuring:

- mechanical elements - determining the physical characteristics, anatomy, the skills it should have and the props it can handle;
- non-mechanical element - that is, creating the appearance of the character, psychological and behavioral features and character's biography.

Can AI support the process of concept art/character design, then?

2.1 A CASE STUDY

One of the game-dev projects performed by students/concept artists has been chosen as case study to illustrate positive and negative aspects of AI-based design. The character was "The Wizard Frog Casting Elemental Spells", a concept art for a third person perspective role playing game. The main idea was to visualize a complex idea of a 3D character that has hybrid anatomy based on frogs and humans (the human-likeness was chosen due to availability of motion capture tracks and a number of ready to use motion making techniques for further in-game development). Moreover, the protagonist should have capabilities both to fight (soldier) and to throw magic spells (wizard), hence the additional requirement for some kind of weapon and visual effects (VFX). For magic component, three kind of elemental forces of nature were investigated: fire, water and earth. In the paper, the result for the concept related to 'fire' element is presented.
To evaluate AI system- based designs, a handful of web based AI art tools were used with a number of 'prompts' including description of character appearance/anatomy (frog, human, wizard, warrior,…) its actions (standing, fighting, casting spells,…), used props (spire, cane, weapon,…) and preferred visual style (concept art, digital painting, realistic).
Sample prompt that resulted in the most promising output:
"A fantasy mage character sheet depicting a standing humanoid frog with flowing robes, presented in front perspective. The character is adorned with magical artifacts representing fire element and has distinct facial characteristics. Studio lighting showcases the shimmering fabric of the robes, while a dutch angle adds dynamic energy. The layout is neatly arranged for easy reference and reproduction."
The most promising results are depicted in Figures 1 and 2.

Figure 1: *A sample collection of AI concept character designs (from top to down: Leonardo, Mage.space, Wombo)*

Figure 2: *The best of acquired AI concept designs (DallE 3)*

Human-made design (artwork provided by Adam Indelak, digital artist/illustrator) made according to classical rules of concept art design discussed in the previous section is presented in Figure 3.

Figure 3: *The illustration of a man-made concept design (digital painting by Adam Indelak©)*

2.2 ASSESMENT

The assessment of concept of digital media can be approached in a table used to cover more dimensions after identifying media and user reaction.

FEATURE	DIGITAL ELEMENTS	AI ART	MAN-MADE ART
Motion	Pose/movement	+	+
Location	Composition/ (a)symmetry, "golden rule"	+	+
Size	Different sizes/sense of scale	+	+
Shape	Various shapes	+	+
Style	Consistent visual style	+	+
Padding	Layout/ foreground/background	+	+
Contrast	Clearly visible details	+	+
Hue	Consistent color palette	+	+
Saturation	Atmospheric effects/ shading/shadows	++	+
Face	Face with eyes	+	+

(-- highly problematic, - problematic, + recommended ++ highly recommended)

Table 1: *Visual emphasis in the AI/man-made designs*

FACTOR	DESCRIPTION/ IMPLEMENTED AS… (some examples)	AI ART	MAN-MADE ART
Analogy	Easily recognized object (frog wizard casting fire spells)	++	++
Real-world/physical correctness	References to physicality- anatomy, recognition of textures, objects (e.g. cloth, skin, fire, etc.)	++	++
Simplicity	Minimalistic visual style – it is a concept art!	-	+
Stereotypes	Commonly accepted/recognized symbols	++	+
Importance	Non verbal experiences/emotions	--	+
Digitization, anatomy	Ready for mesh design/skeleton/skinning/animation	-	+/-

(-- highly problematic, - problematic, + recommende , ++ highly recommended)

Table 2: *Game/media design metaphors related to the AI/man-made designs*

For example, with a "GUI/legibility" analysis following an analysis of delivered message and its legibility. Quantitative (probabilistic) or qualitative analyses also exist in that area. Here we refer visually emphasize and quality (Table 1.) or aesthetically pleasing composition possessing selected visual qualities. Another comparison of AI vs man-made concept art is based on the visual metaphors reflecting visual media/game design of characters/ avatars/ protagonists (Table 2.).

As we can see AI driven character design is being ready to include in the game/media development pipeline and seems to be even better suited for environments and background art [15,16,19]. It is already happening, as various AI services are available to developers (www.rosebud.ai providing ready to implement digital assets for gamedev, https://www.meshy.ai/ featuring AI 'generative' meshes, Luma AI - Interactive Scenes (lumalabs.ai) photorealistic renderer plugin for Unreal Engine based on Gaussian splatting, or 360 backdrops/environments for Unity 3D https://skybox.blockadelabs.com/)

3. WHAT DO ART/DESIGN STUDENTS THINK OF AI?

Three years ago, a number of powerful AI tools for art just by typing in a few words (prompts) became widely available. The visual quality of illustrations, photograph-like images and digital paintings that can be made that way was vastly improved. More and more people, including artists are experimenting with the technology and trying to figure out 'added value' it can bring to their life and work. The definition of art changes over time. AI art is already disrupting many sectors of economy, will we start to accept software systems as themselves artists, independent of their creators? Or alternatively is AI just another tool in a hand of skillful artist?
At the University of Zielona Góra we recently got students of Art and Design to experiment with a handful of AI tools capable of generating images (including Midjourney, Dall-E, Leonardo, Crayon, Wombo, Deep Dream Generator, Ganbreeder). The aim of the study was to identify differences/similarity in perception, acceptance and willingness to use AI based creative tools among the representatives of young (particularly Z) generations of artists.

It was conducted in 2022-2024 by means of direct survey technique, using a categorized and standardized questionnaire. A decision was made to perform a deliberate rather than a random sample selection. The research was a pilot/preliminary study (as a Proof of Concept) to provide an introduction to the broader studies on Polish Generation Z participation in digital technology driven creative industries. Eight questions were asked to 26 students, excluding socio-demographic variables. There were equal gender participation 50% men 50% women.

90% of responders thought AI art made a strong impression, while 10% said it was indifferent in effect. Similar result was obtained with query on whether AI art had a 'natural' look. Over 90% of respondents declared it to be natural while 10% claimed it to be artificial. The research demonstrated that 80% of the respondents considered AI generated images to be neutral while 20% considered them very pleasing to eye, no one claimed them to be ugly. One of the questions was considering technology maturity and whether AI generative art can be a threat to classic media. 65% of respondents confirmed it could be a serious issue, 95% argued it was easy to use while only 5% could not decide. Another question was about intuitive use of this digital technology, 100% of respondents confirmed high usability and ease of use. More over 80% of responders claimed that AI based tools enhance quality of digital art, 20% had opposite opinion pointing out 'homogenous' output of AI GANN image generators. The question on disruption caused by the development pace of digital creative technology in the last 10 years and availability of free to use digital art tools was considered positive by 65% of responders, while 25% suggested it increased competitiveness in this field, 10% stated it had no particular influence on their work/life. When asked whether they would use AI technology in their creative job 65% hesitated, 25% gave positive opinion and only 10% was negative.

Summing up, the understanding of the surveyed participants of AI art is well established. Surprisingly all responders were ready to use AI art and design tools in highly 'native' manner and on a daily basis and required institutions to be at similar level of digital technology maturity. Additional observation is that students/artists with richer vocabulary and strong background in art (history) had better control over generative AI, knew the limits and proposed own visual solutions to compensate lack of some features. By combining generative AI, digital painting tools and other media they created the most appealing works.

3. CONCLUSION

While the forecasting impact of technological development is always uncertain, we witness AI art and design constantly being developed to unpreceded levels. Thus, the topic is of extreme urgency for artists and others involved in creative industries. Digital artwork made with AI shows what artificial intelligence can teach us about society and about ourselves either as creators or just spectators. Artificial AI-generated images have the potential for exploitation in the form of easily recognized 'human artist' art 'styles' but also can lead to new unique techniques. Right now we have relatively basic AI tools which can help to make better art. Those tools are getting better and easier to use and pretty soon we will be in the golden age of creativity, where AI tools will bring anyone imagination to life as vividly and professionally as someone who has dedicated their life to the craft. A digital artist in no more 'elitist'. We are at the point that is impossible to tell what is human art and what is AI art, so lots of creative people including game developers, artists, photographers, graphic designers, illustrators are having a hard time figuring out how to compete and draw attention within the art society and nowadays they have AI to compete with too. Eventually Artificial Super Intelligence (ASI) will be so sophisticated and powerful at high-level abstract thinking that it will be better at the actual creativity part than the humans which may lead to singularity in Art.

4. ACKNOWLEDGMENT

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Exploring Virtual Reality in an Exhibition Context

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ABSTRACT: Virtual reality (VR) is a growing field of research both as a complementary science for other research areas and as a field of research itself. It is also a powerful, immersive technology enabling the creation of visual and interactive worlds that can help experience and understand complex scenarios by exhibition visitors without any required special knowledge beforehand. VR creates visual worlds transcending traditional displays, offering access to past, present, and future realities. This paper explores the transformative potential of VR in exhibitions, enhancing visitor engagement with complex subjects.

The study investigates VR to visualize LiDAR-captured data, referencing Bernd Lintermann's "Traces" project at the ZKM. [1] Furthermore, the VR scenarios can be manipulated so that visitors can experience and reshape them like zooming into objects, rearranging shapes and spaces or interacting with objects. This technology offers new avenues for engagement. It can be used in different scales, times and spaces. Eventually, the paper describes various VR scenarios and delves into the technical background of VR simulations, providing a comprehensive understanding of this technology's applications in exhibition settings.

1. ONE EXHIBITION – LOTS OF DATA

In November 2024, the Interactive Science Lab (ISL) of the Center for Interdisciplinary Digital Sciences (CIDS) at the TU Dresden opened the pilot exhibition //DataSpaces. Experincing Science. Visitors can learn more about research in the field of digital sciences at the TU Dresden with the help of over 15 exhibits. In addition to current research, historical computing technology from Dresden and artistic approaches to the topic can also be seen.

Many of the exhibits are interactive. [2] The pilot exhibition is uniquely situated not within a traditional museum or dedicated gallery, but rather at the very heart of scientific inquiry: the foyer of the Faculty of Computer Science at TU Dresden. This location, while visually appealing, presents distinctive curatorial challenges. The three-story foyer features staircases at both the front and rear, with corridors extending from each landing, offering unobstructed views across the entire space. Seminar rooms and offices line the periphery, their windows providing further perspectives onto the foyer's activity. A glass roof allows natural light to permeate the space, creating a dynamic interplay of light and shadow.

This unconventional setting, with its inherent openness and transparency, requires innovative approaches to exhibition design and visitor engagement. Upon completion of the new building, the exhibition is slated to relocate to the equally distinctive foyer of the Lehmann Centre office building (LZB). This new research facility will eventually house the entire Center for Interdisciplinary Digital Sciences (CIDS), accommodating approximately 600 staff members.

In addition to all this, the exhibition has a special feature: about 20 LiDAR sensors permanently scan the area. They record the movements, the time spent in the various areas, and the length of time visitors stay. To achieve this ambitious vision, the ISL drew upon technology developed by Bernd Lintermann within the framework of the ZKM's Intelligent.Museum project. Lintermann, a researcher and media artist at the ZKM | Hertzlab, created "Traces," a project employing LiDAR sensors (laser scanning) to capture visitor movements in real-time. This anonymized data collection allows for the analysis of visitor behavior and interaction within the exhibition space. [3]

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In the //DataSpaces exhibition, the exhibit “Traces” (illustration 1) shows the collected movement data on a map view. The visitors can see, what the system sees: current positions of tracked users, as well as points of high interest through a heat map and most probable walkways through a vector map.
The interface also allows them to vary the time period displayed. Two other exhibits use the data from the sensors: Datatraces and Faces. Both were created in close collaboration with students of media informatics in a student semester course at the Chair of Immersive Media Design.

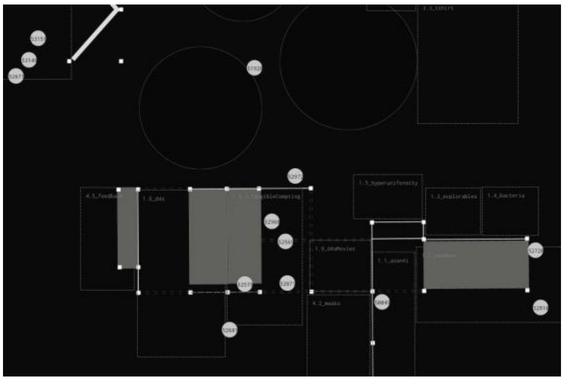

Illustration 1*: Exhibit “Traces” – Live view © ISL*

The students developed a concept and realized a prototype. Together with the ISL, the prototype was further developed for the exhibition. Privacy, data protection, and data security were the central focus of both student projects.

Datatraces (illustration 2) uses the sensor data to profile visitors. Based on the tracked position data and viewing habits, the Open AI-API generates a provocative and humorous, personalized feedback about their exhibition interactions, prompting reflection on their own data traces. The aim is to draw visitors' attention to the possibilities offered by the collection and evaluation of large amounts of data. In doing so, neither the positive nor the negative side is deliberately emphasized.

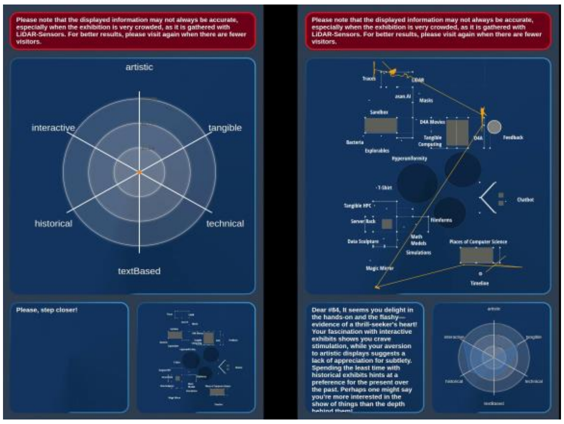

Illustration 2*: Exhibit “Datatraces”, left: idele mode, right: user profile view © ISL*

Faces (illustration 3) approaches the topic from a more aesthetic angle. Rotating masks were installed at various points in the exhibition. With the help of the sensor data, they ‘follow’ the approaching and passing visitors. This is how it creates a tangible and surprising encounter with being observed. Here, too, the exhibit purposefully meanders between a positive and the negative perspective and lets the visitors decide for themselves whether they find the installation more fascinating or rather unpleasant.

Illustration 3*: Mask of the exhibit “Faces” © ISL*

These exhibits are already very inviting for a change of perspective, but the ISL team used additional ways to use the LiDAR data. With the support of the chair for Immersive Media Design they came up with the idea for a VR simulation that allows for deep immersion into the data. At the same time, it offers a completely different exhibition experience.

2. THE DIGITAL TWIN

The VR application serves as both an educational tool and an enhancement to the pilot exhibition //DataSpaces. Visitors can gain new perspectives through this immersive experience, which makes exhibits and their contexts more accessible and engaging. Additionally, the application proves valuable for exhibition stakeholders—including clients, curators, designers, and architects—as well as for visitor research purposes.

The application's strength lies in its ability to visualize typically invisible data within a richly detailed virtual space that transcends physical limitations. Upon wearing a VR headset, users enter a digital replica of the exhibition where they become active participants rather than passive observers. This virtual environment serves as an interactive playground where visitors can explore, manipulate, and reshape their surroundings. Through six interactive elements, users gain unprecedented control over their experience, viewing the space from novel angles and moving beyond physical constraints. The dynamic interaction between space, time, and scale creates a personalized journey, allowing each visitor to craft their own unique exploration while developing a deeper understanding of the exhibition's core themes.

2.1 THE DIFFERENT ELEMENTS

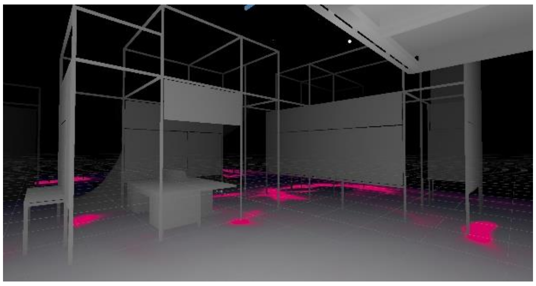

***Illustration 4**: Heatmap © Kelsang Mende*

Element 1 – Heatmap: The virtual space includes a heatmap overlay visualizing visitor activity within the exhibition. (Illustration 4) This dynamic visualization reveals the hotspots where both VR and non-VR users tend to congregate, offering insights into visitor behavior and preferences. This feature encourages further analysis and interpretation of visitor engagement with the exhibits.

Element 2 – Visitor Paths: This feature visualizes visitor movement patterns throughout the exhibition space (Illustration 5). Each visitor's path is represented by an individual fiber, with its color indicating both their walking speed and duration of stay. These temporal and spatial traces create a comprehensive visualization of how visitors navigate the exhibition.

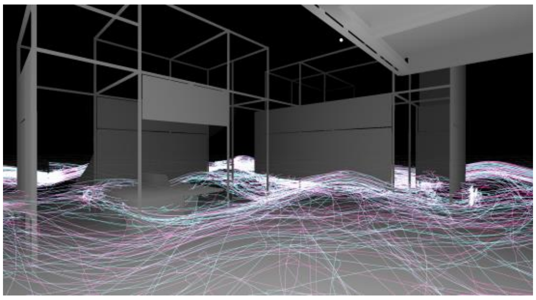

***Illustration 5**: Traces © Kelsang Mende*

Element 3 – LiDAR data: The virtual environment reveals the data capture process from the physical world. Through an intuitive visualization, users can observe how LiDAR sensors collect positional and geometric data throughout the exhibition space (illustration 6). This transparent look at the underlying technology helps visitors understand how the virtual exhibition's complex visualizations are created.

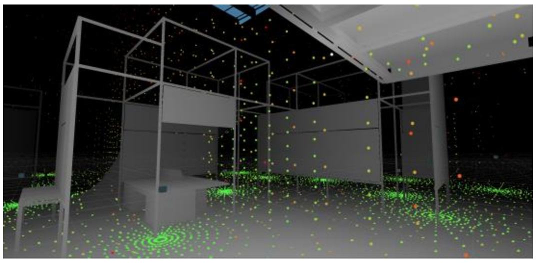

***Illustration 6**: LiDAR Sensors © Kelsang Mende*

Element 4 – Flow Maps: Flow maps (illustration 7) aggregate visitor trajectories to reveal movement patterns throughout the exhibition space. These visualizations illuminate common paths and visitor preferences, transforming complex movement data into actionable insights. Through this analysis, exhibition designers and curators can optimize pathfinding, enhance visitor flow, and identify underutilized areas. This information proves invaluable for improving future exhibition layouts and maximizing visitor engagement.

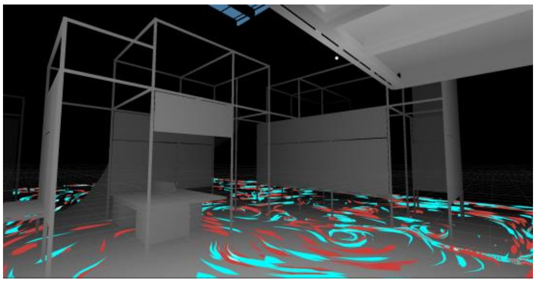

***Illustration 7**: Flow Maps © Kelsang Mende*

Element 5 – Reconfiguration: The virtual environment offers the unique capability to recontextualize the exhibition within its planned future setting. As a pilot exhibition designed for a future building, the surrounding environment can be dynamically altered to simulate the exhibition's eventual context (illustration 8). Furthermore, the modular design of the exhibition, comprising various elements arranged to convey a specific narrative, can be reconfigured within the virtual space. This interactive feature empowers users to experiment with alternative arrangements of exhibit elements, fostering a deeper understanding of curatorial choices and narrative construction. The simulation also allows for the capture and storage of user-generated configurations, providing valuable feedback for exhibition design and potential future iterations.

Illustration 8*: New surroundings for the exhibition in the foyer auf the LZB.*

Element 6 – Usage: Navigation and control within the virtual environment are facilitated by a central console featuring six distinct buttons (illustration 9). These brightly colored buttons provide a stark contrast against the monochrome backdrop of the virtual space, ensuring clear visibility and intuitive interaction.
The first button serves to disable all virtual layers, effectively clearing the visual field with no virtual information at all. The remaining buttons toggle the various interactive layers described previously, allowing for customized exploration of the virtual exhibition space and its associated data visualizations. This minimalist interface design prioritizes user experience, ensuring seamless navigation and effortless access to the virtual environment.

Illustration 9*: LIDAR Sensors © Kelsang Mende*

These interactive elements illustrate the multifaceted potential of VR technology within an exhibition setting. By enabling manipulation of time, scale, and space, the virtual environment showcases VR's capacity to go beyond the limitations of physical reality and offer new ways for visitor engagement and knowledge dissemination. This project shows on a small scale how VR technology can be used in research and exhibition design, and how it might change the way we interact with complex information and environments.

3. TECHNICAL SETUP

In the backend the system utilizes virtual simulations and database queries to feature these elements. The visitor / user can select surroundings, move exhibit elements, use the research project simulation and study the historic exhibits. This immersive experience will be realized via VR headsets, leveraging the ViewR [5] system by IXLAB as well as the Meta Quest SDK [6].

All these systems come together in Unity3D, a game engine that can compile apps for Meta Quest 3. The baseline is a 1 to 1 digital twin of the venue space. In this case it is the foyer of the Andreas-Pfitzmann-Bau at the campus of the TU-Dresden. It features a very detailed geometry derived from a point cloud scan. This geometry has been optimized to run on mobile devices. In a second instance a model of the exhibition itself has been put into the virtual space to get a complete digital twin.

The tracking data through the LiDAR system is cleaned and optimised before processed on the headset. The visualization is realized via the VFX-Graph system. A unity specific tool to create particle systems and simulations.

The last step is to visually present the data in a way that it fits the design of the exhibition and build a visually aesthetic application. To accentuate the visualizations, the virtual environment was rendered in monochrome, allowing the colorful data representations to stand out prominently. For user safety and orientation, a pass-through bubble surrounding the user's feet provides a clear view of the physical environment, mitigating risks associated with real-world movement while immersed in the virtual space. [7]. Interaction within the virtual environment is designed to be intuitive, relying on familiar paradigms such as large buttons that can be readily manipulated using the hand-tracking capabilities of the Quest 3 devices. This approach prioritizes user-friendliness and accessibility, ensuring a seamless and engaging experience for a wide range of users.

4. PERSPECTIVES

While this paper focuses on specific applications of VR within the exhibition, the potential of this technology extends far beyond the presented examples. VR simulations for example offer a powerful tool for exploring and understanding historical objects, providing opportunities for interaction and analysis.

The exhibition showcases a collection of historical artifacts, including computing and computer technology, as well as mathematical models (illustration 10). However, due to conservation and security concerns, these objects are often confined within display cases, limiting visitor interaction. To overcome this constraint, the virtual environment can provide access to 3D scans of these objects, allowing users to virtually remove them from their cases and examine them in detail by zooming in and rotating the exhibits (illustration 11). This functionality opens up new avenues for engagement with historical artifacts, fostering a deeper understanding and appreciation of their significance.

This technology facilitates in-depth engagement with current advancements, enabling both specialists and the public to explore intricate concepts. This approach allows for the integration of elements that might otherwise be inaccessible or difficult to represent due to scale or complexity, thereby expanding the scope of exhibition practices.

Illustration 10*: Punch die for repairing punched tape © ISL*

Illustration 11*: 3D scan of the punch die for repairing punched tape © ISL*

Emerging technologies such as VR simulation and LiDAR sensors offer transformative potential for visitor engagement, facilitating interaction with exhibitions on unprecedented levels. This not only fosters direct participation from citizen scientists and amateur researchers but also presents novel avenues for professionals across diverse fields. Historians, museum professionals, architects, designers, and researchers can leverage these tools to enhance their respective practices, opening new frontiers in object research, audience engagement, and exhibition design. Furthermore, these technologies themselves warrant critical examination. Their role extends beyond mere tools, actively shaping scientific, cultural, and social discourse. This necessitates a careful consideration of the ethical and practical implications accompanying their integration into museum and research practices. [8]

5. ACKNOWLEDGMENT

We would like to thank Bernd Lintermann from ZKM Karlsruhe for providing the traces setup as open source and supporting the implementation at our exhibition. We would also like to thank the Center for Interdisciplinary Digital Sciences for financing the development of the system through the funds of the ExcellenceStrategy. Finally, we would also like to thank the Chair for Immersive Media Design for placing the //DataSpaces exhibition as a case for the student semester course.

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Discussing AI with AI – Interacting with a Chatbot System

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ABSTRACT: This project explores the societal and technological dimensions of artificial intelligence (AI) through an interactive, AI-driven exhibit featured in the //DataSpaces exhibition (November 2024 – February 2025) by TU Dresden's Center for Interdisciplinary Digital Sciences. Developed by students, the system employs advanced Speech-to-Text, Large Language Models (LLMs), and Text-to-Speech technologies to facilitate dynamic conversations with virtual agents. Visitors interact with five chatbot personas—Professor Byte, Carl Corpo, Artsy Anna, Valerie Vintage, and Finn Future—each embodying unique themes like knowledge, morality, and creativity. Designed for third learning spaces, the exhibit emphasizes engagement through minimalistic visual designs, interactive features, and provocative dialogue. By integrating critical discussion with playfulness, it fosters higher-order thinking and creativity. Planned improvements include expanded chatbot personas, refined interactions, and enhanced visual elements. This initiative bridges education and entertainment, encouraging critical reflection and deeper public discourse on AI and its implications.

1. INTRODUCTION

Science exhibits often have to deal with a wide array of different visitors from experts to high-school students. This spectrum calls for approaches for exhibits that can either adapt to knowledge levels and interaction preferences or work in an universal way concerning the design and the content. Furthermore, exhibitions should encourage visitors for participation as knowledge is more easily absorbed in an active state and even more so when presented with an experience that evokes the visitors' emotions. With the development of the AI chatbot exhibit we tried to tackle these aspects.

The developed AI chatbot tries to marry these approaches. Firstly, the medium used to interact is a chatbot system which is widely established and is used in an intuitive way. Secondly, the exhibit embraces different perspectives by using a range of characters and letting the visitor engage and adapt by talking to the chatbot in a natural way by using latest AI technology.
Furthermore, the system and the characters are developed in a way so that it is supposed to be fun to interact capturing visitors that otherwise might be appalled by difficult topics like discussing the implications of AI for society. So with this AI powered system we intent to bridge that gap regarding the knowledge of the visitors and also regarding the knowledge about AI in society in general.

Artificial Intelligence

Artificial intelligence is developing into a central aspect globally, in many aspects of life – from specific work-related applications and processes deep into our daily and private lives in our homes. This development requires an intensive debate about the technology regarding the genesis and the social consequences of AI — not merely as a piece of software, hardware, or a process for enhancing efficiency, but more importantly, concerning its origins and the social consequences it brings. There is a plethora of highly complex topics connected with the rise of AI [1], for example:

- problematic data sources for training AI and the reproduction of attached biases
- usage of content created by humans without acknowledgment/ compensation
- culmination of power by controlling the algorithms through a handful of companies and their owners/CEOs or (autocratic) governments
- monetization of a central piece of technology leading to exclusion issues

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- replacing service personnel with chatbot systems
- expected shifts within the labor market leading to insecurities
- excessive power consumption and high hardware requirements
- combination of AI and robotics to mimic intelligent organic life
- philosophical question of life related to AI and thus its legal status
- potential security risk especially in the field of intelligent weapons
- potential risk of a general AI

These topics need to be discussed so that we as a society can shape the development in a positive way. This discussion needs participants that are well informed. Especially with the blurred lines of truth and fake with the further use of artificial intelligence participants need to be able to grasp the potential consequences of AI in their positive and negative characteristic.

Chatbot system

Chatbot systems have become a widely recognized application of AI, utilized not only in service and workplace settings but also increasingly in education. [2] These systems offer numerous benefits, including personalized learning experiences, enhanced motivation to learn, and the development of critical skills such as problem-solving and critical thinking. [3] However, their implementation also presents challenges. Over-reliance on chatbots can lead to a reduction in independent critical thinking skills among others. [4]

Additionally, the accuracy of content and the potential for miscommunication are significant concerns that must be addressed. [5] So, this technological development of course comes not only with advantages but also disadvantages that need to be considered when setting up the content – what will be communicated and the interaction design – the way it will be communicated.

Learning experience

When employed in third learning spaces, such as exhibitions, the emphasis shifts to visitor engagement. Here, the learning experience extends beyond traditional outcomes to include elements like design and user interaction. [6] Learning experience is especially important in third learning spaces because these environments are often informal, self-directed, and centered around curiosity-driven exploration. Unlike traditional educational settings, exhibitions must captivate diverse audiences with varying levels of prior knowledge and interest.

A well-designed learning experience can transform a casual visit into a meaningful encounter, fostering personal connections to the content and encouraging deeper inquiry. The incorporation of cutting-edge technology in these spaces can captivate visitors, fostering greater attention and a willingness to engage deeply with a complex topic over an extended period of time. [7]

Creativity

The goal in such settings is not only to have visitors absorb information but to encourage them to interact creatively with the content. Ideally, they should not merely reproduce what they learn but connect these new insights to broader topics and personal perspectives. This interaction could even involve discussing AI with the chatbot itself—essentially engaging in a dialogue about AI through AI. According to Bloom’s Taxonomy, this approach aligns with higher-order learning objectives, moving beyond understanding and application to synthesis and creativity. [8]

To foster such creativity, it is essential to design engaging and enjoyable activities. Fun experiences are particularly effective in fostering creativity because they reduce stress, create a sense of playfulness, and encourage open-mindedness. When people are relaxed and enjoy themselves, they are more likely to take risks, explore new ideas, and approach challenges from unique perspectives.

Additionally, fun activities can enhance intrinsic motivation, making individuals more invested in the task at hand and willing to experiment with novel solutions. Tony Ryan’s Thinkers Keys provides a useful framework for this, emphasizing the importance of fun and interactive methods to inspire creative thinking. [9] By integrating these elements into chatbot-based exhibits, it becomes possible to create an environment that is not only educational but also stimulating and thought-provoking, encouraging visitors to explore, question, and innovate.

2. SOLUTION SPACE

This project aims to make complex topics in science, technology, and society more accessible and engaging through an interactive AI-driven system. This chatbot system was featured in the exhibition //DataSpaces by the Interactive Science Lab (ISL) of the Center for Interdisciplinary Digital Sciences at TU Dresden, running from November 2024 to February 2025 in the foyer of the Andreas-Pfitzmann-Bau. (See illustration 1.) Developed by students Hendrik Appel based on his bachelor thesis [10] and Karam Al-Janabi during a research seminar at the Chair for Immersive Media Design together with ISL, the system enables visitors to engage with AI-based conversational agents designed to provoke curiosity, foster understanding, and stimulate critical reflection.

Illustration 1: *The exhibit "Chatbot" © ISL*

The project uses advanced Speech-to-Text, Large Language Models (LLMs), and Text-to-Speech technologies to facilitate natural, educational dialogues. Visitors interact with two virtual agents representing thematic aspects such as knowledge, morality, nostalgia, or arts, either by joining the conversation or observing the agents discuss different perspectives.

This approach creates a public space for discussion about AI while blending entertainment and education to provide a thought-provoking experience. The usage of various perspectives was a central topic in our exhibition and thus also in this exhibit with the different characters. [11]

Concept and Agents

The system revolves around five chatbot personas, each representing a thematic concept (See illustration 2.):

1. Knowledge – Professor Byte: Explores core concepts in science, education, and technological evolution.
2. Morality – Carl Corpo: Examines societal implications of technology and data processing.
3. Arts – Artsy Anna: Discusses the influence of technology on human creativity and artistic expression.
4. Nostalgia – Valerie Vintage: Evokes memories of past technological milestones.
5. Enthusiasm – Finn Future: Inspires excitement and critical thinking about technological advancements.

Illustration 2: *Characters "Chatbot" © Hendrik Appel*

The minimalistic yet distinctive design of the chatbot personas focuses on essential features like eyes and mouths, paired with accessories that reflect their unique themes. Their exaggerated behaviors and responses are intentionally provocative, encouraging visitors to challenge and critically assess their statements.

Visitors can engage with the chatbots in German or English, speaking into a microphone to interact. Alternatively, they can reset the system to experience different combinations of chatbot personas. This design enables dynamic and spontaneous exchanges, allowing visitors to interrupt or redirect the conversation as desired.

Technical Implementation

The project combines hardware and software to create an immersive and interactive experience:

Hardware Setup:

- Two 55-inch portrait-oriented screens display life-sized chatbot personas.
- Two physical buttons handle user input: one activates the microphone for interaction, while the other resets the

conversation and changes chatbot personas and enables language switching.
- A microphone captures the visitor's voice, enabling real-time dialogue with the agents.

Software Components:
- Software developed in Unity: Displays the actual agents, manages the conversation flow and chatbot behavior.
- APIs: OpenAI and Eleven Labs are used for generating conversational content and converting text to speech, ensuring real-time interaction.
- Hardware components: an Arduino micro-controller handles input from the physical buttons.

The backend integrates machine-learning models to process user input, embed it in a prompt, and generate responses based on the selected chatbot personas' characteristics. These responses are vocalized to create a lifelike conversational experience.

Goals and User Engagement

The primary objective is to foster curiosity and understanding as well as creativity by combining informative content with engaging, relatable interactions. Third learning spaces like exhibitions present unique challenges: they must captivate diverse audiences and provide self-directed, curiosity-driven experiences. (See illustration 3.) This system's approachable design and interactive elements aim to transform casual visits into meaningful encounters. By creating an engaging and fun learning environment, the system encourages visitors to explore AI topics deeply and connect them to broader societal questions.

Beyond merely absorbing information, visitors are encouraged to think critically, synthesize new insights, and creatively engage with the content—such as discussing AI with AI. Aligning with Bloom's Taxonomy, this approach emphasizes higher-order thinking skills, moving from understanding and application to creativity and evaluation. (See endnote 8.)

The integration of fun and playfulness is vital for fostering creativity. Drawing on Tony Ryan's Thinkers Keys, activities designed with enjoyable and interactive elements help reduce barriers, spark curiosity, and invite visitors to take intellectual risks, making learning a more dynamic and memorable experience. (See endnote 9.)

Illustration 3: *Exhibit in use "Chatbot" © ISL*

3. CONCLUSION

The chatbot exhibit employs a number of features that ease access for different visitors to the complex topic of discussing the implications of artificial intelligence in society. The usage and the implementation of the latest AI systems like Speech-to-Text, LLMs, and Text-to-Speech enables any user to engage with the exhibit in an intuitive way. The avatars respond quickly and react to the input provided by the visitors.

Furthermore, the development of multiple characters that talk in proactively stereotypical ways helps to create a low-threshold access. This is being realized by making different perspectives on the topic visible from the beginning. Moreover, the fun engagement makes the interaction memorable and helps with absorbing knowledge and with being creative asking questions and engaging in conversations beyond the usual topics. Thus, participation in the exhibition could be significantly increased through interactive and engaging exhibits like the chatbot.

Evaluation

Detailed user feedback will be collected during the exhibition to evaluate usability, interaction design, engagement, creativity and content quality. Key areas of interest include how visitors perceive the chatbots as disruptors and enablers. Did visitors take up new aspects or even change perspectives the topic of AI by interacting the the exhibit? And did visitors feel encouraged to engage with the exhibit in a creative way? A first superficial evaluation revealed that the chatbot was one of the most visited exhibits and was easily accessible supporting visitor participation.

The user view within the thesis project. Since the user was using a VR headset, a complete environment needed to be created to provide an immersive experience.

Illustration 4: *Surroundings "Chatbot" © Hendrik Appel*

Future Work

Looking ahead, several enhancements are envisioned:

- Expanded Agent Variety: Introducing new chatbot personas to cater to diverse visitor interests.
- Refined Interactions: Improving prompts to enable more nuanced and engaging conversations.
- Dynamic Rotation: Automatically cycling through personas to maintain interest during inactive periods.
- Conversation Archiving: Allowing visitors to revisit their interactions securely, fostering further reflection.
- Conversation Analysis: Allowing the analysis of the content of the questions and dialogues between visitors and the AI to take up topics that were of concern. The results could also be made transparent for visitors to experience what other visitors were talking about.
- Visual and Performance Improvements: Adding thematic backgrounds and optimizing latency for a smoother user experience. (See illustration 4.)

By combining cutting-edge technology with thoughtful design, this project aims to stimulate dialogue and inspire a deeper understanding of AI in a creative, engaging and accessible way.

With the broad range of visitors that science exhibitions and the goal of the exhibit to be accessible to many different visitor groups the chatbot system can help to better understand visitor engagement and knowledge reception in other contexts as well.

4. ACKNOWLEDGMENT

We would like to thank the Center for Interdisciplinary Digital Sciences for financing the development of the system through the funds of the ExcellenceStrategy. We would also like to thank the Chair for Immersive Media Design for placing the //DataSpaces exhibition as a case for the student semester course.

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DAY II
“CH Digitally Formatted”

Thursday, March 13, 2025

SESSION I

"Memory Twins I"

Moderation: Oliver Schreer
(Fraunhofer Heinrich-Hertz-Institute HHI)

Beyond Digital Twins: Introducing the Memory Twin for Cultural Heritage

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ABSTRACT: The Memory Twin extends the Digital Twin concept by addressing the challenges of preserving digital cultural heritage holistically. Unlike traditional Digital Twins, which focus on physical attributes, the Memory Twin integrates paradata, metadata, and data to provide a compre-hensive representation of cultural assets. This layered approach ensures the preservation of historical significance, contextual narratives, and physical characteristics. By embedding contextual and struc-tural information, Memory Twins transform static digital copies into dynamic, interactive resources. This framework enhances accessibility, supports advanced archival practices, and fosters immersive user experiences. As an adaptable solution, the Memory Twin enriches both tangible and intangible heritage, offering innovative strategies for preservation and engagement in the digital age.

1. INTRODUCTION

The concept of Digital Twins has significantly impacted diverse fields, enabling detailed digital replicas of physical entities for analysis, simulation, and engagement ([3], [11]). Within the domain of cultural heritage, Digital Twins have transformed the way artifacts and sites are preserved, studied, and accessed ([9], [17]). By creating virtual models of cultural assets, this approach supports conservation, facilitates remote interaction, and enhances educational and interpretative experiences ([3]). However, the traditional Digital Twin model often focuses narrowly on replicating physical characteristics, leaving out the broader contextual and experiential dimensions critical to understanding cultural heritage fully ([19], [20]).

The Memory Twin addresses these limitations by integrating three essential layers: paradata, metadata, and data ([1], [10]). While metadata provides structured information describing attributes like provenance, content, and quality ([6]), and data constitutes the core digital representations (e.g., 3D models, photographs, and textual records) ([7]), paradata serves as a contextual layer that captures the processes, decisions, and methodologies involved in digitization ([1], [19]). This integration offers a holistic approach to preservation, emphasizing not only the physical attributes but also the narratives, workflows, and interpretative frameworks that give cultural assets their deeper significance ([5], [17]).

Since its adoption in 2006 through the London Charter, the concept of paradata has been a pivotal element in the digital documentation of the past ([19]). Initially introduced to address issues like expressing alternative interpretations, estimating probabilities, and supporting scholarly interrogation ([11]), paradata has grown to encompass workflows, data acquisition methods, and sustainability practices ([9]). It has become a cornerstone of high-quality digital cultural heritage (DCH) resources, working alongside metadata and geometric data to enrich 3D assets, foster knowledge creation, and promote reusability ([17]). Despite its importance, the DCH community continues to grapple with the definitive differentiation and articulation of paradata and metadata, as well as their specific benefits for stakeholders, owners, and the broader multidisciplinary community ([8]).

The urgency of establishing clearer definitions and frameworks for paradata is further underscored by the European Commission's Recommendation for the Collection of 3D-Digitized Cultural Heritage Assets ([6], [19]). Addressing these gaps was the focus of two pivotal webinars held under the auspices of the UNESCO Chair on Digital Cultural Heritage and the EU Eureka3D project in April and May 2024 ([1]). These sessions brought together international experts to review and establish definitions for paradata and explore its

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applicability throughout the digitization lifecycle ([3]).
The Memory Twin integrates these advancements, transforming traditional digital models into comprehensive, interactive, and contextually enriched resources ([1]). By embedding paradata and metadata alongside core data, it redefines how cultural heritage is preserved, accessed, and interpreted ([4]). This paper delves into the theoretical foundations of the Memory Twin and its practical applications, demonstrating its potential to advance cultural heritage management and engagement in the digital age ([8], [10]).

2. MEMORY TWIN CONCEPT

The Memory Twin framework (***Figure 1***) represents a transformative evolution from the traditional Digital Twin, introducing a holistic approach that integrates physical, historical, contextual, and experiential dimensions of cultural artifacts. This expanded concept moves beyond replicating physical attributes to capturing the narratives, workflows, and decisions that give cultural heritage its richness and depth. The implementation of this concept is guided by a structured workflow that ensures the accurate and meaningful preservation of cultural heritage, culminating in the dissemination of validated knowledge.
The workflow begins with a clear understanding and documentation of primary stakeholder requirements. These stakeholders, ranging from cultural institutions and researchers to local communities, provide insights into the desired outcomes and contextual significance of the artifacts or sites being documented. These requirements form the foundation for creating digital tangible objects, which act as the core components of further data processing and representation.
In the next phase, physical cultural objects are converted into digital formats using advanced digitization techniques such as 3D scanning, photogrammetry, and laser scanning. These methods capture high-fidelity details of the artifacts, ensuring that the physical attributes, textures, and spatial configurations are preserved. To enrich these digital representations, inputs from subject matter experts, historians, and practitioners are incorporated. Their contributions provide valuable historical context and practical insights, ensuring that the digital models are not only accurate but also meaningful.
The gathered information is then classified into three key layers: paradata, metadata, and data. Paradata captures the processes, methodologies, and decisions involved in the digitization workflow, offering transparency and supporting future research or replication efforts. Metadata provides structured information about the content, attributes, and context of the artifacts, facilitating efficient organization, retrieval, and management. The data layer includes the core digital representations, such as 3D models, high-resolution images, and textual documentation.
These three components are combined to create a comprehensive digital representation. This integrated information undergoes rigorous quality assurance checks to ensure its accuracy, relevance, and completeness. The quality assurance process includes evaluating hypotheses based on the collected data, formulating research questions, conducting experiments, and analyzing results. The aim is to validate the information and enhance its credibility as a scholarly and educational resource.
Additionally, the workflow involves creating narratives and storytelling elements to provide context and make the digital representations more engaging. This step ensures that the resulting digital models are not just static records but dynamic, interactive resources that can support educational initiatives and foster public engagement. The process also assesses the condition of the materials and monitors the structural integrity of the physical objects represented digitally, ensuring that both digital and physical preservation goals are met.
The final step involves the dissemination of the validated knowledge. The curated digital resources are published on platforms like Europeana and national aggregators, making them accessible to a wide audience. These platforms enhance the visibility of the cultural heritage assets, supporting research, education, and public engagement on a global scale.
This structured workflow, illustrated in the paper's accompanying chart, highlights the systematic approach required to address the complexity of cultural heritage digitization. By incorporating stakeholder requirements, leveraging advanced technologies, and ensuring rigorous quality control, the framework delivers high-quality digital resources that balance scholarly rigor with accessibility and engagement. This ensures that cultural heritage is not only preserved but also made relevant and meaningful for future generations.

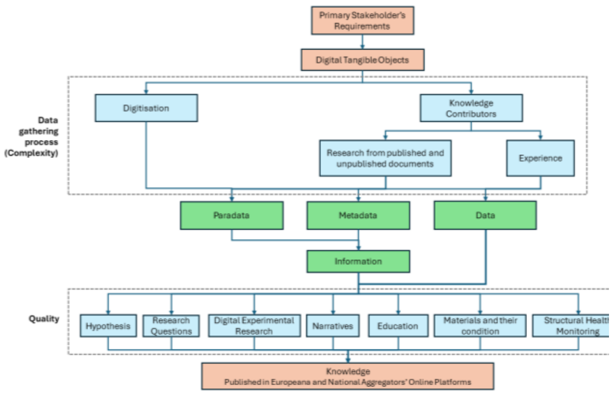

Figure 1: *Memory Twin concept*

CASE STUDIES

3.1 FIKARDOU VILLAGE

Fikardou village (***Figure 2***) provides a compelling case study in how a layered, integrated approach to cultural heritage preservation can address the challenges of both tangible and intangible heritage ([16], [21]). Situated in the Troodos Mountains of Cyprus, this traditional settlement embodies the architectural and cultural practices of rural Cyprus from the 18th and 19th centuries. The village faced significant threats due to urban migration and abandonment, which left many of its structures in a state of disrepair. Recognizing its value, the Department of Antiquities designated Fikardou as an "Ancient Monument" in 1978 ([21],[7]), initiating preservation efforts that included restoring key buildings and revitalizing its infrastructure. These efforts secured its listing on the UNESCO Tentative List of World Heritage Sites, underscoring its global cultural significance ([21]).

The documentation process began with an extensive data acquisition phase, employing advanced technologies such as terrestrial laser scanning, drone imaging, and 360-degree photography. These tools enabled the capture of high-fidelity details of the village's architecture, including its stone-built homes, cobbled streets, and historical landmarks. The use of drones proved particularly effective in documenting Fikardou's spatial layout, capturing aerial views that contextualize its setting within the surrounding natural landscape. The raw data gathered was processed into detailed 3D models, forming the foundation for digital representations that preserve the physical attributes of the village.

To enhance the value of these digital representations, the project integrated contextual information at multiple levels. Detailed records of the methodologies, tools, and decisions employed during the digitization process were documented as paradata([1],[2]). This layer of information provides insights into the workflows and techniques used, ensuring transparency and enabling future researchers to replicate or build upon the work. For example, decisions regarding scanning angles, environmental conditions, and the selection of specific technologies were meticulously recorded to create a comprehensive account of the digitization process.

Metadata played an equally crucial role, serving as the structural framework for organizing the digital archive. Each element of the village, from individual buildings to smaller architectural features, was annotated with attributes such as historical significance, construction materials, and architectural styles. This metadata not only facilitates efficient retrieval and management of the digital assets but also enhances their usability for various stakeholders, including researchers, educators, and policymakers.

Beyond its physical heritage, the project recognized the importance of Fikardou's intangible cultural elements. Oral histories and traditional practices were documented through interviews with residents, many of whom shared stories passed down through generations. These narratives provide a deeper understanding of the village's identity, shedding light on its role as a cultural hub in the region. For example, residents recounted communal activities, agricultural practices, and seasonal celebrations that shaped the social fabric of Fikardou. Incorporating these stories into the digital archive ensures that the cultural context of the village is preserved alongside its physical structures.

The outcomes of this effort were made accessible through an interactive digital platform, designed to engage both academic and public audiences. Users can explore the village through virtual tours, interact with high-resolution 3D models, and delve into multimedia resources that narrate Fikardou's history and traditions. The platform also includes educational tools, such as thematic modules and storytelling features, to make the heritage of Fikardou accessible to younger audiences and international visitors. This digital dissemination not only promotes cultural awareness but also supports sustainable tourism by reducing the physical impact of visitors on the fragile site.

The approach taken in Fikardou demonstrates the potential of integrating advanced digital technologies with community engagement and scholarly rigor. By combining tangible documentation with the preservation of intangible narratives, the project creates a comprehensive record that captures the full essence of the village. This methodology ensures that Fikardou's heritage is not only safeguarded for future generations but also presented in a way that fosters engagement, education, and appreciation on a global scale. The case study serves as a model for how cultural heritage preservation can evolve in the digital age, balancing the need for historical accuracy with accessibility and adaptability.

The development of the efikardou.eu platform (***Figure 3***) ([8]), exemplifies a holistic approach that embodies the principles of the Memory Twin framework, ensuring that both the memory and identity of Fikardou are preserved and celebrated. By integrating immersive virtual tours, interactive exhibits, and educational resources, the platform goes beyond merely replicating the physical attributes of the village. It captures the essence of Fikardou's cultural and historical narrative, offering users a comprehensive understanding of its heritage. This approach ensures that the tangible and intangible elements of the village—its architecture, traditions, and stories—are digitally preserved in a way that keeps its identity alive.

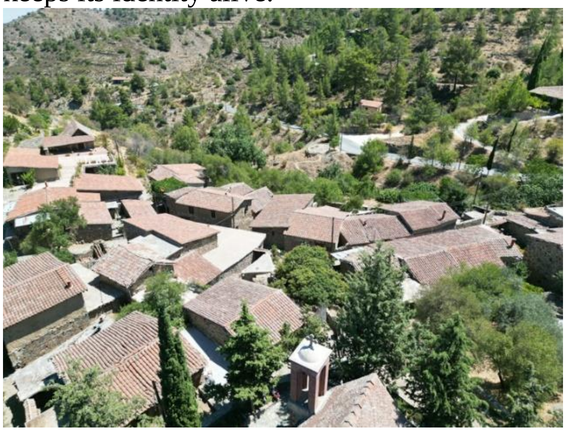

Figure 2: *Fikardou village, drone image*

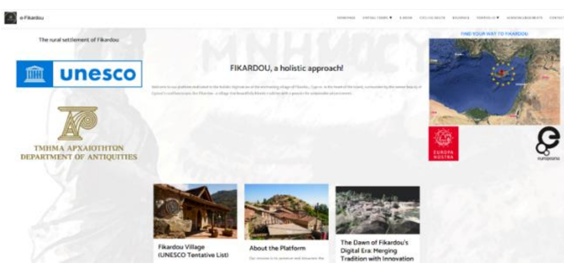

Figure 3: *Holistic documentation - efikardou.eu platform*

3.2 LAMBOUSA FISHING TRAWLER

The Lambousa fishing trawler (***Figure 3***) offers a rich and complex case study in the application of a comprehensive digital preservation framework ([14], [15]). As a historic vessel deeply tied to Cyprus's maritime history, Lambousa represents not just a piece of naval architecture but also a cultural artifact that encapsulates decades of Mediterranean fishing traditions, economic activities, and social resilience ([15],[23]). Built in 1955 by Dimitrios Zacharias in Perama, Piraeus, Greece, the vessel became a cornerstone of Cyprus's fishing industry upon its arrival in Famagusta in 1965 ([15]). Despite its prominence, Lambousa faced threats from aging, environmental changes, and regulatory pressures that required innovative preservation measures ([14], [15]).

The vessel's significance lies not only in its architectural and functional attributes but also in the stories it embodies. Measuring 25 meters in length with a gross tonnage of 48 tons, Lambousa was a marvel of mid-20th-century naval engineering, capable of reaching speeds of up to 10 knots. Its primary use for bottom trawling—a demanding and skill-intensive fishing method—underscored the expertise of its captains and crew. Over its operational life, the vessel became a symbol of resilience, navigating not only treacherous waters but also complex socio-political landscapes. For instance, in the summer before 1963, Lambousa's crew escaped Turkish port authorities under gunfire, showcasing their bravery and resourcefulness.

The Turkish invasion of Cyprus in 1974 marked a turning point for the vessel, as it was forced to relocate from its primary operating areas. Post-invasion, Lambousa continued its fishing operations in the free areas of the island, contributing to the revitalization of Cyprus's fishing industry despite mounting challenges such as overfishing and environmental degradation. Recognizing the trawler's unique cultural and historical value, the Municipality of Limassol undertook efforts to preserve it as a floating museum. This initiative, supported by the European Maritime and Fisheries Fund, involved extensive restoration work to maintain the vessel in its original condition while complying with regulations aimed at reducing fishing capacities to protect marine life.

The preservation efforts extended into the digital realm, spearheaded by the UNESCO Chair on Digital Cultural Heritage and EU-funded projects like Eureka3D and H2020 ERA CHAIR - MNEMOSYNE ([1]). The digital

documentation of Lambousa employed advanced techniques such as photogrammetry and terrestrial laser scanning to capture the vessel in both its decayed and restored states. A photogrammetric survey conducted in January 2023 documented the trawler's structure in detail during its decayed phase, while a subsequent laser scanning survey in October 2023 captured the geometry of its timber framework during restoration. These datasets were further processed to create a comprehensive CAD 3D model, incorporating all 440 distinct elements of the vessel.
Paradata played an essential role in documenting the methodologies, tools, and workflows employed during the digitization process. This contextual information not only supports transparency but also provides a valuable resource for future researchers and conservators. Metadata was meticulously compiled to describe the trawler's physical characteristics, historical significance, and restoration phases, creating a robust framework for organizing and accessing the digital assets.
To make the results widely accessible, the digital assets were integrated into the Europeana platform, enhancing the visibility and educational potential of Lambousa's story. The project also launched the elambousa.eu platform (***Figure 4***) ([9]), which offers interactive and educational tools such as virtual tours, 3D visualizations, and multimedia content. Users can explore the vessel's history through photos, videos, interviews, and detailed 3D models, gaining insights into both its functional and cultural dimensions. Features like educational games and e-books further engage younger audiences and promote maritime heritage.
The Lambousa project exemplifies how digital preservation frameworks can transcend traditional archiving methods by integrating physical, historical, and experiential dimensions. By capturing not only the vessel's structure but also the narratives that define its legacy, this initiative ensures that Lambousa's story continues to inspire and educate future generations. The approach demonstrates how the integration of advanced technologies with thoughtful storytelling can create a lasting and meaningful connection to cultural heritage, setting a precedent for the preservation of similar artifacts worldwide.

Figure 4:*The Lambousa Fishing Trawler*

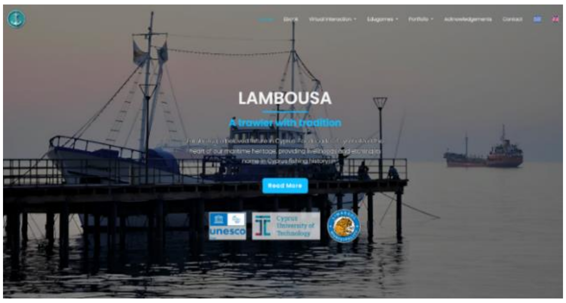

Figure 5: *The elambousa.eu platform*

4. CONCLUSION

The application of the Memory Twin framework represents a paradigm shift in the preservation and interpretation of cultural heritage, addressing both tangible and intangible dimensions ([1], [16]). By integrating paradata, metadata, and data, this methodology creates a comprehensive and dynamic representation of cultural artifacts and sites, offering new opportunities for understanding, accessibility, and engagement ([1], [3]). The case studies of Fikardou Village and the Lambousa fishing trawler illustrate how this approach can be effectively implemented to capture the historical, contextual, and experiential richness of heritage assets ([16], [23]).

Fikardou Village demonstrates the value of a holistic approach in preserving both physical structures and the cultural narratives that define a community's identity ([16], [21]). Through detailed digitization, contextual documentation, and community engagement, the initiative not only safeguarded the village's heritage but also made it accessible to global audiences via digital platforms ([8],[9]). Similarly, the documentation and dissemination of the Lambousa fishing trawler showcased the potential of integrating advanced technologies with thoughtful storytelling to preserve maritime heritage ([14], [23]).

The workflow underlying the Memory Twin framework ensures that the digitization process is methodical, transparent, and adaptable ([1], [19]). By systematically capturing stakeholder requirements, employing advanced data acquisition techniques, and rigorously validating the resulting digital representations, the framework ensures the creation of high-quality, reusable digital resources ([1], [17]). This approach enhances not only the preservation but also the interpretability and usability of cultural heritage for diverse stakeholders, including researchers, educators, and the general public ([3], [8],[9])).

As digital technologies continue to evolve, the Memory Twin concept provides a forward-looking strategy for addressing the challenges of cultural heritage preservation in the 21st century ([19], [20]). Its emphasis on holistic documentation, contextual enrichment, and global accessibility ensures that cultural heritage remains relevant and meaningful ([16], [20]). By bridging the gap between tradition and innovation, the Memory Twin framework paves the way for more impactful and sustainable practices in the stewardship of cultural heritage, ensuring its legacy for future generations ([10], [15]).

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Digital Ghosts: Flusser, Vampyroteuthis and Li Yi-Fan's Virtual Memories

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ABSTRACT: This paper examines Taiwanese artist Li Yi-fan's work "howdoyouturnthison" (2021) as a case study to explore how the artist invents and interrogates the use of digital toolkits as instruments for producing images and as means of reshaping reality and generating memories. Li employs a game engine and real-time images to design and create virtual avatars that move freely in a virtual space, unconstrained by physical limitations. Utilizing virtual reality (VR) headsets and body controllers, Li assumes the roles of director, actor, voice actor, and photographer, intuitively and sensually manipulating and capturing these dynamic images. His creative process emphasizes that digital tools are not merely instruments for image generation but also tools for reshaping reality and crafting new memories, challenging traditional methods of image production through the manipulation of virtual space.

1. INTRODUCTION

In contemporary digital art, the intersection of virtual reality, gaming technology, and artistic expression has opened new frontiers for creative exploration. This paper examines how digital tools transcend their role as mere image-making instruments to become active participants in reshaping reality and generating memories. Through analysis of Li Yi-fan's work "howdoyouturnthison" (2021), this paper investigates how contemporary artists challenge traditional narrative and image-making processes by designing their own creative tools.

2. THEORETICAL FRAMEWORK AND METHODOLOGY

2.1 VILÉM FLUSSER'S THEORY

This study draws significantly on Vilém Flusser's *Vampyroteuthis Infernalis* (1987) as a theoretical framework. Co-authored with artist Louis Bec, this work uses the deep-sea cephalopod as an antipode to human existence, creating a unique dialogic exercise that challenges anthropocentric perspectives. While the text presents itself as a scientific treatise, it functions as a philosophical fable that encourages humans to observe themselves through the lens of a creature inhabiting a literally opposite universe. Flusser's concept of technical images as "artificial memories" provides a crucial lens through which to examine Li's work. According to Flusser, technical images represent a new form of memory manipulation that transcends biological constraints, allowing for conscious control and mutation of information rather than relying on natural selection. This framework of examining the non-human perspective and artificial memory systems particularly resonates with Li's exploration of digital tools and alternative realities.

2.2 METHODOLOGICAL APPROACH

The analysis employs a qualitative case study methodology, examining:

- The technical aspects of Li's image-making process
- The conceptual framework underlying the work
- The relationship between virtual tools and memory creation
- The role of body-technology interaction in digital art creation

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3. ANALYSIS OF "HOWDOYOUTURNTHISON"

3.1 TECHNICAL INNOVATION AND VIRTUAL SPACE

Li's work represents a significant departure from traditional Machinima techniques. Through the use of game engines and real-time imagery, he creates virtual avatars that move unencumbered by physical constraints. This technical innovation allows for:

- Freedom of movement in virtual space

- Real-time manipulation of digital entities

- Immediate response to artistic impulses

- Integration of multiple creative roles

3.2 THE BODY-TECHNOLOGY INTERFACE

Li's use of VR headsets and body controllers creates a unique interface between human intention and digital creation. This relationship manifests in several ways:

- Intuitive control of virtual avatars

- Direct bodily engagement with virtual space

- Immediate translation of physical movement to digital expression

- Synthesis of multiple creative roles (director, actor, photographer)

3.3 NARRATIVE STRUCTURE AND MEMORY CREATION

Behind the seemingly absurd imagery lies a sophisticated narrative technique. The work's structure incorporates:

- Whispered confessions that draw viewers into the creative process

- The concept of "ghost in the shell" stimulating bodily perception

- A reflexive exposure of internet generation reality

- Liberation of traditional narrative constraints

4. DISCUSSION

4.1 DIGITAL TOOLS AS MEMORY MAKERS

Li's work demonstrates how digital tools have evolved beyond simple image-making devices to become instruments of memory creation. This transformation aligns with Flusser's vision of technical images as artificial memories, where:

- The image-making process becomes a form of memory manipulation

- Technical tools enable conscious control of information

- Virtual reality creates new forms of experiential memory

- Digital spaces become sites of memory generation

4.2 IMPLICATIONS FOR CONTEMPORARY ART PRACTICE

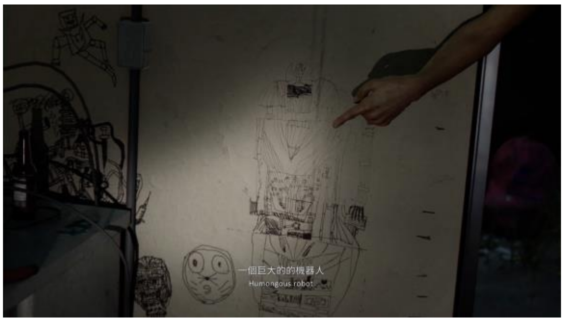
The study reveals several important implications for contemporary digital art:

- The evolution of artist-tool relationships in the digital age

- New possibilities for narrative construction in virtual spaces

- The role of technology in memory creation and preservation

- The changing nature of artistic authorship in digital contexts



5. CONCLUSION

Li Yi-fan's "howdoyouturnthison" represents a significant evolution in digital art practice, demonstrating how modern tools enable artists to not only create images but also reshape reality and generate new forms of memory. Through game engines and real-time imaging, Li creates dynamic visuals that exemplify contemporary technical image production. His intuitive and experiential approach to "writing" images through virtual reality equipment reveals the complex relationship between humans, technology, and imagery in our time. The work transforms the image-making process from mere objective documentation into an interactive dialogue between participant and technology. This artistic practice aligns with Flusser's concept of technical images as "artificial memories" - a process that transcends biological constraints through conscious manipulation of information, rather than relying on natural selection.

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The Virtual Time Machine: An Artistic Exploration with Generative Artificial Intelligence in Heritage Practices

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ABSTRACT: This project explores whether Generative Artificial Intelligence (GenAI) can serve as a 'virtual time machine' to represent intangible cultural heritage (ICH) across multiple temporalities, with a specific focus on the Cheung Chau Bun Festival in Hong Kong. The authors use GenAI to reimagine historical documentation, speculate on the Festival's future, and then create an interconnected narrative. To showcase these AI-generated audiovisuals, two artworks were created: an interactive video installation, *Folding Fan*, and an AI short film, *SAIENTIENT?*. User perceptions of these artworks were assessed through an open-ended survey, exploring how GenAI can blend different temporalities and establish links between the past, present, and future in heritage storytelling. Preliminary findings suggest that GenAI has the potential to transform traditional heritage into nuanced emotional experiences, deepening audiences' understanding of the evolution and significance of cultural heritage.

1. INTRODUCTION

Intangible cultural heritage (ICH), transmitted across generations, establishes a strong connection between the past, present, and future of individuals and communities. Festivals and rituals, as significant components of ICH, encapsulate art, cultural and customs symbolism [1]. They serve as living archives that preserve collective memory, making their continuity essential for reinforcing place identity and fostering a sense of community belonging [2], [3]. Recent studies have increasingly explored how artistic and design practices, combined with emerging technologies, can support and advance ICH [4], [5]. Generative Artificial Intelligence (GenAI) has increasingly been integrated into the creative process, offering innovative possibilities for artistic creation and enhancing human creative productivity [6]. Notably, GenAI provides powerful visualization tools that facilitate the enhancement of historical documentation and enable the speculation of future scenarios. This potential aligns with Heidegger's theory of time, which challenges the traditional linear perspective by viewing the past, present, and future as interconnected dimensions of human existence.

In Heidegger's philosophy, authenticity is intrinsically linked to the human attribution of time [7]. This raises a philosophical question: Can Heidegger's concept of the 'past-present-future dimension' be applied to heritage narratives to convey the essence of heritage existence? This inquiry further leads us to explore whether GenAI can act as a virtual time machine, illustrating the temporality of heritage and fostering deeper emotional engagement with traditional practices.

In response to these questions, this paper employs an arts-based methodology to illustrate how cultural festivals can evolve and be safeguarded within multiple temporal frameworks. It aims to create an immersive experience that transcends temporal boundaries, fostering an emotional connection between audiences and heritage. This project involved multiple stages and resulted in the creation and analysis of two artworks, '*Folding Fan*' and '*SAIENTIENT?*', which combine historical documentation with the authors' artistic interpretations. In the artistic creation process, we gathered historical and contemporary documentation of the Cheung Chau Bun Festival (hereafter referred to as the

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Festival) in Hong Kong. Using GenAI, including text-to-image and text-to-video AI generators, we created audiovisual materials that not only enhance and reimagine the collected historical documentation but also envision potential future scenarios. By blending elements from various time periods into an interactive narrative, GenAI can act as a virtual time machine to engage audiences with heritage practices across the past, present, and future. A preliminary open-ended survey was conducted to assess the value of cultural heritage and evaluate whether our specific interventions promote a more authentic understanding of time.

In summary, this paper is structured into the following sections. First, we explore the connection between Heideggerian time and cultural heritage, examining the potential of GenAI to enhance our understanding of the temporality inherent in both cultural heritage and human existence. Second, we outline our artistic objectives and approaches for using GenAI to represent ICH across the temporal dimensions of the past, present, and future. Finally, we present our creative process and preliminary findings from user evaluations, analyzing the capabilities, potential, and limitations of our approach.

2. BACKGROUND

2.1 HEIDEGGERIAN PHILOSOPHY OF TIME

The conceptualization of time is one of the oldest and most debated philosophical topics, addressing fundamental aspects of human existence [8], [9]. Unlike the traditional view of time as a one-way linear progression, such as an abstract or objective measurement (i.e., clock time), Heidegger offers an alternative perspective. It forms the foundation of human existence, shaping how we understand ourselves and our place in the world [10]. Heidegger's concept of temporality consists of three dimensions: past, present, and future, which are not isolated entities but interconnected aspects of human existence [11]. This theorization of time highlights the dynamic interplay of human existence, where our being is shaped by projecting into the future, drawing from the past, and engaging with the present [12], [13]. Heidegger further refers to this as 'authentic time,' emphasizing that true engagement with time occurs when we meaningfully reflect on and interact with its three dimensions, particularly through our experiences, relationships, and awareness of our finitude (i.e., inevitable demise) [14]. This perspective provides a deeper understanding of what it means to live authentically in the world.

2.2 UNDERSTANDING THE TEMPORALITY OF CULTURE HERITAGE

UNESCO's definition of ICH introduces a key innovation: understanding cultural expressions as evolving processes shaped by time and usage, rather than solely emphasizing their intangible nature [15], [16]. Therefore, previous research emphasizes the central role of time in ICH [17], noting that, as a form of cultural production, the temporalities embedded in heritage practices shape contemporary identities and societal narratives [18]. Drawing on Heideggerian time, we can connect it to the temporality of cultural heritage, which is not merely a static artifact of the past, but an evolving process that links us to our history, informs our present, and shapes our future. This interconnected view of time guides us to consider using a potentially nonlinear approach to understand and tell ICH stories. Storytelling, as a means of engaging with ICH, serves as a platform to express the temporality embedded in heritage practices. By adopting a nonlinear approach to storytelling, informed by Heideggerian time, we aim to create an interconnected narrative that reflects on the past, imagines the future, and brings deeper meaning to the present.

2.3 TRADITIONALIST HERITAGE, COLLECTIVE MEMORIES AND NOSTALGIA

Nostalgia, defined as a longing for the past or a yearning for familiar times, places, and experiences [19]. Since it is often associated with significant life events, including cultural rituals, scholars also refer to it as a cultural sentiment, enlightenment, or identity [20], [21]. Given its widespread presence across different cultures and age groups [22], [23], scholarly research has explored nostalgia from multiple perspectives, including its social, artistic, and political dimensions [24]. Notably, the relationship between nostalgia and cultural heritage has received considerable attention, with research suggesting that nostalgia serves both as a motivator and an outcome for engaging with cultural heritage, particularly in the context of heritage tourism [19], [25], [26]. Specifically, it provides visitors with a 'glorified representation of the past' [19], while simultaneously raising public awareness of the importance of heritage preservation [15]. Hence, nostalgia and cultural heritage intersect in their shared capacity to evoke memories of the past and shape both individual and collective identities. In addition, studies have shown that nostalgia is more than a passive reminiscence of the past; it creates a distinct temporal experience by reinterpreting memories in the present and interacting with different temporal dimensions [24], [27]. Recent research further suggests that incorporating nostalgic elements into artistic expression can evoke a sense of shared memory and strengthen connections to history [24].

3. OBJECTIVES AND APPROACHES

3.1 ARTISTIC INTENTIONS

Our artistic intentions are as follows: (1) To use GenAI as a 'virtual time machine' to romanticize the past, speculate on the future, and thereby create an interconnected narrative that makes ICH meaningful in the present; (2) To use GenAI to transform traditional heritage into subtle emotions, such as the feeling of nostalgia; (3) To enhance public understanding of the temporality of ICH (i.e., how ICH evolves over time).

3.2 EVOKING NOSTALGIA FOR HERITAGE THROUGH GENAI

Old photographs serve as strong catalysts for nostalgia, as revisiting them can reinforce and even reshape personal memories [28]. Recent research indicates that visual stimuli, such as pictures and artworks linked to memory scenes or past experiences, can elicit more detailed recollections and related episodes. [29]. Hence, we utilize GenAI to enhance and reinterpret the historical documentation (e.g., old photos and records) of the Festival, making traditions and history more accessible and emotionally resonant for contemporary audiences. This approach can also be seen as a process of 'remediation' [30], where one medium (old photos) is represented through another medium (AI-enhanced or generated visuals).

3.3 SPECULATING ON FUTURE HERITAGE WITH GENAI

Recent studies indicate that design researchers and practitioners are increasingly utilizing GenAI to explore preferred futures, including ideation and concept development of future scenarios [31], [32]. In this project, we use design fiction [33], [34], a design approach that blends science with imagination, to explore potential future scenarios of the Festival. The artists and AI co-created a design fiction for the future of the Festival, incorporating concerns about environmental degradation and the potential misuse of AI. To visualize this design fiction, several AI generators were used, including MidJourney, Stable Diffusion, Runway, and Luma AI.

4. ARTISTIC PRACTICES

4.1 THE CHEUNG CHAU BUN FESTIVAL AND ITS EVOLUTION

The Festival is an annual cultural event held on Cheung Chau Island, one of the largest outlying islands in Hong Kong, renowned for its local religious practices and vibrant community. Supported by the local government, the Festival has increasingly been commercialized and commodified to promote local tourism development, processes that have also reshaped its original content [35]. As local residents actively participate in the planning and execution of the Festival, it serves as a catalyst for community engagement and identity reinforcement [36]. To preserve traditional elements while accommodating modern needs, we developed an interactive installation and an AI short film that present multiple temporal perspectives of the Festival, fostering emotional engagement between traditional heritage and audiences.

4.2 *FOLDING FAN*: AN INTERACTIVE INSTALLATION

Folding Fans is an interactive installation that blends historical documentation with AI-generated visuals, offering an immersive exploration of the Festival. The installation begins with a collection of historical photographs sourced from social media, documenting the folklore activities of the Festival and their different expressions across various time periods. We utilized a large language model (LLM; i.e., ChatGPT) to analyze these historical images and generate textual prompts, imagining the hidden stories behind the documents. To ensure the AI-generated narratives aligned with the specific historical context and festival traditions, the artists reviewed and refined the AI-generated prompts. Subsequently, text-to-image AI tools were used to regenerate images based on these textual prompts and the original historical images. The AI learned and applied the traditional Chinese technique of burning foil, creating a unique visual style that enhanced the scenes and characters from the old photographs. By combining these AI-enhanced visuals with contemporary video recordings, the video component of the interactive installation constructs a comprehensive narrative that bridges the past and present, evoking a sense of nostalgia. It consists of four 20-30 second short videos, each showcasing a different aspect of the festival, including its historical roots, religious ceremonies, representative activities, and community spirit.

Figure 1: *Top left: Selected old photo from 1961. Top right: Corresponding AI-enhanced image. Bottom left: Selected old photo from 1969. Bottom right: Corresponding AI-enhanced image.*

In Chinese culture, the folding fan's ability to open and close freely symbolizes the concept of 'going with the flow.' This metaphor reflects the vision of preserving traditional heritage while adapting it to modern needs, ensuring that tradition remains relevant and dynamic in the contemporary world. As viewers approach the 'peace bun,' a symbol of peace and safety during the festival, a short video is randomly projected onto a fan-shaped screen (see Fig. 2). This interactive design invites the audience on a journey of discovery, fostering a deeper connection with the festival's history.

Figure 2: *Left: The installation setup. Right: User interaction with the installation.*

4.3 *SAIENTIENT?*: AN AI SHORT FILM

SAIENTIENT? is a computer-animated short film co-directed by the artists and AI directors (ChatGPT). Presented from the AI's first-person perspective, the film raises questions about the potential of technological advancements to create either a utopian or dystopian future, while emphasizing the importance of safeguarding heritage in a rapidly evolving society. Through dialogue between the character and AI (ChatGPT; see Fig. 3), festival scenes across different timelines are presented to viewers.

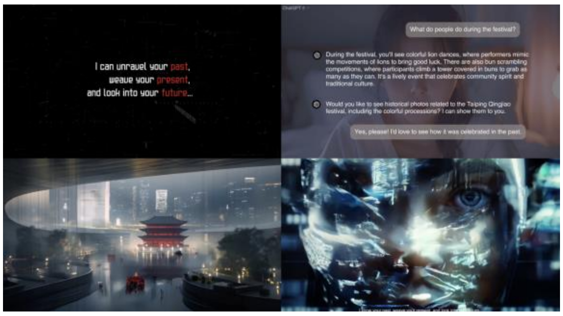

Figure 3: *Screenshots from the AI-generated film.*

5. PRELIMINARY STUDY

5.1 METHOD

To investigate user perceptions of the aforementioned artistic practices, we conducted a preliminary open-ended survey. A total of 10 participants were recruited from Prolific.com and compensated HKD 40 for their participation. All survey participants had no prior knowledge of the Festival. Initially, participants were asked to view two videos showcasing our artistic practices in full-screen mode. The first video (2 minutes) presented user interaction with the interactive installation Folding Fan from a third-person perspective, featuring selected video excerpts and documentation of the production process. The second video was the AI short film SAIENTIENT? (5 minutes and 32 seconds). Subsequently, participants answered a series of follow-up questions on whether the artworks elicited emotional changes and contributed to a deeper understanding of the temporality and significance of cultural heritage.

The researchers used inductive thematic analysis [37] to identify and extract themes from the open-ended responses. Given the potential and efficiency of LLM in processing and enhancing the comprehension of qualitative data [38], [39], [40], we integrated ChatGPT into the data analysis process, acting as a co-pilot to assist human researchers in detecting and summarizing codes. First, a human researcher iteratively read and coded the data, generating initial codes based on frequently mentioned or notable features in the open-ended responses. This process was then repeated using GPT-4 to enhance the efficiency of the analysis, replacing the previous, more manual approach. After combining the results of the human and AI analyses, and engaging in discussions among the researchers, the final codes and themes were identified.

5.2 PRELIMINARY FINDINGS

A preliminary analysis of participant responses revealed a heightened awareness of the temporality of ICH, particularly how traditional festivals evolve and adapt over time (N=10, labeled P1 to P10). Participants consistently reflected on the interplay between past, present, and future within ICH. P1 pointed out that ICH has the unique ability to bridge past, present, and future, suggesting that these temporal dimensions can be meaningfully intertwined. Similarly, P5 said that these artworks highlighted the interconnectedness of different time periods, demonstrating how traditions can adapt and evolve while maintaining their essence. This temporal awareness also deepened participants' understanding of the importance of cultural safeguarding. P10 reflected on how modern elements could be integrated into traditional practices, ensuring their vitality and relevance in contemporary contexts while preserving the core values of ICH. Notably, participants' perceptions of the temporality of the Festival demonstrated a sense of continuity and fluidity, reflecting a nonlinear, spiraling perspective on time (N=4). P6 for instance noted that while ICH originates from the past, it remains present in contemporary cultural practices and actively drives the evolution of cultural development into the future. While P8 believed that 'history repeats itself,' other participants, such as P7, argued that it is difficult for things to remain unchanged over time. This brings to mind the concept of spiral time and the spiral nature of cultural change, which refers to non-closed cycles and a directional process [41], [42]. Moreover, we observed a trend suggesting that this spiral temporality evoked emotional responses in participants, including nostalgia for ICH and anticipation for its future (N=6). For instance, P10 expressed excitement, as they realized how the future could be more advanced while being integrated into the present.

6. CONCLUSION

This article presents our artistic practices using GenAI to represent heritage practices, emphasizing its potential as a virtual time machine that interconnects the past, present, and future through the lens of Heideggerian time. By engaging audiences in interactive storytelling, these practices introduce an innovative approach to experiencing the three temporal dimensions of ICH. Preliminary findings suggest that this nonlinear, spiraling perception of time enhances participants' understanding of heritage's significance, evoking nostalgia and fostering anticipation for its future.

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Using Kitodo for Digitizing your Resources

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ABSTRACT: People often prefer to view digital representations of cultural- historical objects online via the Internet if this is sufficient to answer their questions, and travel costs can be saved. By digitizing their holdings, cultural heritage institutions can preserve the use of their collections and at the same time present them Open Access to a wide audience, so that their visibility and importance increases. Kitodo is a multilingual software available under the GNU GPL. It is a pair, Production and Presentation, that has been built specifically for the purpose of digital image acquisition and visualization. The two components were built from the grassroots by its users for two decades, thus all their experience in daily Digital Asset Management and documentation, supporting a wide range of metadata standards, is included. Kitodo is more than a long decade already backed and maintained by a dynamic user and developer community and the non-profit association Kitodo e. V., a Registered Association under German law, who carries the constant maintenance and further development of this unique open-source software. So, you benefit from the experience in Digital Asset Management, that makes an effort from the smallest to very large institutions and for cost-efficient mass operation.

1. INTRODUCTION

Digitizing many objects is a complex business, as the media disruption must be continuously managed throughout the process. Objects must be available, i.e. not just on loan, their conservation must be protected and ensured through the process, and they must not be damaged, yet the physical objects must be both digitized and be available for quality assurance, as well as transport, throughout the process. At the same time, the digital representations must be managed so that employees can use them as needed without risking damage to the digital work of art.

Descriptive data may already be available (such as catalog systems), or it must be acquired in the process, or existing catalog entries must be deepened. Employees can have very different qualifications, from specialist employees and scientists to simple scanning employees with special restrictions.

Then, the digital data obtained must be presented in a way that displays quickly, is of high quality, is efficiently searchable, can be shared and cited, while complying with legal requirements such as copyright restrictions or moving walls.

All these challenges and all of this work is supported by this software, that is open-source, and does not hide any unpleasant surprises or costs. There is a large community of libraries, archives and museums using it. You can get support and help with, and even technical support, responsive mailing lists.

2. PRODUCTION

As already mentioned, creating a digital version of a valuable original is a complicated process. There are many things that come into play, explained in detail: If you want to handle many objects, there must be a well-established structure, we call this the workflow. This is the same for all similar objects, and every item goes through it. The workflow consists of steps for individual objects. Individual steps can be of a practical nature (transport), object protection (professional assessment, restoration, cleaning), the actual digitization. Care should be taken to ensure that the original is subjected to minimal

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mechanical and light stress, while at the same time ensuring maximum quality of the produced representative (image sharpness, freedom from distortion, color fidelity according to international standards). Workflow steps also include image post-processing, quality control through technical and human measures and improved cataloging with lots of complex metadata according to international standards There may be steps that can be automated by software, such as optical character recognition, and that can run in parallel with other tasks.

The many work steps involve different people, with different tasks and different qualifications, who can be at different locations in the world, for organizational reasons (like a specialist in Sumerian languages in the Middle East who transcribes characters into the Latin script), or home office offers for employees, that are today also becoming more important. All this is possible via software that runs entirely on the Internet.

In addition, employees sometimes work for different clients and perform different tasks with different authorizations for different clients. For this, fine-grained management of authorizations must be available, which also provides a full user interface for specialists, but a simplified interface for people with special limitations, an interface that supports accessibility. Of course, the interface is also multilingual, for both itself and metadata tagging.

The software simplifies work as much as possible, so that existing data collections (such as catalog databases) can be integrated, and mass digitization orders can be created by importing lists, without needing to click every single item. Also, processing in groups is possible, so not every element in a transport box must be clicked individually, but work can be done efficiently. It provides a clear file management, so that users can see their own files, without having to click through long lists, also to avoid damage.

In the event of an error, it is possible to go back for a particular cultural root, then one or more steps must be carried out again, or not, all of this is considered, processed efficiently and guaranteed to be carried out.

We pay a lot of attention to the complex description of cultural-historical objects with complex semantic meta-data catalogs. We call this a ruleset, which allows the various inputs such as texts, long texts, numbers, dates, and URIs. It can provide from select-one or select-multiple choices, and allows groups in the metadata description, like acting people, which can consist of first name, last name, name suffixes, dates of birth and death and references to authority records. There is a large selection of interdependencies, which deals with allowed and required semantics for different structural levels. For complex works such as newspapers, navigation can be done with a calendar, and the software supports time stamps in video and audio. This is achieved with the power of XML and XSLT processing, using international metadata standards such as METS, MODS, MARC, EAD, but also custom data formats are possible.

At the end, when everything has gone as smoothly as possible, the new elements should be presented worldwide, and digital archiving can also be ensured.

For all of this, costs are minimized and sovereignty over the data is ensured, which means we use free Open Source and Linux, standardized formats and access to data is always guaranteed so that you can operate it in-house. By default we use Tomcat, MariaDB, OpenSearch, but more standard software is supported.

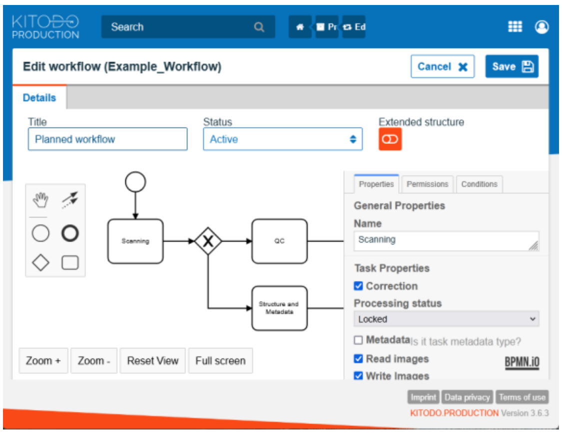

Figure 1: *You plan a successful workflow through your digitization, here is an example with branching.*

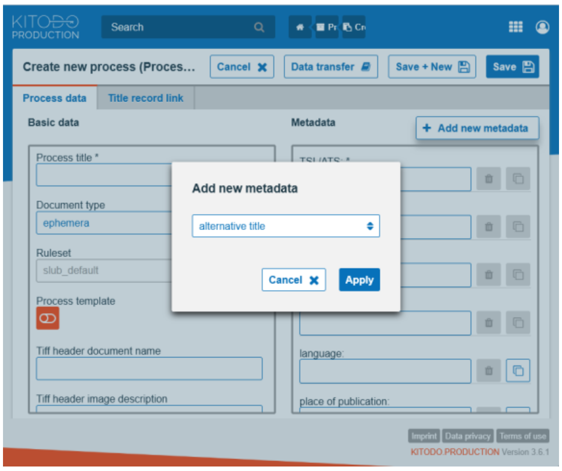

Figure 2: You create a new digitization process with metadata capture.

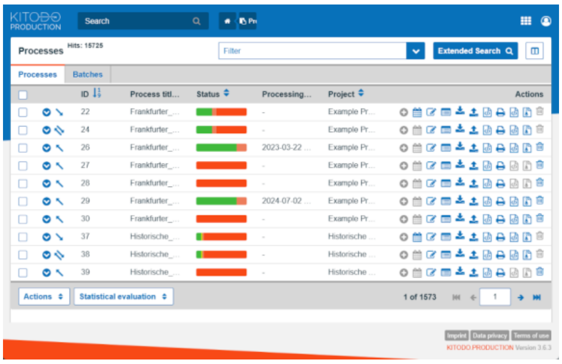

Figure 3: The software gives you a powerful interface for controlling the assets in work.

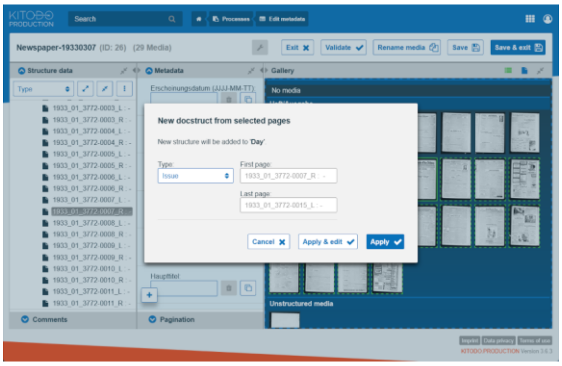

Figure 4: Define document structure and assign metadata in the professional browser-based editor.

2.1 PRESENTATION

The Presentation extends the TYPO3 Content Management System (CMS) with functions for displaying, navigating and searching in digital documents and collections. It can be integrated into an existing website or linked to it. You can use the TYPO3 CMS to design pages according to your Corporate Identity, so that it is seamless with existing web-sites, and beautiful. A predefined template allows you to get started without having to worry about the details of the CMS. It is intuitive for the user to navigate using the mouse with the attached structure, for example. Indexed metadata and full text can be searched quickly and easily. The display is pleasant and can also display images and complete documents from IIIF servers. Various options can be offered for downloading, such as individual images or entire PDFs, or user compilations in a shopping basket. An integrated OAI-PMH Version 2.0 interface enables standards-compliant, simple and fast provision of data.

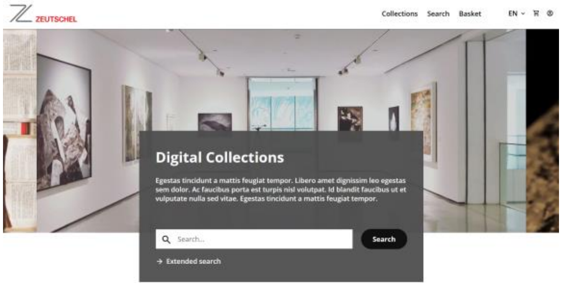

Figure 5: Landing page.

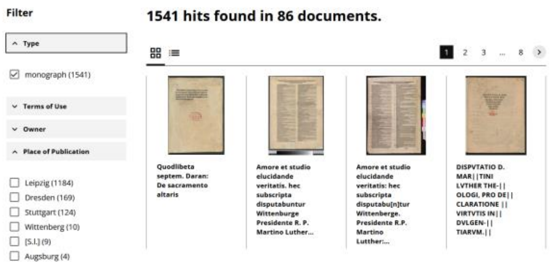

Figure 6: Search result list.

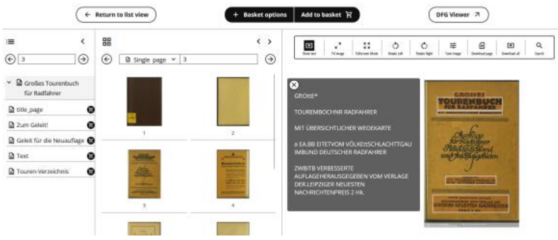

Figure 7: Work view.

3. CONCLUSION

The usage of the Kitodo software is totally free and based on recognized international standards in the cultural heritage sector. The applications are productive tools for you to digitize and share cultural-historical treasures to the world. They are ready and available.

An important aspect to consider is the customization and personalization of the system according to your needs. Through specific paid work, the whole system can be highly tailored to your needs. This is truly important to speed-up for example the integration of Kitodo into other existing eco-systems or add to its standard functionalities additional add-ons.

4. ACKNOWLEDGMENT

We acknowledge German and European laws, as well as Open Source licenses, especially General Public License (GPL). Software development is work based on the shoulders of giants and uses stacks of other software.

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SESSION II

"Memory Twins II"

Moderation: Ralf Schäfer
(Fraunhofer Heinrich-Hertz-Institute HHI)

Tohyve: Walkable 360° Videos for Hybrid Formats

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ABSTRACT: As part of the ToHyVe research project an approach for movement through virtual representations of real spaces using interactive 360° video recordings was developed. Trading time axis for an additional space axis, the video playback rate is adjusted to the spectator's speed of movement, thus achieving walkability in high-resolution video panoramas on predefined paths. Implementation in a game engine allows for any digital augmentation with digital assets or interaction possibilities. The successful realization of a demonstrator shows that this approach provides photorealistic walkable experiences as a highly authentic, cost-effective alternative to elaborate 3D modeling, while still offering no limitations regarding interactivity or additional rendering.

1. INTRODUCTION

Numerous technologies and developments, such as virtual concerts, work meetings in the Metaverse and increasingly affordable and powerful VR glasses, show the growth of virtualized experiences and events. While many applications use rendered graphics to ensure maximum flexibility and interaction possibilities, camera-based approaches, such as the use of panoramic photos or videos, can achieve a photorealistic experience with manageable effort. Thus, they are particularly suitable for applications that place great value on authenticity, such as exhibitions, tours of historical sites or concerts. However, they offer limited freedom of movement and are less flexible regarding interaction possibilities. Various approaches to solve these limitations demonstrate both the need and potential ofwalkability in photographed or filmed environments. For example, products such as Google Street View [1] create a panoramic photo tour through a rough spatial sampling combined with LIDAR depth measurement, which allows the viewer to jump from one viewpoint to another. Other approaches use a spherical camera array [2] or combine a video with an AI-based depth estimation, thus enabling movement in 6 degrees of freedom, though limited to a sphere of 70cm. The modern approach of Gaussian splatting uses a completely new method to create and render an environment. However, models for larger scenes become increasingly difficult to compute, and many aspects of Gaussian splatting, especially the ability to render dynamic scenes, are still the subject of ongoing research. As part of the ToHyVe research project, which is developing innovative technologies for virtual conferences and events, a new approach was taken to solve this problem.

2. APPROACH

2.1 CONCEPT

The following is an outline of the basic technique used to allow the walkability of panoramic videos: As a basis, full-spherical 360° panoramic videos are recorded on predefined paths. By keeping track of the camera's location, each frame can be attributed

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to a position in the room. Thus, any speed of movement along the predefined paths can be translated into a corresponding video playback rate, effectively trading the time axis for an additional space axis. By implementing this approach in a game engine, the panoramic video can be combined with 3D assets. Adding a sufficient geometrical model of the filmed environment to the game engine allows for optical effects like occlusion.

2.2 TECHNICAL REALIZATION

To evaluate the potential as well as the feasibility and limitations of this technique, a technical proof of concept was performed by recording a panoramic video, implementing the required mechanics in a game engine and finally showing the result as a demonstrator. According to the context of ToHyVe, a large conference room was chosen as the location for the test production. To avoid any lighting changes or motion in the scene, the room was emptied and only unnatural light sources were used. To allow for the spacial location of the video frames, a robotic dolly was used to move the camera with a constant, slow speed during the recording.

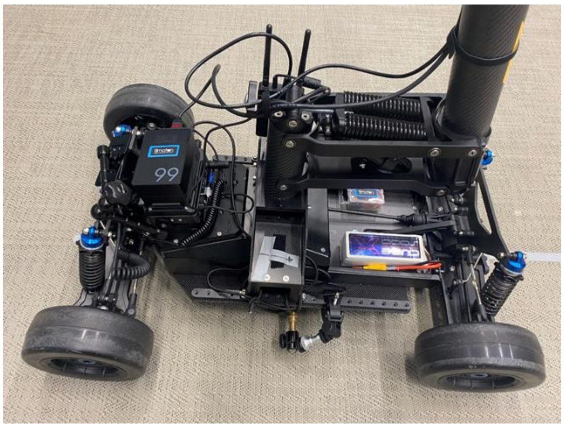

Figure 1: *Robotic dolly which was used to move the camera*

The OmniCam-360, a high-resolution parallax-free panoramic video camera was available for shooting. However, since it does not allow for full-sphere images, and, more importantly, exceeds the dolly's weight limitation, an Insta360 Pro 2 was used. After the recording of the panoramic videos on predefined paths was finished, work continued in the Unity3D game engine. The video playback logic was implemented and optimized for smooth forward and backward movement. 3D assets are added. To simulate occlusion effects from objects in the video, e.g. pillars, the geometry of the video material needs to be adjusted to fit the virtual camera. Then, occluding elements can be virtually modeled and positioned as a masking layer in the game engine. During video playback, the virtual camera position in the game engine remains static. To keep the perceived position of the occluding elements and 3D assets consistent with the panoramic video, they were animated manually using keyframes. Realistic lighting of the assets is achieved using virtual light sources, replicating realistic angles, color temperatures and diffusion properties.

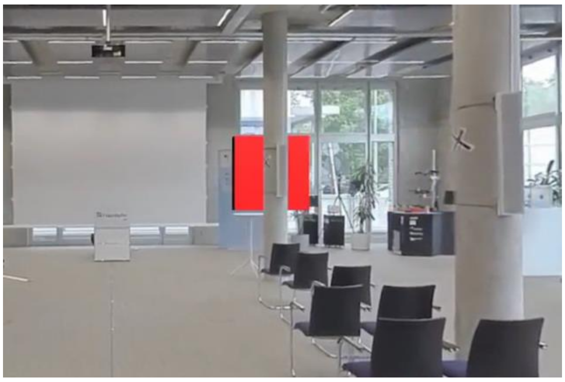

Figure 2: *The pillar as part of a panoramic video occludes a 3D-Asset, the red box*

2.3 EVALUATION

A demonstrator implementing the presented technologies was built successfully. However, the production also revealed potential room for improvement. For example, the parallax of the camera required extensive manual work to place assets and occluding objects in accordance with the geometry of the video. Using a parallax-free camera such as the OmniCam-360 would solve this problem. However, part of the recording area would be lost, since it cannot record the whole sphere. The use of depth estimation algorithms could solve the problem without any reduction of the recording area. Their successful integration would significantly reduce the post-production workload. Thus, further evaluation of this approach seems promising.

3. CONCLUSION

The successful realization of a demonstrator which achieves both walkability in and digital augmentation of a panoramic 360° video demonstrates the feasibility of the presented concept. With further development and technical improvements, the process might provide photorealistic spacial experiences as an alternative to elaborate 3D modeling of spaces, while being both more cost-effective and authentic, and offering no limitations regarding interactivity or additional rendering. Potential applications are numerous: The authenticity of the approach seems especially suitable for cultural applications like virtual exhibitions, digital museums or art events. Historically or culturally significant locations could be digitized, preserved and visualized for everyone to experience. Furthermore, the integration of this technology into existing platforms such as web browsers, stand-alone apps like Iventic and TriCAT spaces®, VR headsets, and immersive event spaces with multi-projection systems could expand the possibilities of the technology, benefiting any hybrid or fully-virtual event.

4. ACKNOWLEDGMENT

We would like to thank the interdisciplinary consortium of industry and research partners that participated in the development and evaluation of the technologies of the ToHyVe research project.

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D(A)Nte's (I)Nferno
Rappresentazione Dell'inferno Dantesco Attraverso Tecniche Di Disegno Integrato A.I. E Parametrico.

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ABSTRACT: The Divine Comedy is a narrative work of great imaginative power in which Dante Alighieri conveys otherworldly scenarios that come to life in an extremely vivid way; its description has offered artists in every historical period an inexhaustible source of inspiration, prompting them to capture the visual and symbolic essence of Dante's work. The proposed research aims to recover the diagrammatic tradition, transporting it to the contemporary through the use of artificial intelligence technologies and parametric drawing to reconstitute a virtual model of Dante's inferno. Text-to-image (DallE3, Midjourney, KreaAI, Flux, Stable Diffusion), text-to-3d (LumbasAI, Luma AI Genie) and image-to-3d (Rodin AI, 3DFY, Meshy, Alpha3D) AIs will be used synergistically to model Dante's territory. AI-generated images trained with input models derived from Dante's iconography, making use of text-to-image/image-to-image algorithms, will serve as a 3D matrix to generate semi-three-dimensional structures that will generate backdrops and soils, while Image-to-3d algorithms will provide three-dimensional elements that will be recomposed into the circles through generative processes and traditional 3D modeling and arranged through algorithmic-procedural methodologies.

1. INTRODUCTION

The Divine Comedy is a narrative work of great imaginative power in which Dante Alighieri conveys otherworldly scenarios that come to life in an extremely vivid way; its description has offered artists in every historical period an inexhaustible source of inspiration, prompting them to capture the visual and symbolic essence of Dante's work. The visual representations that have become an integral part of the collective imagination are those pertaining to Renaissance and neoclassical painters and engravers, which can be divided into two types. The first is the narrative type, in which we can distinguish Federico Zuccari's two-colored engravings, with a dramatic and scenic style, and Gustave Doré's illustrations;

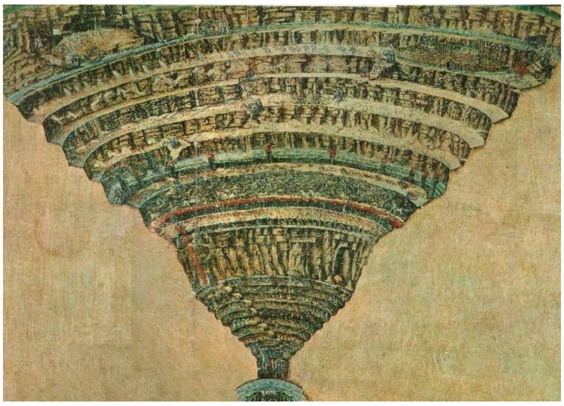

Figure 1: *The Hell, in "Divina Commedia" illustrated by Sandro Botticelli 1480.*

the latter strongly influenced the image of the Divine Comedy in modern audiences, thanks to the expressive power of chiaroscuro contrasts aimed at emphasizing the moral and spiritual

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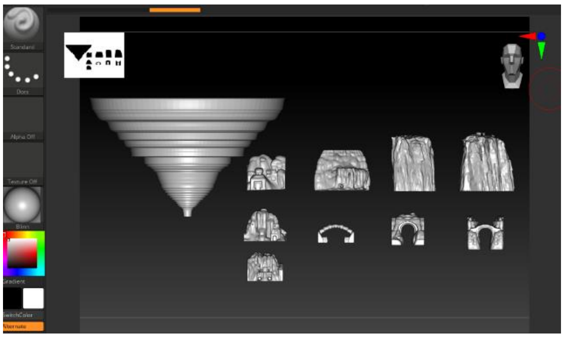

Figure 2: *Soft edge modelling of the overall structure of hell and 3d generated assets in ZBrush.*

tension of the work. The second representational type is the diagrammatic form, focused on illustrating the physical and symbolic structure of Dante's landscapes, constituting the iconographic reference in the collective imagination for the setting of the work as a whole. The epitome of this illustrative form is the perspective section of Sandro Botticelli's Inferno, a veritable topographical map of the Inferno that offers a synoptic image of the infernal architecture, somewhere between a teaching guide and a work of art. Johannes Brit's illustrations also diagrammatically depict the locations of the Comedy through singular geometric projections, close to zenithal (for hell and paradise) or axonometric (for purgatory) perspectives with a didactic and analytical approach. In the modern and contemporary, however, diagrammatic type representations have disappeared in favor of narrative ones, more inclined to a personal stylistic interpretation of the artist, decreeing a progressive evolution of the graphic language towards the dreamlike and abstract as can be seen from the works of Franz von Bayros, to those of Salvador Dali and, more recently, of Mimmo Palladino. An alternative representation of Dante's Inferno is also proposed in meta-cultural spheres such as video games (recall Dante's Inferno from 2010 by Visceral Games) or comics (The Divine Comedy - Omnibus by manga master Go Nagai) in which labyrinthine scenarios and their division into sectors, specifically characterized by creative peculiarities, lend themselves to a visual narrative typical of the division into levels of video games or comic book chapters. Once again such a highly intellectualized concept influences worlds seemingly so distant from literature or classicist art. The proposed research aims to recover the diagrammatic tradition, transporting it into the contemporary through the use of artificial intelligence technologies and parametric drawing to reconstitute a virtual model of Dante's inferno. Text-to-image (DallE3, Midjourney, KreaAI Flux, Stable Diffusion), text-to-3d (LumbasAI, 3dAIStudio, Sloyd, Luma AI Genie) and image-to-3d (Rodin AI, 3DFY, Meshy, Alpha3D) AIs will be used synergistically to model Dante's territory. Through 2.5D digital reconstruction methodologies, AI-generated images trained with input models derived from Dante's iconography, making use of text-to-image/image-to-image algorithms, will act as a 3d matrix to generate semi-three-dimensional structures (exploiting the well-known techniques of Bump and Displacement) that will generate backdrops and soils, while text-to- 3d algorithms will provide three-dimensional elements that will be recomposed into the circles through generative processes and traditional and algorithmic-procedural 3d modeling. The experimentation will highlight what are the imaginative and representational potentials of artificial intelligences in a process of building complex 3d structures and their deficits in dealing with a complex subject with a highly inhomogeneous iconographic background, on which it will be interesting to try to trace the references used in the training phase. Once the three-dimensional model is created, it will be used to reproduce the particular diagrammatic representations or explored in real-time appreciating the scenic perspectives.

2. ICONOGRAPHIC SELECTION

In the iconographic tradition linked to the Divine Comedy, a category often obscured by the production of the great masters of the Renaissance and Neoclassicism - who codified a vision more consistent with perspective and compositional models - is that of the earliest and oldest representations, preserved in illuminated codices made in the 14th century and coming from various regions of Italy, from the Lombard schools to those of Rome, Emilia and Florence, to influences that could bring them back to Giotto's orbit. Such sources form the basis for the study of the semantic and symbolic construction of Dante's imagery, where the absence of rigorous perspective setting or accomplished naturalistic realism becomes the sign of an interpretive tension that cannot be reduced to formal reproduction alone. The strongly evocative and stylistically distant from contemporary taste nature of these ancient image repertoires is inscribed in the semiological perspective outlined by the great theorists of sign and interpretation-from Ferdinand de Saussure to Charles Sanders Peirce, via Roland Barthes

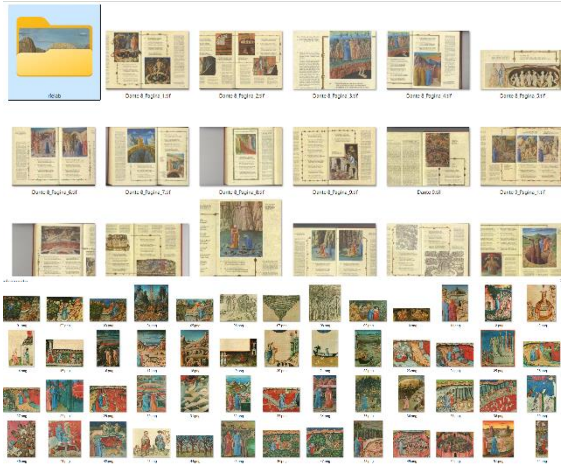

***Figure 3:** Iconographic collection, from "Divina Commedia" edited by Fratelli Fabbri Ediori.*

and Umberto Eco [1][2][3][4][5] - according to which the meaning of the visual work lies not simply in what it shows with greater or lesser fidelity to reality, but in the complex network of references, allusions, codes and subcodes activated in the observer, feeding his or her interpretive faculty through a process of recursive semiosis. In these early representations, "pre-structural" with respect to the maturation of a coherent linear perspective vision, the lack of "second articulation" - the property of languages capable of discrete and combinatorial decomposition on multiple levels [6] - does not appear as a mere technical deficiency, but as a peculiar poetic device that gives the visual sign a different, more connotative semantic weight, closer to that realm of the icon identified by Peirce [2], in which simile, visual suggestion and symbolic tension are multiplied without being bound to a rigid logical grid. In this sense, the comparison between the evocativeness of the two-thirds-fourteenth-century miniatures and the refined elaboration of later illustrative cycles (e.g., the engravings of Federico Zuccari or Gustave Doré) reflects the dialectic between more or less codified sign systems, well distinguished in semiotics: on the one hand, a repertoire of images free from strict spatial conventions, filled with evocative value; on the other hand, more narrative, rational visual forms consistent with the fifteenth-fifteenth-century language of perspective, capable of taking on an almost "discursive" tone in an attempt to restore Dante's architecture of hell. Privileging these ancient iconographic sources over the more well-known and popular ones - more comfortable for the modern eye - thus represents not only a philological option, a parallel between the infancy of representational techniques and the development of generative artificial intelligences, but also a choice endowed with a precise semiotic will.

The adoption of medieval-inspired miniatures, with less sharply encoded symbolic references and less sign articulation, allows the interpretive and generative aspects to be experimented with greater formal freedom in the perspective of graphic processing by artificial intelligence: the AI is confronted with a less rigid and more suggestive, almost dreamlike semantic field, potentially more adherent to the cryptic nuances, intertextual references and cultural sedimentations present in the Comedy. The tension between the indeterminacy of the sign under study and the need to construct a coherent model of the infernal landscape finds a point of contact in Sandro Botticelli's "Voragine Infernale" (ca. 1480), a perspective section of the Inferno that, although with greater spatial definition, does not renounce a strongly evocative dimension, becoming the structural basis of the digital reconstruction. If Botticelli, to some extent, mediates between the more archaic and the more modernly coherent imagery-thanks to its funnel-shaped structure-the 14th-century miniatures, less oriented to rigorous perspective rendering and more devoted to a symbolic narrative, can offer to the artificial intelligence system a raw material of extraordinary interpretative ambiguity, a visual palimpsest of signs and subsigns from which it is possible to bring out forms, patterns, architectures and spatial dynamics that cannot be reduced to simple Euclidean coordinates.

Experimenting with 2.5D digital reconstruction processes and combining text-to-image, image-to-image, text-to-3D, and image-to-3D algorithms on these sources does not amount to a mere aesthetic exercise, but becomes a true heuristic paradigm in the semiotic sense, a set of interpretive criteria that serve as a starting point for the investigation and discovery of meanings, within which semantic elements can be broken down, connected, and reassembled with the intent of producing new interpretive hypotheses. As Eco suggests, each interpretation fits into a pre-existing cultural encyclopedia, and signs require an interpretive act that connects them to a set of knowledge, allusions and inferences [4][5]. The choice of these ancient repertoires thus represents a strategy to put back at the center of the process of construction of digital imagery that complex interaction between sign, interpreter and object identified by Peirce [2], since the image is not pure appearance, but a structure of cross-references whose understanding depends not on an unambiguous code but on a nonlinearly and non-hierarchically organized fabric of cultural, historical, and symbolic references, a broad and layered context in which AI, however sophisticated, struggles to orient itself, generating new ambiguities, shifts in meaning, and potential semantic imbalances. In this perspective, the "evocative" quality of these images and their distance from modern canons of perspective do not constitute a limitation, but a semiotic virtue to be cultivated in order to probe the potential and limits of an artificial cognitive process that, starting from such a complex iconographic substrate, attempts to reconstruct hellscapes in a three-dimensional dimension, operating in a signifying fabric that draws on the past but projects into the future, enriching semiosis with new interpretive nuances. To complement the previous reflections, we can analyze three examples that demonstrate the semiotic potential of the Ferrarese miniatures, selected to be processed by the interpretive/generative A.I. Created between 1474 and 1482, represents a further example of how medieval and proto-Renaissance iconographic works can serve as a privileged ground for semiotic exploration and experimentation with generative artificial intelligences. These illustrations, while belonging to the second-half of the 1400s – a stylistic phase marked by greater attention to detail and more articulated narrative intentions – retain the evocative and symbolic quality that makes the miniatures of the 14th century so fascinating in terms of their interpretive openness. They offer a representational model where the strictness of perspective is not yet absolute, allowing for a fluid dialogue between reality and symbol, between figure and meaning. The first miniature, depicting Dante and Virgil in the circle of the thieves (Inferno, Canto XXIV), focuses on the representation of the sinners' bodies, entangled and penetrated by snakes that visually embody the concept of transformation and loss of identity. The scene, characterized by a quasi-theatrical spatial arrangement with the sinners placed on a tilted plane and framed by a rocky background, exemplifies how gesture and symbol converge in a visual narrative with strong emotional impact. The second miniature, portraying Dante and Virgil with the falsifiers of metals (Inferno, Canto XXIX), centers on the physical and moral disintegration of the damned, afflicted with horrific diseases that deform their bodies. The space of the bolgia, bordered by towering rocky walls that seem to compress the action, reflects the oppression and despair of a humanity condemned to eternal suffering. Finally, the third miniature, dedicated to Canto XXXII of the Inferno (lines 103-105), portrays Dante and Virgil in the frozen lake of Cocytus, where the traitors are immersed in ice up to their necks. Here, the immobility of the sinners' bodies, trapped in an eternal state of rigidity, contrasts with the majesty of the rocky walls surrounding the scene, creating an atmosphere of solemnity and dread. The ice, a symbol of the absence of human warmth and total alienation, becomes the visual centerpiece of the composition, an element that, despite its simplicity, encapsulates profound symbolic meaning. From a semiotic perspective, the scene suggests a tension between physical immobility and inner anguish—a dialectic that artificial intelligence can leverage to create three-dimensional environments characterized by an oppressive sense of stillness, where ice becomes not merely a visual element but The first miniature, illustrating Dante and Virgil in the bolgia of the thieves, presents a jagged and oppressive rocky terrain that dominates the composition. The chaotic arrangement of the stones mirrors the disordered moral state of the sinners, whose identities are constantly in flux as they merge with serpents. The angularity of the rocks and their overwhelming presence create a claustrophobic atmosphere, emphasizing the inescapable nature of the punishment. This topographical chaos, devoid of any guiding linear perspective, invites an interpretive openness that generative AI could leverage to craft dynamic and fragmented environments.

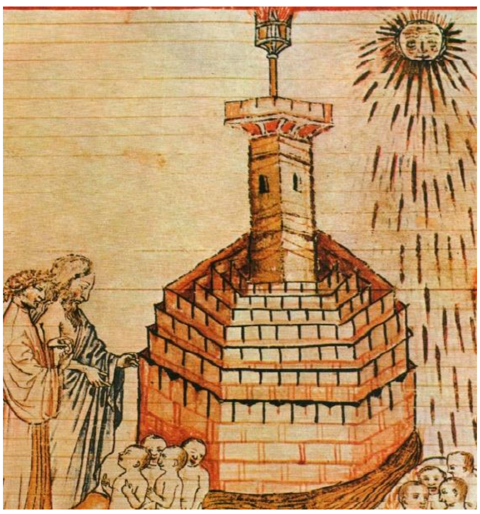

Figure 4: *Inferno iv 83-84. Emilian miniature painting late xiv century (Rimini, gambalunga library).*

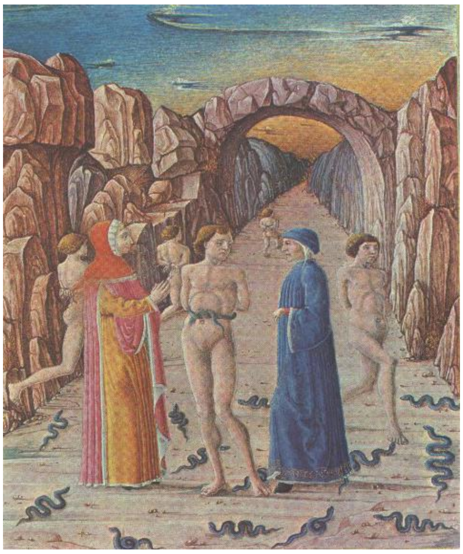

Figure 5: *ante and Virgil in the Bolgia of the Thieves. Ferrarese Miniature, 1474-1482.*

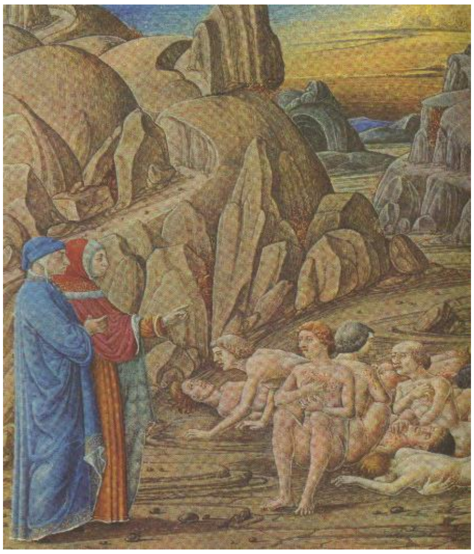

Figure 6: *Dante and Virgil with the Falsifiers of Metals. Ferrarese Miniature, 1474-1482.*

Figure 7: *Inferno IX, 104-105. Miniata Fiorentina, XIV Secolo. (Parigi, Biblioteca Nazionale).*

3. 2D IMAGES AND 3D MODELS, EVOLUTION OF RODIN.

The generation of two-dimensional images through neural networks has greatly revolutionized the critical attitude and creative approach to artistic productions, speeding up the time but also impoverishing the factor of inprinting- authorship and control over the production stages and critical analysis of a work. one of the most popular approaches is the use of generative Adversarial Networks (GANs). They consist of a generator and a discriminator: the generator creates synthetic images through what is called random noise; the discriminator is tasked with assessing whether an image comes from a given dataset (thus defining it as a real image) or whether it was generated by AI [7]. The neural network training process is nothing more than a kind of two-way game between the generator and the discriminator, in which the generator tries to fool the discriminator by gradually improving the images it generates to make them look more and more real (similar to those in the dataset). Some of the best known GAN networks are: DCGAN, StyleGAN, which deals mainly with high-resolution scaling, and CycleGAN, which transforms images from one domain to another (e.g., from photos to paintings). Another approach, however, is diffusion models, a family of generative algorithms based on stochastic processes designed to generate synthetic data of all kinds (images, audio, etc.). They are characterized by two main processes: one of diffusion (training) in which a Gaussian noise is progressively superimposed on a real data (e.g., an image) until it is converted into pure noise (image degradation is a controlled process based on probabilistic transitions); and one of denoising (generation) in which the process is exactly the reverse; thus, it starts with a noisy image and ends with a coherent and detailed image. Unlike GANs, diffusion models are more stable and more controlled (e.g., mode collapse is avoided, i.e., when there is an imbalance between generator and discriminator and limited outputs are ignored by ignoring diversity in the training database). Some of the best known diffusion models regarding images are the DDPM (Denoising Diffusion Probabilistic Models) Stable Diffusion and have application in what is called text to image (DALL-E). Other approaches are Autoregressive Models characterized by their large resource use and computational slowness

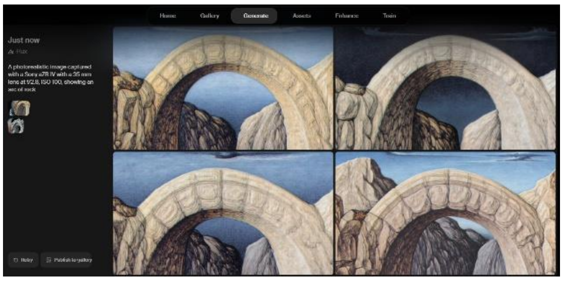

Figure 8: *Flux Generation of style model based on input from original images for Train steps(processing by authors).*

and Tansformers characterized by their ability to model complex reactions between data, which are widely used in the text to image process (DALL-E or Imagen) and image transformation (Image-GPT).

Regarding the generation and synthesis of new views, then the generation of 3D models from neural networks, research is constantly evolving, with approaches falling mainly into three categories: use of multiple images, use of a single image, and use of 3D prompts or semantic information. When images captured from multiple viewpoints are available, it is possible to generate a three-dimensional representation of the object that allows new perspectives to be created. This process can be accomplished by exploiting techniques based on multi-view geometries or depth maps. With the advent of artificial intelligence, deep neural networks (DNNs) are taking a central role in the analysis of spatial dimensions. Some studies have focused on creating synthetic images from depth maps with gaps or characterized by noise, while others have explored the generation of alternative perspectives from two or more images with reduced baselines. An additional area of research involves volumetric rendering to create implicit voxel clouds, which do not explicitly represent the object surface but are used to generate new views. Methods for synthesizing views from a single image are distinguished by the different approaches taken. One is to use large image datasets, supplemented with 3D and semantic information (e.g., depth maps and ground truth data), to train algorithms capable of three-dimensional representation of the object present in the source image. However, such methods require long processing times and the use of advanced 3D acquisition technologies, such as depth cameras or LiDAR sensors. Other studies propose an end-to-end approach, in which DNNs directly perform view synthesis, or rely on embeddings learned during the training

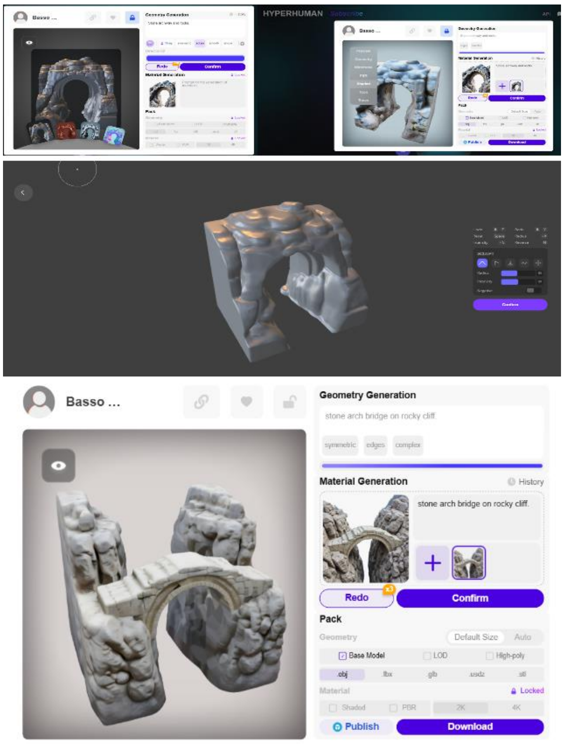

Figure 9*: Rodin AI platform_Creation of 3d model for AI self-modeling via image input bridge synthesis.(processing by authors)*

phase to recognize patterns or classify objects in the image.

Despite advances, these techniques have some limitations. Some methods, for example, focus on specific classes of objects or handle only small changes in viewpoint, resulting in errors when shifts become larger. Others focus on particular movements, such as forward movement, as in the case of the KITTI dataset [8]. A related area is that of “zero-shot” processes, which refer to a model's ability to deal with tasks for which it has not been explicitly trained. In this context, a model can generate a completely new image based on examples assimilated during training. Methods such as SynSin, PixelNerf, Make-it-3D, DreamCraft3D, Zero-1-to-3, Magic3D, LRM and Triposr [9] share the goal of generating and manipulating three-dimensional content from 2d data (images) or other partial representations of 3D. These approaches leverage various advanced artificial intelligence technologies: some exploit depth maps or multiple views; others use Nerf (Neural Radiance Field) for rendering. In 2022, Rodin was developed, a diffusion model initially designed for automatic generation of three-dimensional digital avatars that has now evolved into its Gen-1RLHFV0.9 (Public Beta) version becoming an excellent tool for generating any 3d object from a single image. Despite recent advances in generative diffusion models and implicit neural radiance fields (NeRF), there is still a great challenge in creating fine details such as precise textures or realistic hiper details. In the methods widely adopted today, 3D generative models usually use a two-step process:

- Proxy representation: A simplified 3D representation (such as triplanes or volumes) is created from unstructured data (mesh or point clouds). These data are usable by diffusion models. A decoder, shared among all avatars, generates 360° images from this representation.
- Generation by diffusion models: These models work on the proxy representation to generate diverse avatars. However, the finer details remain problematic.

For example, the old version of Rodin uses a 2D refiner to improve visual quality, but this compromises 3D coherence, which is critical for many applications. However, the new version uses a “roll-out” diffusion network to automatically generate digital avatars represented as neural radiance fields (NeRFs), which describe the color and volumetric density of each 3D point, but to address the memory and computational cost issues associated with generating high-quality models, Rodin introduces an innovative approach based on three key elements: 3D-aware convolutions that exploit the “tri-plane” representation where the 3D volume is represented by 3 orthogonal planes; latent conditioning integrated with CLIP in which a latent vector is used to ensure global consistency in the 3D volume; and hierarchical synthesis that generates a low-resolution tri-plane that is gradually enhanced by an upscaling process. Rodin was trained on a multi-view dataset of 100,000 avatars created by 3D artists, with diverse styles of identity, clothing and hairstyles. This allows the model to generate an unlimited number of unique and detailed avatars not found in the original dataset. This method overcomes many limitations of previous techniques. Rodin still employs the same method to generate complex objects from images.

4. DESIGN PHILOSOPHY

The project, still under development, aims to describe an innovative methodological approach for the creation of digital three-dimensional models inspired by the imagery of Dante's Inferno, based on the use of advanced artificial intelligence technologies and on a careful analysis of Renaissance graphic references, in particular the section of the Inferno by Sandro Botticelli. The integration of AI and parametric modelling offers extraordinary potential for reinterpreting such a complex iconographic heritage, transforming it into three-dimensional representations consistent with historical aesthetics and at the same time adapted to contemporary technological needs. The project explores the possibilities offered by generative models, highlighting how these techniques can contribute to the enhancement and communication of cultural heritage, with applications ranging from immersive environments to serious games in VR mode[10]. The introduction of artificial intelligence in architectural design, both two- and three-dimensional, represents a significant advancement over traditional algorithmic approaches. Currently available generative processes allow for unprecedented automation, transforming traditional manual control into a highly autonomous system. These algorithms, structured as an ‘autopoietic process’, require increasingly limited inputs, relying on functional, user-friendly and contextual criteria to generate innovative and often unexpected solutions. This shifts the design focus from simple formal verification to the search for optimal configurations, capable of dynamically adapting to aesthetic and functional objectives. However, the use of deep neural networks also brings with it aspects of unpredictability, producing non-deterministic results that, while going beyond mere mechanical reworking, can generate variations and anomalies. While this aspect broadens creative possibilities, it also poses challenges in terms of controlling the design process, which is often delegated to the algorithm itself. Within this scenario, we have observed the growing role of the prompt engineer, a figure responsible for defining parameters and rules for generation, but delegating executive decisions to the algorithm. This process, if not properly managed, risks causing a loss of the cultural and existential value of design, a discipline that artificial intelligence can nevertheless compensate for through its ability to learn from input data and generate meaningful representations. The research presented here focused on the development of a customised workflow that combines advanced tools to create a digital process capable of integrating tradition and innovation, while accommodating better process control. Through experimentation and analysis of results, the aim is to demonstrate how AI can become an empowering tool for iconographic representation in 3D representational modes and process development that actively includes 2D, becoming an interesting alternative for analysing Intangible Heritage.

4.1 A.I. WORKFLOW

The workflow is summarised through essential steps that include the systematic collection of data, their labelling, the creation of a reference model and the guidance of the creative process through a synthesis reference image, which in turn becomes the main input for the 3D self-modelling. The work process consisted of several steps. Firstly, in order to define a solid starting data base, an in-depth analytical study was conducted on a series of historical illustrations of Dante's Inferno, including paintings, engravings and drawings produced over a period of three centuries.

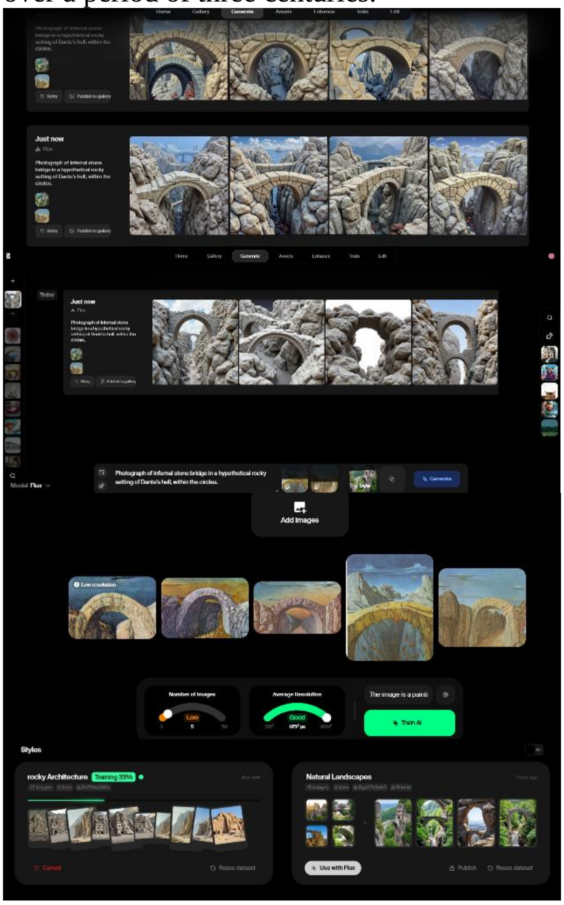

Figure 10: Training process in Flux Ai platform relates the semantic elemnt of the bridges.

This iconographic corpus was supplemented with photographic images of landscapes and natural or architectural structures, such as canyons, hermitages and rock formations, that recall the material suggestions of the Inferno described by Dante. The selection of images was guided by specific criteria, including their ability to represent the distinctive elements of the complex narrated body, such as landscapes, portals, bridges, architectures and decorations. An attempt was made to preserve the classical style of representation, while avoiding sacrificing the aesthetic coherence of the historical sources. The selected images were necessarily pre-processed in order to standardise their size, thus optimising the final dataset, which was prepared through a manual segmentation of the images using software such as Photoshop. This preliminary phase made it possible to highlight morphological and semantic features relevant for the subsequent artificial intelligence training phase. The segmentation was carried out by means of digital masks and transparencies, with the aim of isolating the main iconographic elements, eliminating figures and characters by means of Adobe's integrated AI system and enabling the algorithm to analyse the illustrations with greater precision. In parallel, photorealistic graphic styles were created, using platforms such as Flux AI and Krea.ai. These styles, through a complex reiterative process of creation and transformation, made it possible to generate the final synthesis images to be used in the three-dimensional AI training, simplifying the reinterpretation phase of the visual characteristics of the historical and photographic sources, while guaranteeing stylistic coherence with the narrative essence of Dante's Inferno.

Although during the training phase in the Flux workspace it is possible to dose the weight and influence of each individual image in the dataset by means of seed control, training steps and learning rate, as an alternative to this highly automated workflow, several complementary tools were used to create a different workflow, each with a specific and crucial role in the development pipeline [11]. Exclusively for some particularly articulated typological elements, an innovative approach structured on the node system ‘ComfyUI’ was tested, which is in fact characterised by a modular interface based on nodal modelling that facilitates the understanding and management of complex interactions between the various components of the workflow, together with version 1.5 of Stable Diffusion, today one of the most robust models for image generation and compatibility with the various components available online.

Thanks to intensive preliminary training, this model is suitable for further optimisation and customisation [12].
In addition, the ‘WD 14 tagger’ module was employed to automatically assign semantic tags to the images in the dataset, transforming visual information into textual data that can be interpreted by the algorithm. This process facilitates the analysis and contextualisation of the visual content, making it more accessible and intelligible, a task in the previous structural approach intended for a more time-consuming and complex human manual segmentation intervention in Photoshop. For the algorithm training process, DreamBooth is used, a tool that allows customisation and implementation of deep learning models by developing a basic checkpoint that allows the system to be modelled according to specific needs, integrating the visual data and semantic labels previously constructed with the WD 14 tagger module. The final stage of this alternative workflow includes the ‘Apply ControlNet (Advanced)’ and ‘AIO Aux Preprocessor’ nodes, which improve image processing by applying artificial intelligence algorithms capable of offering granular control over visual properties, ensuring a satisfactory end result in the generation of the final sample images to be submitted to the three-dimensional AI self-modelling system. After these preliminary stages of synthesised image creation, the next phase involves the use of Rodin AI, currently the most powerful platform for generating hyper-detailed 3D models [13], and in part of Luma Genie, for the insertion of further decorative and enhancing elements of the 3D spatial model generated exclusively by textual prompts. The two-dimensional images, produced in the previous phases, were then transformed into three-dimensional assets by means of AI algorithms (ControlNet) this time completely in the background, capable of analysing the images and interpreting their perspectives, colours and depths in a highly accurate manner. Rodin AI allows not only to generate detailed models from 2D images, but also to enrich them with high quality BPR (physically correct) material textures, such as Albedo maps, Normal maps and Bump maps, and to refine their quality through proprietary 3D sculpting tools, which can be directly executed by the user during editing. This refinement phase proved fundamental in obtaining three-dimensional assets consistent with the aesthetic and functional expectations of the project, ready for export to any precomputed or Real Time rendering platform, presenting a complex polygonal morphological topology consistent with the external geometry together with an excellent texture mapping (uv map) that is well-structured and easy to read for any rendering engine, so that the 3D output model can be integrated into any complex digital environment.

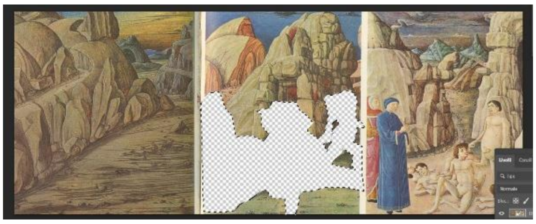

Figure 11: *Segmentation of the original art scans in Photoshop environment.*

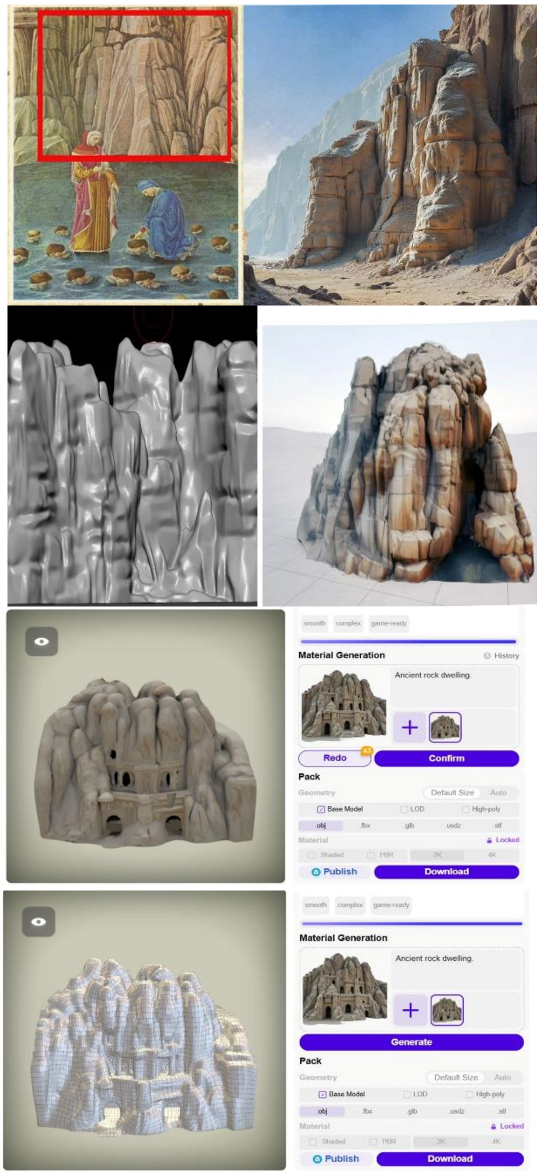

Figure 12: *Complete Self-modellation process from the original drawing scan through 2D generative AI and the 3D model generated with Rodin AI.*

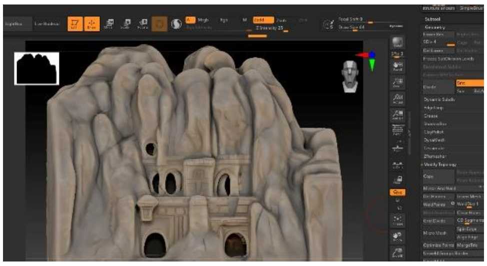

Figure 13: *Final 3D Generative AI Products generated with Hyper3D Rodin and post-processed in ZBrush.*

Figure 14: *Final 3D Generative AI Products rendered within Twinmotion environment.*

4.2 PARAMETRIC WORKFLOW

Once generated, the three-dimensional assets were assembled into an overall model, articulated according to the nine circles/planes configured in Botticelli's Inferno as a structural guide. This historical reference was used to define proportions, scale and architectural relationships, giving coherence and credibility to the project. The assembly was realised with advanced parametric tools such as Rhinoceros and Grasshopper, which allowed the optimal distribution of assets within the model. This parametric approach also made it possible to replicate and vary architectural and decorative elements, creating different versions for each circle of Hell. The methodology is based on the use of advanced computational tools to ensure geometric consistency and design flexibility, while preserving complete control over the entire process through parametric algorithms. The starting point is the import of the generated assets into a modelling environment such as Rhino, with a subsequent evaluation of their scale with respect to the pre-existing architectural and topographical elements. The scaling is done by parameterising the process according to a reference height, which represents the vertical distance between two rounds or key points of the project. Through the bounding box of the assets, the minimum and maximum values on the Z axis are extracted to calculate the current height of each model. This is compared with the reference height to generate a scaling factor, applied uniformly along the Z axis. This operation ensures that all assets are proportionate to the spatial context and can integrate harmoniously into the overall composition.

Once resized, the assets are distributed along a basic curve for spatial organisation. To ensure ‘natural’ positioning, the curve is divided into randomised points using a subdivision and ‘culling’ algorithm for points that are too close beyond a certain teshold set parametrically to the size of the current round, while tangent vectors at each point are extracted to determine the orientation of the assets. In parallel, a parametric algorithm models through sweep series the structure of the Inferno, following as a proportional reference the section drawn by Botticelli, through curves that are dynamically shifted and scaled with parametric sliders, tracing the proportions and geometry characteristic of the original representation, while keeping the entire process completely parametric. The choice of using the eighth bolgia of the “Malebolge” as a ‘proof of concept’ allows us to test the effectiveness of this approach in a reduced context, even though it is already representative of the general complexity of the work.

Asset orientation requires the construction of positioning planes defined by an X-axis tangent to the curve, a Z-axis perpendicular to the curve but confined in the XY plane, and a Y-axis parallel to the global Z-axis. These planes are calculated through a sequence of vector products: the first generates the Z-axis as a vector orthogonal to both the tangent and the global Z-axis, while the second vector product recalculates the X-axis to ensure it is perpendicular to the new Z-axis. This process maintains geometric consistency and uniform orientation of the assets along the entire curve.

For specific assets intended to serve as pavements, additional measures ensure that their Z-axis is oriented perpendicular to the XY plane and that the X-axis remains tangent to the curve, using radial vectors calculated with respect to the centre of the circumference as a reference for direction.
The distribution of the assets on the base curve takes place under a condition of controlled randomness by means of a random selection system that allows the models within a list to be mixed and distributed unevenly along the points of the curve, while still maintaining control over the distribution through the use of randomisation seeds and customised weights to favour the presence of certain models. In addition, filters can be applied based on a minimum distance between points, using proximity analysis to eliminate any unwanted overlaps.
Throughout the process, visualisation tools such as preview planes and orientation vectors are used to verify the correct positioning and orientation of assets, providing immediate and iterative feedback for any modifications or optimisations. This workflow represents a rigorous and flexible approach to parametric modelling, combining geometric precision, design narrative and spatial adaptability, making it particularly suitable for complex, narrative contexts such as the Botticelli-inspired infernal reconstruction.

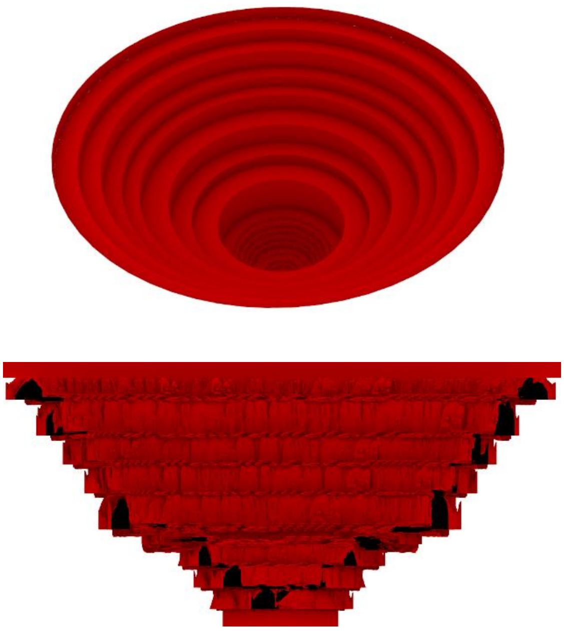

Figure 15: *Final results of the proof of concept: bird's view from above and section of VIII Circle "Malebolge"*

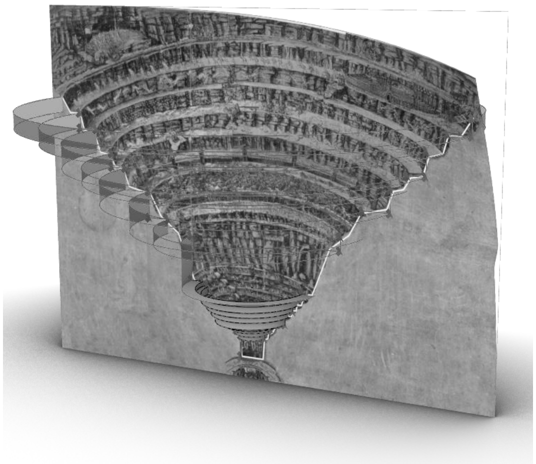

Figure 16: *Parametric modeling of the rough formal structure on the Botticelli's drawing in Rhinoceros through Grasshopper parametrization.*

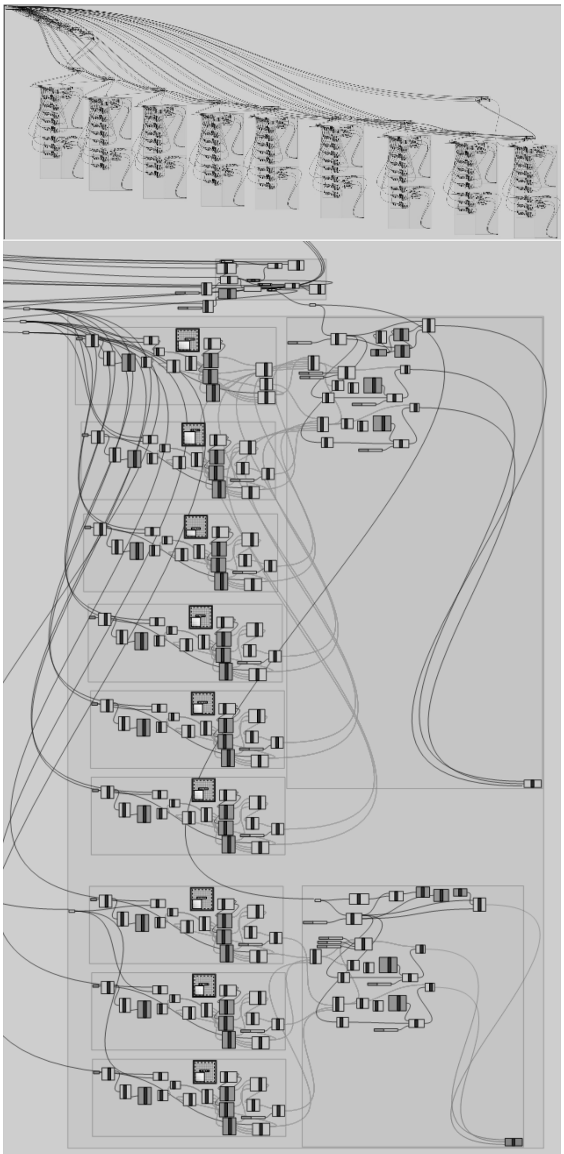

Figure 17: *Grassopper algoritm viewport for the assets scattering.*

5. CONCLUSION

The end result is a scalable three-dimensional model that combines a rigorous historical reading with the technological innovation of AI self-modelling, not only offering a detailed and immersive representation of Dante's Inferno, but also serving as an example of how AI techniques and parametric modelling can be used to reinterpret historical imagery in a contemporary key. The whole process demonstrates the potential of (partly) open-source tools, such as Flux AI, Krea.ai, Luma AI and Rodin AI, integrated with advanced parametric platforms, in the field of intangible cultural heritage representation. This research shows how the use of advanced digital technologies can overcome the limitations of traditional tools, offering new perspectives for the study and valorisation of such a vast artistic and literary corpus as the Divine Comedy. Finally, the resulting model is not limited to representing a static vision of the Inferno, but opens the way to possible dynamic applications, such as the creation of immersive environments or serious games, making Dante's work accessible and engaging to a contemporary audience. In conclusion, it is important to mention that the project is still in work in progress, currently under development with the focus on the creation of AI procedural elements and the compilation of the first compositing processes supported by Grasshopper's algorithms. Despite the preliminary phase, the overall quality of the project is remaining high, suggesting promising opportunities for future improvement and optimisation. The ultimate goal is to create a model that can also be explored on interactive platforms, offering an innovative and multidimensional experience that integrates cultural heritage with the potential of digital technologies.

Figure 18: *Final real time rendering of a partition of the Inferno model composed of AI models and procedural distribution of elements. (processing by authors)*

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Transformation Of a Dor Beetle – From a Scientific Collection Object to a Multimedia, Hybrid, Interactive and Barrier-Free Experience

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ABSTRACT: How can collection objects be shared with as many interest groups as possible in a creative, sustainable and effective way? Based on an example from the Museum für Naturkunde Berlin, we show how a collection object was used to develop a responsive tactile model. To increase the outreach and diversify the user experience, the model is now being transferred to the digital realm through a web-based application. This article gives an overview of the evolution of the analogue tactile model and then focuses on the methods and development steps leading to the digital twin.

1. INTRODUCTION

The Museum für Naturkunde Berlin (MfN) has a scientific collection with more than 30 million objects. The MfN's Future Plan intends to develop the collection, digitise it, open it up for innovative applications and make it more accessible in general [1]. Two of the MfN's internal units are directly linked to these Future Plan projects:

- Mediasphere For Nature – the lab for digital media (Mediasphere)
- Data Portal – the publicly available access to the digitised collection objects

While the Mediasphere focuses on the reuse of digital media in the context of innovative cooperation projects, the data portal not only displays the MfN's digital media but also contributes to the contextualisation of the media with elements such as a blog, an audio section and a story section.

Both units pursue the goal of using new technologies to realise pioneering projects relating to the MfN's digital media. In doing so, they often venture into new territory, but it is precisely this experimental way of working that is necessary for an institution like the MfN to be able to succeed in the digital environment in the future [2].

The project presented in this article began as a co-operative development of a demonstration model by Mediasphere and led to the further development of a digital online experience by the data portal team. The project focuses on a dor beetle (*Anoplotrupes stercorosus*) from the MfN's entomological collection, and the 3D scan created from the specimen.

2. DEVELOPMENT RESPONSIVE TACTILE MODEL

In autumn 2021, a mass digitisation project began at the MfN with the aim of making the in-house insect collection accessible using state-of-the-art technologies [3]. In parallel, the Mediasphere team was in dialogue with the education department, which showed interest in a true-to-scale insect model to complement the in-house tactile experience tours for blind and visually impaired people.

Inspired by these two concepts, Mediasphere launched a new cooperation project with the Berlin model-making company werk5 GmbH at the end of September 2021. The aim of the project was to develop a demonstration model: a highly scaled insect model that is equipped with audio content and can be operated independently by blind and visually impaired people using technical resources. The goal was not only to develop a tactile model, but rather an intelligent learning object that combines tactile and auditory information and is easy to operate.

The following key questions had to be investigated during the realisation of the project:

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- How can 3D data, audio data and scientific information be transferred into an exhibit, that can be operated completely independently by visually impaired people?
- Which materials are best suited to offer an exciting tactile experience and at the same time optimise the functionality of the technology/sensory system?
- How can navigation over the tactile model be made as simple and intuitive as possible?

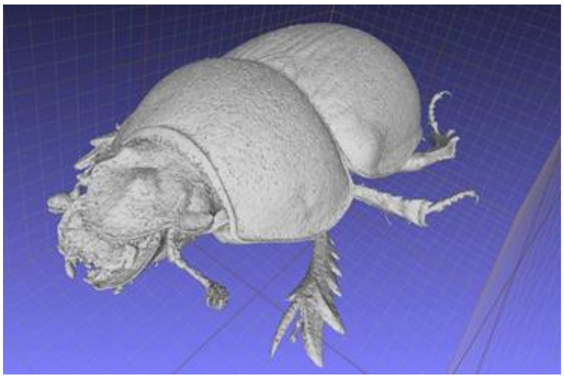

Figure 1: *Dor beetle 3D scan; scan: Kristin Mahlow, Eva-Maria Unglaube, Eva Patzschke, all MfN*

The starting point for the project was the 3D scan of a dor beetle created in the museum's Micro-CT laboratory (Figure 1). Some details had to be added to this original 3D model, for instance, high-resolution photos of the original beetle from the collection were needed to accurately reproduce the surface texture. These custom images were taken by the MfN digitisation team.

Before the refined, digitally processed 3D beetle model could go into physical production, various materials were tested. These materials not only had to be robust but also resemble the surface texture and feel of the original and enable the use of internal sensor technology.

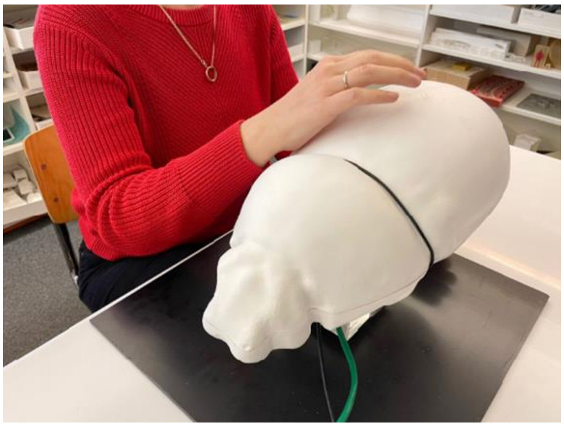

Figure 2: *Prototype being tested by blind test person; photo: Ellen Schweizer*

While working on the digital 3D beetle model, an initial, simple prototype of the tactile model was created (Figure 2). Using this prototype, the modelling and technical team went through several iteration loops in which the gesture control, the size of the model, initial audio content and general navigation across the model were tested. During the entire development process, the team was supported by a focus group of blind and visually impaired people, who regularly tested the progress and gave feedback and optimisation ideas.

In total, the beetle body was divided into five audio areas. Two further subject areas, which are not directly related to specific body regions, can be activated via additional sensory points on the touch surface below the beetle (Figure 3).

After testing various gestures, it was identified that a simple double tap is the most intuitive gesture for triggering audio content for a specific area by touching the surface. The use of other gestures, e.g., circular or swiping movements, was discarded as the test participants found them too complicated. As a result, the entire navigation of the model is carried out using only the double-tap activation and the start button. The start button also functions as a stop or reset button. Another navigation aid for operating the model is volume control. If a person activates the audio content for a specific area and then moves their hands away from this area, the sound becomes quieter. As soon as at least one hand touches the area of the activated sound again, the sound becomes louder again.

Different departments of the museum contributed their help in creating the audio content. At the very beginning of the activation of the model, an introductory text is played for all users, providing background information on the model and explaining how it works. After the introduction, all further content is freely selectable. It is not necessary to follow a specific order when activating the sections.

The audio content included primarily provides information on different parts of the body, e.g., the head or forewings. At the request of the focus group, some ‘fun facts’ were also added, which, for example, point to surprising findings from research projects. A recording of dor beetle stridulatory sounds from the museum's animal sound archive has also been added.

A mix of materials was chosen for the construction of the model. For most of the surface, we chose the solid mineral material Corian®, which is rigid and very robust, and was processed using an industrial milling machine. Delicate body parts, such as the legs, were created by 3D printing. After several material tests, the decision was made in favour of a very tough yet flexible plastic. The flexibility is important to avoid the risk of injury from sharp body parts, for instance the claws at the end of the feet. If you touch these parts of the body, the material gives way, and the risk of cuts is averted.

Also, after the final tactile model was created, further test loops were carried out to optimise the sensors, navigation and audio content. Finally, the model was tested by the focus group, but also with sighted people at public events at the museum and at trade fairs (e.g., MUTEC, FOCUS). The official handover of the model from werk5 to the MfN took place in April 2023.

The result of the development can be summarised as follows:

- an upscaled, responsive tactile model of a dor beetle, which is lined with sensors on the inside and transmits audio content about the touched surface area to the user via headphones
- an accessible model whose functionality enables especially visually impaired people to experience it completely independently
- a clear and accessible design that appeals equally to people with and without disabilities
- a working model burgeoning on market maturity that demonstrates the development of an innovative tactile model concept
- a project that was positively received by both industry professionals and the public and received a delina Innovation Award for Digital Education at the LEARNTEC trade fair in 2023
- as described by one of the test persons from the focus group: “the tactile model offers a multi-layered exhibition that is completely stowed away in a single object and can be experienced comfortably without having to move from A to B.” This was perceived as a significant advantage.

Figure 3: *final tactile model; photo: werk5 GmbH*

3. THE DIGITAL TWIN EMERGES

A major disadvantage of the physical tactile model is that it can only be used by a small number of people, i.e., it is only available as a learning experience to a very limited group of users.

The success of the physical model gave rise to the idea of transferring the analogue tactile model to the digital world in the form of a web-based application and thus making it accessible to a global user base. Since all materials such as transcripts, audio files and 3D models were already available digitally, the development of the first prototype was a logical next step.

The application is freely available on the Internet [4]. The corresponding source code and content can be viewed on Github [5].

The central element of the application is a controllable 3D model that can be rotated, enlarged or reduced in size. Hotspots on the beetle surface enable targeted interaction with the model and the available content (Figure 4).

Figure 4: *The digital twin with available hotspots*

In contrast to the physical model, the content is not only available in spoken form, but also in text form (Figure 5).

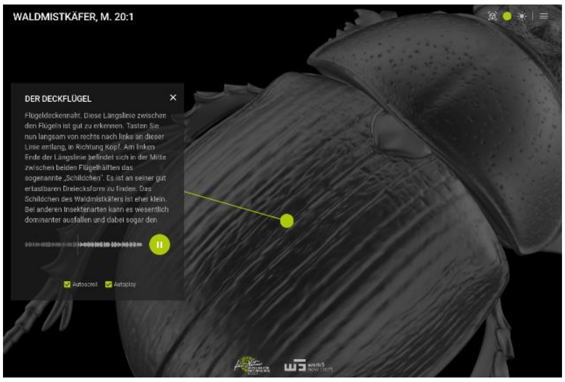

Figure 5: *Further information is available after the user clicks on a hotspot*

As with the original, the user can explore the model freely and is not tied to a guided tour. As an additional function, the user can display the dimensions for the model and the original beetle (Figure 6).

Just like the tactile model, the digital twin is expandable and will be supplemented with sign language videos and other language versions in the future.

Even if the application attempts to imitate the physical model, it can still serve as an independent learning experience. Learners can decide for themselves which mode or combination they want to use. They can discover the physical model in the museum or immerse themselves in the web application from the comfort of their own home. In combination, the digital application can serve as a follow-up to the museum visit.

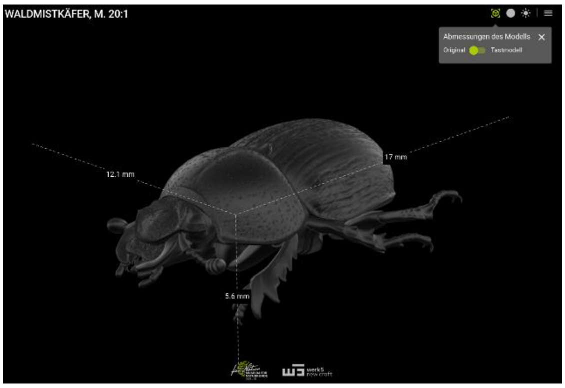

Figure 6: *The user can inspect the size of the physical model as well as the real beetle*

4. CONCLUSION

During our journey and countless activities such as creating the first sketches, running material tests, building prototypes, conducting user tests and developing the digital web application, we have learned a tremendous amount and here are our findings:

(1) Develop a long-lasting relationship.
Developing viable business models is not easy, especially when public institutions cooperate with the private sector. From our point of view, the long-term partnership is the foundation for the future success of our shared journey. In addition, successful innovation projects often last longer than the usual duration of publicly funded projects. Results that fit into high-value reports are often only available at a later stage.

(2) If you design something tangible, also consider the intangible world.
In the beginning, we wanted to build something that was inclusive. But later we realised that it was also exclusive. So, we decided to build a digital twin. Although we don't have any empirical results at the time of writing this article, we strongly believe that the intangible world will have a strong impact on the viability of a potential business model. A hybrid mindset not only helps to increase the number of users but also promotes engagement with culturally significant artefacts.

(3) Hybrid thinking: there are endless options.
When developing the digital twin, we initially only tried to replicate the core functions. But as a digital application, it offers us new possibilities that are difficult to implement with the physical model. The integration of videos with explanations in sign language and the use of AI for voice control or automatic translation into other languages are just two examples. Of course, this could also be integrated into the physical model, but with the digital twin, a wide variety of possibilities can be explored in a prototypical approach and tested for their feasibility and desirability.

5. ACKNOWLEDGEMENT

The finalisation of the tactile model was made possible in the context of the Collection Discovery and Development project at MfN. werk5 GmbH contributed a considerable amount of the development costs.

Throughout the project, Mediasphere was supported by numerous in-house experts, including from the Entomology, Education and Digitisation Departments. Further help was provided by staff of the Micro-CT laboratory, the animal sound archive, social media experts, design direction and visitor research.

External expertise was provided by the model and exhibit builders from werk5 and their partner company Interactive Scape, who supported the development of the underlying technology, among other things. Ellen Schweizer from schweizergestaltung provided expertise in the field of accessibility. The project team was supported by a focus group of blind and visually impaired test users, who were able to continuously initiate important optimisation processes through their feedback.

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SESSION III

“On Display – Experiencing the New Museum”

Moderation: Dominik Lengyel
(BTU Cottbus-Senftenberg)

Mobile Museum

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ABSTRACT: New technologies offer the possibility for museums to extend their scope substantially. Digitized objects, virtual reality and mobile domes are the components.

1. INTRODUCTION

Museums have plenty of treasures. How can these treasures be exploited more than today. There are actually two dimensions to it: quantity and geography.

2. SHOWING HIDDEN TREASURES

Many of the treasures are in the archive due to the limited exhibition space. Some of them may never be shown to the public. But a lot of the objects are digitized today, are available as 3D images. Instead of just putting these objects on the web, there is a possibility to show them to the public in a controlled way. In a Mobile Dome they can be shown as a virtual 360° museum via a guided tour. The objects can be picked-up individually by the guide and shown to the visitors in all their beauty. Several exhibitions organized according to topics can be developed and be displayed following the interest of visitor can be scheduled. Such a Mobile Dome can be installed inside or outside the museum.

3. GOING ON TOUR

Many of the museums want to show their treasures not only locally but also nationally and even internationally. With his, they want to create financing contributions and attract visitors to their museum. By creating virtual versions of their museums using 360° videos, photos and digital representations of their treasures in a mobile dome, museums can create tours to various locations and impress their audience with a modern and fascinating installation. And all this is possible without moving the precious real objects geographically.

3. A DEMO

The presentation shows a video of a prototype of a Mobile Museum developed by tat-team.

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From Museum to Theatre Digital Humanities Tools Towards Inclusive and Cultural Fruition

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ABSTRACT: The aim of the research From Museum to Theatre concerns the enhancement and promotion of museum artifacts related to mask culture, for their use in innovative and inclusive digital environments and the possibility of making them an active part of their theatrical and social location again. The Erasmus Blended Intensive Program (BIP) workshop was prepared considering the interdisciplinary characteristics of the participants, both faculty and students, all of whom were directed to the focus of Digital Humanities and aimed at innovative and inclusive uses for the promotion of cultural heritage aiming at the involvement of diverse audiences through the use of digital projects, three-dimensional prototyping, VR and AR animations, videos, etc. The project includes three phases to be held in three different European locations: the first and second phases of the study and analysis of classical Greek theater masks and Polish Carolinian masks have already taken place at the Aeolian Archaeological Museum's headquarters in Lipari and at the PJAIT headquarters in Warsaw; the third phase involving the design and creation of a traveling exhibition will take place at the ESAD in Porto.

1. INTRODUCTION

As part of European exchanges between university an Erasmus Blended Intensive Program (BIP) has been carried between the Mediterranea University of Reggio Calabria, Department of Architecture and Design (dAeD) together with three European partners: the Polish-Japanese Academy of Information Technology (PJAIT), Department of New Media Art in Warsaw, the Escola Superior de Artes e Design / College of Art and Design (ESAD) in Porto, Portugal, the Democritus University of Thrace, Department of History and Ethnology in Komoni.

A total of more than sixty students, teachers and experts in the field of humanities, representation and visual communication of cultural heritage participated. Erasmus Blended Intensive Programs allow for an internationalization experience that combines a short virtual mobility of scientific and organizational introduction with physical mobility. The aim of the BIP From Museum to Theatre concerns the enhancement and promotion of artifacts related to mask culture for their use in innovative and inclusive digital environments and the possibility of making them an active part of theatrical scenes again.

The first phase of the project took place in May 2024 at the Aeolian Archaeological Museum “Bernabò Brea” in Lipari (Aeolian Islands). In this phase, artifacts related to classical theatre culture were studied. Scientific partners who are experts in classical philology and ancient theater culture as Elisabetta Matelli professor of Classical Philology at Università Cattolica del Sacro Cuore in Milan, and Roberto Danese professor of Classical Philology at University of Urbino lectured respectively on the use of masks in Greek theater and on the symbolic representation and meaning of the masks in *Commedia dell’Arte*. Also involved were, Maria Clara Martinelli, archaeologist, and Rosario Vilardo Director of the “Bernabò Brea”

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Museum in Lipari who proposed interesting presentations on the significance of the masks stored in the museum.

The in-person activities, over a period of six days, took place on the Island of Lipari where some of Greek masks were surveyed and represented. The second phase took place in November in Warsaw at the PJAIT, here masks of traditional rural culture stored at the Muzeum Etnograficzne im. Seweryna Udzieli in Krakow were studied and analyzed.

An initial introduction to the culture of folk masks was given by Mirosław Kocur professor at Uniwersytet Wrocławski who refers about Masks in the theatre, while a specific lecture was given by Magdalena Zych curator of vernacular collection at Ethnographic Museum of in Krakow. The museum tour took us through the rural world of the region and to the knowledge and understanding of ritual manifestations of different social groups.

Finally, the meeting with the curator of the Modern Art Museum Famous Sebastian Cichocki tell us about his curator vision of the modern exhibition.

Figure 1: *Greek masks stored in the Aeolian Archaeological Museum Bernabò Brea in Lipari.*

Figure 2: *Traditional masks stored in the Muzeum Etnograficzne im. Seweryna Udzieli in Kraków.*

2. FROM MUSEUM TO THEATRE

The workshop project was prepared considering the interdisciplinary characteristics of the participants, both teachers and students, all addressed to the focus of Digital Humanities and aimed at innovative and inclusive uses for the promotion of cultural heritage, and the involvement of a diversified audience, thanks to the use of digital projects, three-dimensional prototyping, VR and AR animations, videos, etc. Six thematic workshops were proposed.

2.1 DIGITAL SURVEY AND MODELING OF THE MASKS

Photogrammetric surveys of Greek masks [1] kept at the Aeolian Archaeological Museum and traditional ritual masks found at the Muzeum Etnograficzne im. Seweryna Udzieli in Kraków.

Based on the acquired photographic datasets, we were able to experiment with the photomodeling process aimed at digitizing the museum artifacts, sharing them online, and 3D printing them.

Figure 3: *Photogrammetric survey and 3D model of Greel masks.*

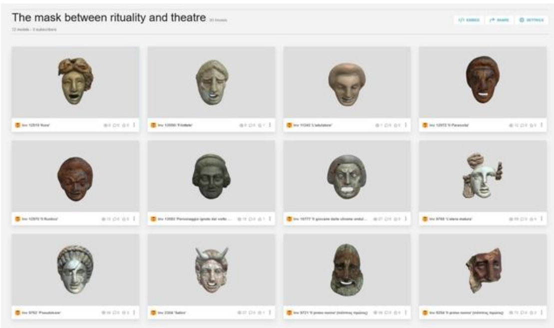

Figure 4: *Digital open sharing: the masks between real and virtual.*

Initially, work was done on digitizing and translating the archival cards related to the selected masks.

Then the images were aligned through the use of Agisoft Metashape software for the production of the dense point cloud and the processing of the mesh and its texturing. Digital models were then extracted and shared with other laboratories through the use of a web platform [2].

The masks selected for this project were the greeks Pseudo-core and the satyr Io, while for the traditional Polish masks was surveyed some decorated wooden masks both carnival and cerimonial ones. 3D printing at different scales of reproduction, including at the 1:1 scale, was also experimented with.

Figure 5: *Survey and 3D model of Polish traditional masks.*

Based on the photogrammetric survey and the three-dimensional rendering of some masks present inside the Muzeum Etnograficzne im. Seweryna Udzieli w Krakowie, the workshop consisted of the construction of a storytelling based on the facial motion capture technique, focused on the narration of the masks and the personalized involvement of the different users [3]. Based on the principles of edutainment, the 'talking mask' manages to tell the story and myths linked to the mask itself in a more engaging and personalized way [4].

Figure 6: *Facial motion capture ok greek masks.*

During the workshop, each participant produced –from the drafting of the text, to the acting up to the video production– the animation of a mask, based on personalized stories aimed at its humanistic diffusion [5].

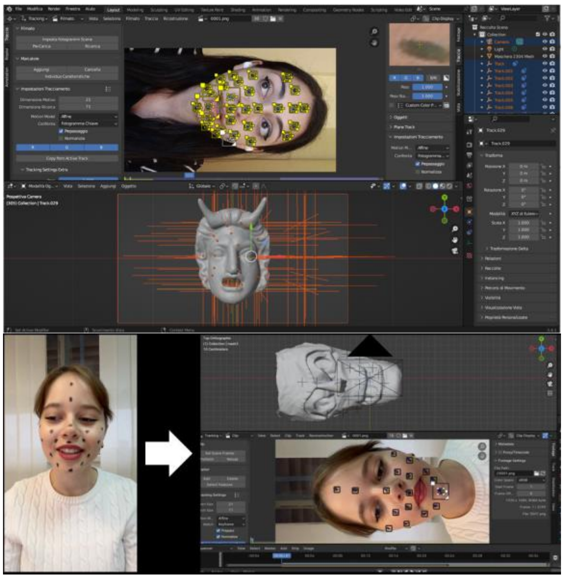

Figure 7: *Process of Facial Motion Capture*

2.2 AUGUMENTED INFOGRAPHIC

This work is based on innovative project that combines art, history and digital technology. The focus was on the reinterpretation of the Pseudokore, for a transposition into an interactive experience thanks to the use of augmented reality (AR), creating a digital poster that tells its story and its symbolic evolution. The project developed around an AR poster, with a QR code integrated into its center. By framing the code, the mask comes to life on the screen: it begins to tell its story, revealing its cultural and artistic meaning. During the story, something extraordinary happens: the mask takes on the appearance of a real woman generated with AI, embodying what it would represent in contemporary society.

The interactive experience combines additional elements: a virtual button that shows the original colors of the mask, allowing you to appreciate its liveliness and original appearance; an interactive little man who walks on a timeline and places the Pseudokore historically, offering a chronological and cultural context; a direct link to the 3D model of the mask that allows an even more detailed and complete exploration.

The result is a product that not only educates, but involves the user in an immersive experience, stimulating curiosity and reflection. Through Pseudokore, our group wanted to demonstrate how technology can amplify the narrative potential of art, transforming an ancient mask into a bridge between past and present.

Figure 8: *Interactive masks.*

2.3 MAPPING ON MASKS

The workshop is based on video mapping for creating interactive masks. One of the main idea was to lay the concept of youth and old age.
Initially, it created an interactive mask consisting of the shape of a young and an old face. The focus was on the eyes, because they are the only organ that does not change in size, throughout life. Also, 80% of all information a person receives from the outside world passes through the eyes.
At the beginning of the project, you can observe the faces from young to old in black and white, but the eyes remain colored throughout the project to show their power. The project ends on the frame, where the eyes completely cover our mask, creating a pattern on it.
The mirror reflection mask is an artistic representation of aging and self-reflection. The surface, composed of small mirrored tiles, fragments the viewer's face into multiple reflections.
You can see his eyes, visibly aged through the holes in his mask. This symbolizes how time reshapes the way we see ourselves, both physically and emotionally, highlighting the fragmented and evolving nature of identity as we age.

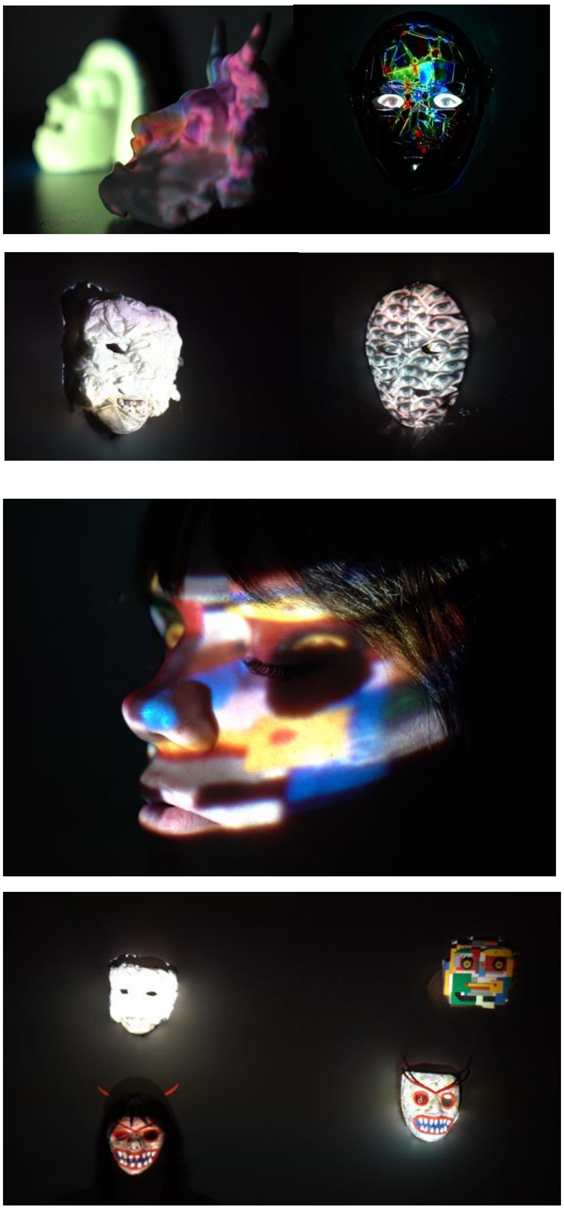

Figure 9: *Projection Mapping.*

2.4 VISUAL IDENTITY

The project involved integrating photographs of incomplete ancient Greek theater masks from the archaeological museum in Lipari with elements of local flora, patterns painted on ceramic tiles, and fragments of other projects created by the students during the workshops. By combining these visually disparate elements, we aimed to reflect the diverse interpretations of the local context.
The result of this collaborative effort was a logotype titled “Masks: From Museum to Theater,” featuring handwritten lettering to emphasize the humanistic philosophy of the project. We also developed a series of posters

showcasing the adaptability of the designed identity through the use of masks.

In the second part of the workshop which took place in Warsaw, the visit to the Ethnographic Museum of in Krakow provided students with a chance to explore the folk traditions of southern Poland, which starkly contrasted with the classical aesthetics of ancient Greece. The masks used in festivals and rituals, crafted from materials like cloth and fur, served as both inspiration and a challenge for expanding the existing identity project to incorporate new cultural contexts and visual forms.

Looking ahead to the third workshop planned in Portugal next year, we decided to shift our approach. Instead of relying on photographs, we focused on combining drawings of selected masks, offering students greater flexibility in blending various visual elements. To further unify the project, we introduced a color-coding system: blue for Italy, red for Poland, and green for Portugal.

Through joint discussions and consultations, students gained invaluable experience, which I regard as one of the most enriching aspects of the workshop. The resulting identity design remains true to the principles established during the first workshop, with the flexibility to adapt and incorporate distinctive elements. This dynamic approach allows the identity to appear fresh and varied while retaining a cohesive and recognizable structure.

Figure 10: *Visual Inspirations.*

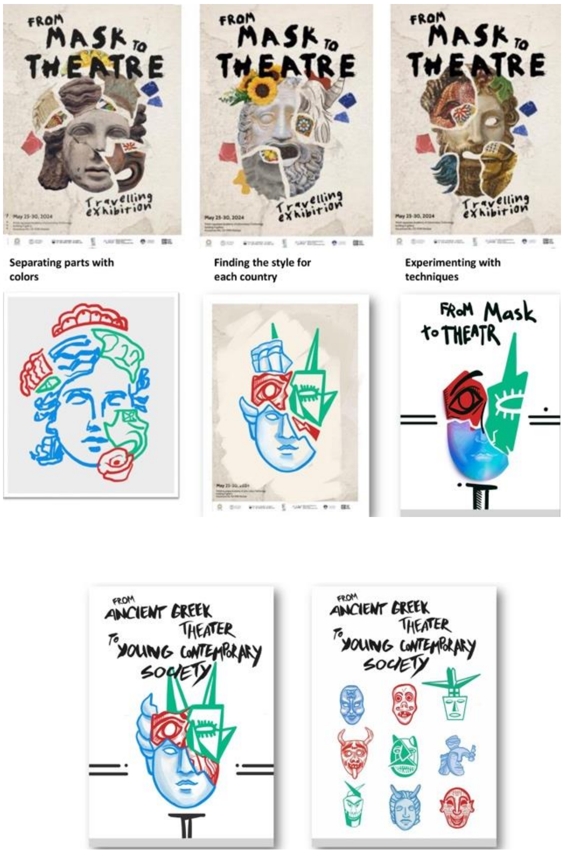

Figure 11: *Elaborations of the posters.*

2.5 TRAVELING MASKS

In this multidisciplinary context, the Traveling Mask workshop is linked to the possibility of communication and dissemination of the results of the BIP, a series of devices that can guarantee the dissemination of the project in a traveling exhibition.

The installation uses the fundamental parameters of architecture, such as space, shape, light, proportion, materials, rhythm, measure; while the design is based on the experience of space, the design of atmospheres, proxemics, which includes the experience of the use of space, the behavior of man in space, and the meanings that are attributed to it, different, depending on the different cultures.

The exhibition of the masks presupposed the study of a series of spatial, psycho-perceptive and temporal conditions so that the objects produced, of different nature and consistency, could establish a relationship with the exhibition space, but above all generate meaning, conveying and inducing an experience [6].

During the first workshop held in Lipari, in collaboration with all the other groups, the themes and contents of the traveling exhibition program were defined. The role of Greek masks

in antiquity, in relation to the places that generated them and in relation to society.
A process of defining the objectives and the design of the exhibition devices was started. In the second stage of the workshop, in Warsaw, with the study of traditional Polish masks it was possible to fully outline the contents of the research and the elements to be exhibited [7].

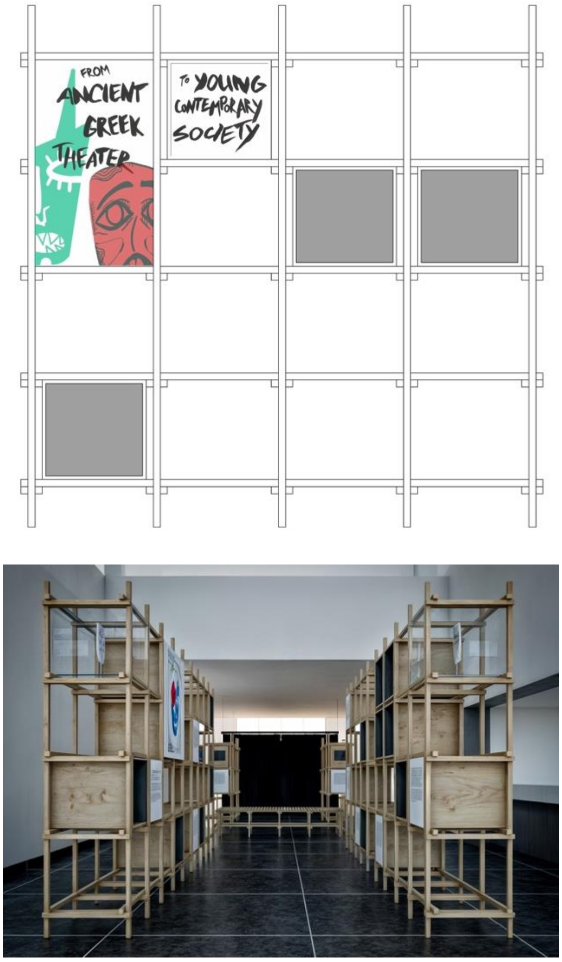

Figure 12: *Concept of masks exhibitions.*

A programmatic text was built by relating the two types of masks, that of classical theater and those of Polish popular traditions, thus defining a programmatic text, capable of communicating values and meanings of a cultural heritage that includes many European countries, specifically the three countries involved in the workshop: Italy, Poland, Portugal, today represented by classical masks and those of popular tradition.
The programming of a further stage that will be held in Portugal, all groups of students will be invited to build the exhibition devices designed in Warsaw, in a self-construction process, and to design the installation of the first traveling exhibition that will be held in the ESAD atrium in Porto [8].

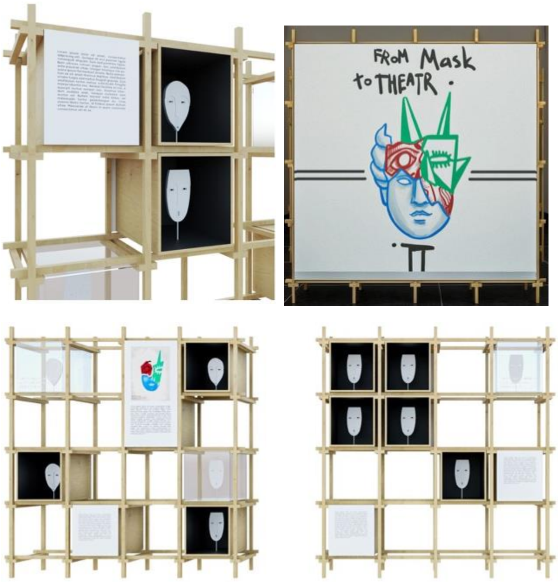

Figure 13: *Design of exhibition furniture.*

2.6 MASK TO PERFORMANCE

The characters present in the reproduction of the Aeolian masks are linked to the literary genre to which they belong. They represent the testimony of the presence of a rootedness in the cult of Dionysus and the relationship with all the theatrical production of tragedy and comedy, in which the themes are used as symbols of a happier world.
The study of the figurative characters of the theatrical masks stored at the Museum of Lipari was mainly based on two examples of female figures: the Pseudokore with a serious style, soft features and draped hair and the figure of the priestess Io, a young satyr, identified by the presence of horns after the transformation into a heifer.

Figure 14*: Physic model of Greek masks.*

The production of the two masks enlarged to a congruent scale to be worn by an actor allowed us to consider the specificities of every detail of the Aeolian *coronoplastica* that for each character sculpts a personal expressive communication. The masks were staged in narratives aimed at creating an original production of stories and images.

***Figure 15**: Scenic performance.*

The experience of Lipari supported the idea that physical representation through masks is capable of being a vehicle of communication with a high emotional value.
In the Warsaw workshop, the reference to popular ritual masks was interpreted as an element of narration of interesting themes deduced from everyday life (the characteristics of family resemblance, or cartoon characters, etc.). The masks created by deconstructing not other images, but a narration of the contemporary world, made visible social themes and behaviors in relation to cultural origin. The experiment of staging in urban environments documented the emotional state in which it is evident that “images in modern society have a practically unlimited authority and the capacity of these images derives from the very characteristic of images” [9].

***Figure 16:** Modern interpretation of masks.*

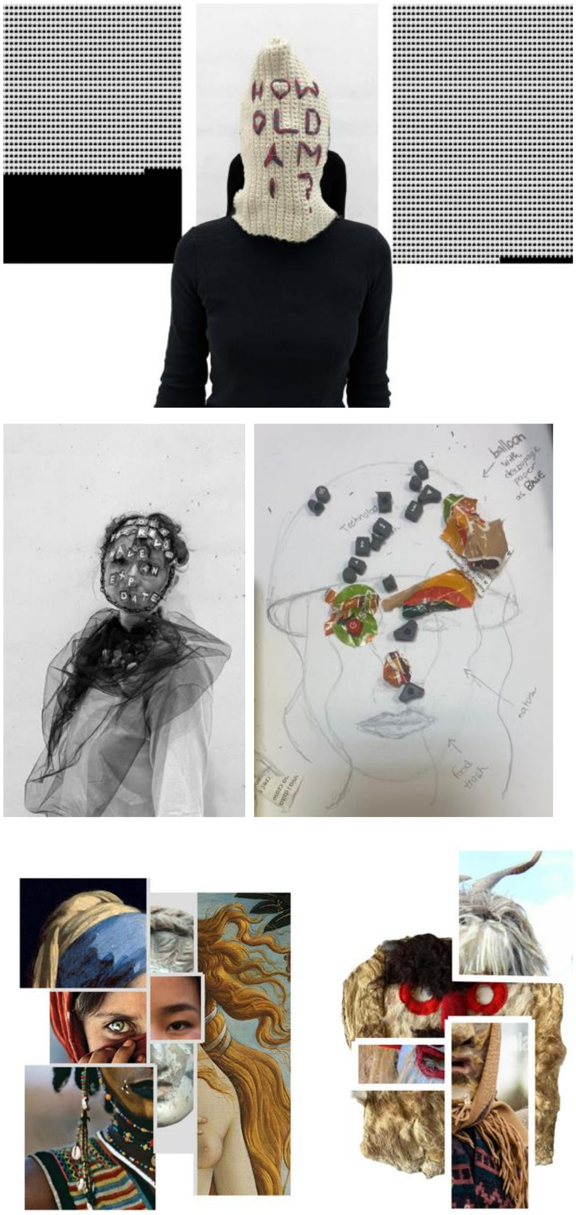

***Figure 17:** Research of new social code in masks.*

3. CONCLUSION

The production, digital and analog, of the masks and the experiments through performances will be used for temporary or permanent installations, as an incentive to enhance the cultural and touristic value of the territory in which they will be hosted and as an example for a wider and new cultural diffusion in compliance with the principle of maximum diffusion and accessibility of research products.
The interdisciplinary experience of the BIP *From Mask to Theatre*, through the study of Greek masks and Polish ritual masks, has highlighted the aspect of symbolic communication through images: “the presumed effectiveness of images to propitiate and control powerful images” [9].

The survey with digital techniques has allowed the museum finds to be used in an innovative and more inclusive way, both in the museum context (permanent and temporary exhibitions) and in the theater context (setting up shows).
All phases of the project were aimed at the scenic performance linked to the use of the mask, within the anthropology of the scenic gesture, based on the literary, Greek and Roman production and the photographic production of Polish masks.
The 3D reconstruction of the masks promotes knowledge of the artifacts exhibited in museums according to the paradigms of the semantic web.
This encourages the sharing of new knowledge, interactive dialogues, personalized stories, engaging multimedia content.
The project that aims to identify the functionality of the mask in the contemporary cultural context is based on the idea that the search for visual representation through symbols can dialogue with the themes of contemporary culture, through the production of events, exhibitions and theatrical performances that enhance the heritage of material and immaterial culture linked to the territory.

4. ACKNOWLEDGMENT

The paragraphs described in the article correspond to the six laboratories workshops that were held in the Erasmus BIP, specifically:
- *Digital Mask: Digital survey and modeling of the masks*, tutor: Francesca Fatta, Sonia Mollica Lorella Pizzonia, Francesco Stilo.
- *Augumented infographic*, tutor: Marcin Wichrowski, Maria Trombetta.
- *Mapping on masks*, tutor: Mateusz Król.
- *Visual Identity*, tutor: Jan Piechota.
- *Traveling Masks* tutor: Maria Milano.
- *Mask to performance*, tutor: Ewa Satalecka, Paola Raffa.

A total of other 50 students from the Erasmus partner universities participated in the six laboratories.
The authors would lile to thank the Director of the Aeolian Archaeological Museum “Bernabò Brea” Rosario Vilardo and the Head of the Department of Zbigniew Raszewski Theatre Institute Olga Sobkowicz for their collaboration on the project

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Visualising Piffetti's Library in Villa Della Regina Museum: an Interdisciplinary Digital Project for Knowledge Accessibility

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ABSTRACT: This paper presents interdisciplinary research to enhance knowledge accessibility in museums. The scientific project is finalized to return to the public the imagery of the library crafted by Pietro Piffetti, a recognized masterpiece of 18th-century cabinetmaking, within its original location in the Villa della Regina. In the past, the library was moved to the Quirinale, where it is located today. The work pipeline includes the archival research and bibliographical studies in the art-historical field; the 3D digital survey of the library at the Quirinale and the room, now empty, in Villa della Regina; the recognition of the original parts by Piffetti; the reconstructive digital modeling and texturing of the library; the creation of the app and services for augmented and virtual reality experience aimed to interactive enjoyment of the reconstructed model.

1. INTRODUCTION

This proposal arises as part of interdisciplinary research developed within a PNRR (National Recovery and Resilience Plan) project in the Accessibility sector that funded the Villa della Regina Museum (one of the Savoy royal residences managed by Direzione regionale Musei Piemonte) in Turin, Italy. The research concerns the digital reconstruction of a precious library made in the 18th century by the cabinetmaker Pietro Piffetti to furnish a small room in the Villa della Regina, later adapted with modifications and additions to a larger room in the Palazzo del Quirinale.

The work pipeline includes the archival research and bibliographical studies in the art-historical field; the 3D digital survey of the library at the Quirinale and the room, now empty, in Villa della Regina; the recognition of the original parts by Piffetti; the reconstructive digital modeling and texturing of the library; the creation of the app and services for augmented reality (AR) and virtual reality (VR) experience aimed to interactive enjoyment of the reconstructed model.

2. RESEARCH FRAMEWORK

The PNRR's goal of reducing obstacles, inequalities, and gaps that limit citizens' participation in cultural life and heritage has been interpreted in this project as a stimulus to increase the accessibility to knowledge.

The multidisciplinary team that developed the project includes scholars and professionals in art history, digital acquisition, 3D modeling methodologies, and the design of digital solutions for heritage presentation. The goal of the work is to return to the public the imagery of the library crafted by Piffetti, a recognized masterpiece of 18th-century cabinetmaking, within its original location in the Villa della Regina, inside the small study room of the Duke Carlo Emanuele III of Savoy.

The phases of the research include:

- The bibliographical and archival research about the artifact and the related studies in the art-historical field;
- The survey of the library by digital photogrammetry and Structure from Motion (SfM) technique and the comparison and

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integration with a laser-scanner survey by Studio Azimut in 2016;

- The SfM photogrammetric survey of the room in Villa della Regina;
- The recognition of the original and added parts, and the changes that occurred in the transfer from Turin to Rome;
- The reconstructive digital modeling and texturing of the library in the original layout and the room in Villa della Regina, carried out using geometric modeling techniques;
- The creation of an app and services for handheld devices (iOS and Android smartphones and tablets) and desktop devices (personal computers) for content fruition;
- The development of the augmented reality (AR) experience for mobile devices for interactive enjoyment of the reconstructive model within the Villa;
- The development of the virtual reality (VR) experience for immersive remote enjoyment through a web platform.

In two previous papers presented at the 29th CIPA Symposium [1], [2], the project's concept and the integrated survey of the cabinet, related to the first and second phases listed above, were described. In the present contribution, we report the entire project's development. We intend to explain how the digital processes characterizing the workflow are integrated, the potential, limits, and foreseeable development of the work done, and the scalability to museums and other cultural entities.

3. PIFFETTI'S LIBRARY FROM TURIN TO ROME

The bookcase made by Piffetti, one of the leading cabinetmakers of the 18th century, active mainly in the service of the Savoy court, is one of the most significant interventions related to the interior spaces of the Villa della Regina in Turin.

Since the end of the previous century, the building had been the favorite residence of Anna Maria d'Orleans, wife of Vittorio Amedeo II, King of Sicily, since 1713. The subsequent arrival of Filippo Juvarra in Turin involved, among other interventions, the rethinking of the architectural spaces of the Villa and their decoration. Further renovations, relating mainly to the gardens and decorative cycles, began in 1733.

The bookshelves were crafted between 1733 and 1739 and located in the *Gabinetto verso mezzanotte e ponente* (Cabinet toward midnight and west) inside the King's Apartment.

Figure 1: *Villa della Regina library cabinet (Photo: C. Teolato).*

Precious wall covering with poplar shelves veneered with fine woods—rosewood of four varieties (rio, india, angelo, mocassar), boxwood, yew, and olive—embellished with refined ivory inlays reproducing floral decorations made with the pyrographic technique, featured the library.

With the handover of the Villa della Regina to the Istituto delle Figlie dei Militari between 1867 and 1868, the library was disassembled and taken to the Guardaroba in the Castello di Moncalieri. Only in 1876 was the furniture transferred to the Palazzo del Quirinale, which was elected as the King's residence after the transfer of the capital to Rome. The furniture was destined, in 1879, for the cabinet next to Princess Margherita's bedroom. The new location required adaptations and additions for the room, which was larger, higher, and of different proportions. The adaptations and restoration were entrusted to Giacomo Quarelli, who brought the library back to Turin to carry out the work completed in three months in his workshop. At the same time, some masonry work affected the cabinet at the Quirinale.

Piffetti's woodwork was placed on three walls of the new room, while the fourth wall with the window was covered with a new set of shelves. The console under the mirror, not mentioned in the 1755 inventory of Villa della Regina, was also included with the 19th-century arrangement, while the one on the opposite wall features representations of military exploits from 1733 and 1734, one of them signed by Piffetti. The fascia and frieze were also added to adapt the furniture to the greater height of the cabinet [3], [4]. The possibility of restoring, albeit in digital format, Piffetti's library at Villa della Regina, inside the original room for which it was designed and built, today deprived of this heritage (Fig. 1), will allow an essential part of the Villa's history to be returned to visitors' enjoyment, thus helping to make accessible content that is currently no longer intelligible.

4. 3D DIGITAL SURVEY

The library survey considered the case studies' scales, geometry, and material characteristics.
Two acquisition campaigns were organized at the architectural scale (Fig. 2). Studio Azimut surveyed the Quirinale library's room in 2016 with a 3D laser scanner Focus 3D (Faro), generating a final 3D point cloud with a resolution of 0.5 cm. The Villa della Regina room survey was carried out in 2023 using a photogrammetric methodology with Alpha 7R IV (Sony) equipped with a CMOS sensor (9504 X 6336 pixels), a focal length of 28 mm, and an average working distance of 300 cm, obtaining an average GSD of 0.4 mm.
Besides, the library survey in Quirinale required more complex planning to overcome some bottlenecks. The first was the low illumination level provided by a big window and a central chandelier. The latter was also an obstacle due to its position 300 centimeters from the floor and its diameter of 150 centimeters. The second bottleneck was given by the materials and surface finish of the artifact, which presented optical non-cooperative materials and reflective surfaces. For all these reasons, the library's 3D acquisition was based on integrating different active and passive 3D techniques, validating the 3D data accuracy and reliability.
First, we considered integrating the previous 3D active acquisition with a photogrammetric campaign in the summer of 2022. The photogrammetric campaign used a 6D Mark II (Canon) equipped with a 36 X 24 cm CMOS sensor (6240 X 4160 pixels) with a fixed 24 mm lens at a working distance of 150 cm, achieving an average GSD of 0.4 mm on the library surface. Besides, 26 GCPs (Ground Control Points) were extracted from the range-based cloud, reducing possible orientation errors. In addition, different active and passive sensors have also been integrated in the detail scale, comparing photogrammetry in the same external conditions with an iReal 2S 3D Laser Scanner (Scantech) triangulation infrared instrument. The survey highlighted the geometric issues and scale variation in such a complex artifact, testing the instrumentation for this specific activity.

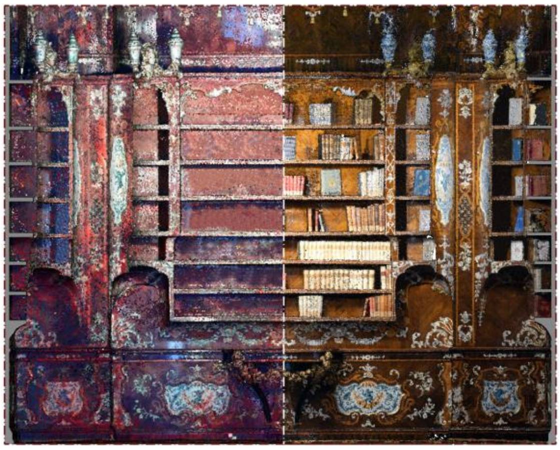

Figure 2: *The front side of the library. On the left is the range-based data, and on the right is the point cloud from photogrammetry. (Editing: M. Russo)*

The acquired 3D data were processed separately. The range maps from TLS have been aligned and optimized in the JRC Reconstructor program (Gexcel), to be managed within the ReCap PRO program (Autodesk) for visualizing and extracting the GCPs. The data from the triangulation system were oriented thanks to the feature detection, translating it into point clouds and mesh models. Finally, the images were all processed within the Metashape program (Agisoft), keeping the GCPs as a reference to reduce frame orientation errors. All 3D data from Quirinale have been integrated into the same reference system, comparing data at different scales and analyzing the reliability of the acquired library [2]. Besides, the survey in Villa della Regina has been processed and managed separately from the Quirinale, considering the different scopes of modeling and visualization of the case study.

5. ISSUES OF DATA TRANSPARENCY IN HERITAGE DIGITAL RECONSTRUCTION

Since the digital transition began, technological advances have made digital tools more accessible and affordable, revolutionizing how cultural institutions study, communicate, and represent cultural heritage. These technologies enable better information connections and scientific hypothesis representation, advancing heritage research and dissemination [5]. People increasingly recognize cultural heritage as a shared asset that must be preserved for future generations while maintaining its authentic traditions and memories. Digital visualizations are crucial here—they preserve cultural heritage and form an essential part of our reality and communal culture.

To maintain their value, reliability, and transparency in digital heritage communication must be ensured [6].

Transparency in digital heritage reconstruction presents two key challenges: mediating information for scholars and the public. For researchers, transparency maintains scientific rigor by allowing them to retrace steps and validate results. It enables scholars to evaluate their methods critically and ensures their interpretative choices in reconstructions remain clear and replicable. Transparency enhances understanding through accurate, coherent knowledge presentation for the public, supporting cultural institutions' educational goals.

Virtual reconstruction—a cornerstone of digital heritage—demonstrates why transparent methodologies matter. The Seville Principles (2012) define it as digitally reorganizing material remains to suggest past states. It helps plan physical restoration, rebuild lost artifacts digitally, and preserve intangible heritage. Through transparent communication, virtual reconstructions are understood as possible interpretations rather than definitive truths. This clarity enriches both academic discourse and public engagement with heritage.

Furthermore, transparent visualizations serve dual roles: as communication tools and research frameworks that deepen knowledge. By clearly conveying historical authenticity and interpretative decisions in digital reconstructions, they enable critical public engagement with cultural heritage, fostering new ways of interaction and thinking. This approach supports cultural democratization by promoting accessibility and deeper heritage connections. As Cesare Brandi notes, cultural heritage finds meaning not just in its creation but in its recognition by contemporary consciousness. Digital tools, used with transparent methods, bridge historical authenticity and modern understanding [7].

In conclusion, data transparency forms a fundamental principle of digital heritage reconstruction—not just a technical requirement. It strengthens scholarly work, builds public trust, and ensures digital visualizations meaningfully contribute to heritage preservation and sharing, translating verbal hypotheses into visual forms [8]. By making transparency central to their process, digital heritage projects achieve scientific excellence and cultural impact, securing their value for current and future generations.

6. PRELIMINARY RECOGNITION OF THE ORIGINAL PARTS

As seen when moving the library from Turin to Rome, Quarelli needed to adapt the artifact.

Concerning the point cloud and the digital model representing the current configuration of the artifact at the Quirinale, the digital reconstruction of the library in its original location required the analysis and photogrammetric survey of the room in which it was built, the study of the scientific literature concerning its construction, disassembly, and reassembly phases with additions, together with the analysis of an essential survey of the time (1876), which confirms the reconstructive hypotheses. The analysis of the cabinet at the Villa della Regina allowed us to verify the presence on the (original) plaster of a geometric grid used to assembly the furniture and wooden dowels held by iron hooks necessary to fasten the woodwork to the walls, according to a technique used in other rooms of the building [9]. Dimensional surveys have confirmed the complete correspondence of the traces on the plaster with the dimensions and subdivision of the individual modules of the bookcase, which, as hypothesized in previous studies [10] and confirmed by more recent investigations, were positioned in the room to form a quadrilateral with the four corners in the shape of a double recess: the central body of the bookcase at the Quirinale, now placed between two false pillars, was positioned on the short side of the Cabinet next to the entrance of the room; the other two modules of the bookcase, placed on the opposite long sides of the room, ended framing the French window on the west side and, symmetrically to the main body, with the other two openings. The frieze above the bookshelf is now tripartite due to the greater height of the room at the Quirinale: even from the drawings of the time (Sezione della Nuova Biblioteca di S.M.), it is evident that only its central band was the original part of the frieze (called ‘fregio esistente’, existing frieze, in the drawing). In contrast, the other two (a ‘giunta al fregio’, added to the frieze, and a ‘soprafregio’, above frieze) were designed to adapt the furniture to the new room. As seen above, the primary sources, referring to the inventories of 1755 and 1811 [10], also make it possible to imagine that of the two *consolles* currently present in the library, only one found its place in the original configuration, the one belonging to the central body: the other, reasonably added at the time of the new installation at the Quirinale, could be a readaptation of a game table mentioned in the 1811 inventory [11].

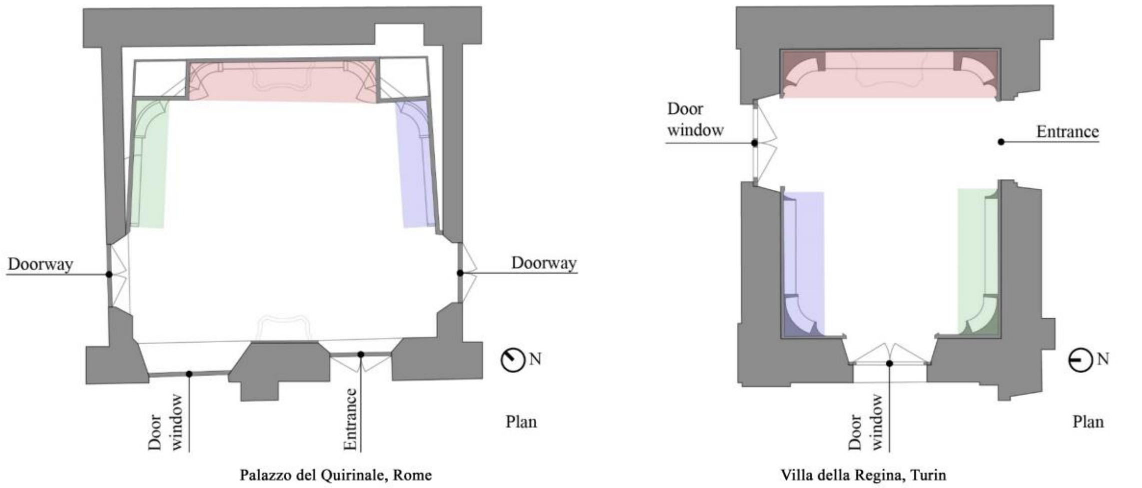

Figure 3: *The library assets in Palazzo del Quirinale and Villa della Regina. (Editing: M. Vitali).*

7. DEFINITIVE RECOGNITION, 3D RECONSTRUCTIVE MODELING AND TEXTURING

Piffetti's library digital modeling followed a philological approach that reversed the transformations undergone by the artifact over time. From its current location at the Palazzo del Quirinale, digital reconstruction sought to restore its original configuration at Villa della Regina in Turin. As shown in the process diagram (Fig. 4), this task utilized widely adopted digital tools in the cultural heritage domain [12] and required a rigorous methodological framework for selecting modeling techniques [13].

Geometric components (e.g., planar surfaces, single- and double-curvature surfaces) were modeled using NURBS geometry, while sculptural elements of high morphological complexity were retained as meshes derived from digital surveys. This approach optimized the balance between representational accuracy and computational manageability of the model, tailored to the specific requirements of AR and VR applications while maintaining high fidelity to the original artifact.

The digital reconstruction adhered to principles of visual abstraction, maintaining a balance between scientific accuracy and historical interpretation [14].

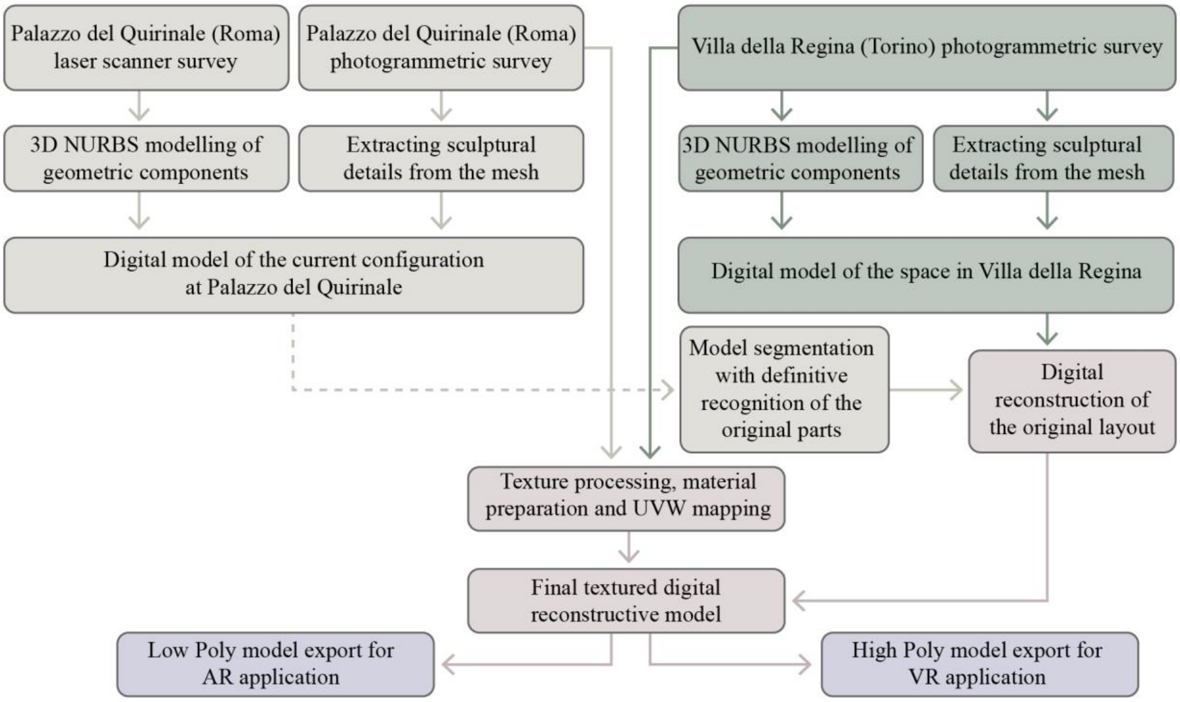

Figure 4: *Process diagram illustrating the digital modeling workflow of the Piffetti's Library, from source data to the generation of optimized models for AR and VR, encompassing NURBS modeling, sculptural detail extraction, and texturing. (Editing: E. Pupi).*

The methodology adopted furthermore aligns with the latest research on visualization in digital cultural heritage modeling, where representation simultaneously serves communicative and scientific research purposes, effectively addressing the complexity of the studied object [15].

Digital modeling was conducted using McNeel Rhinoceros 8, while Agisoft Metashape 2.1.3 was employed for processing digital photogrammetric surveys. Initially, the digital model of the current state was developed based on a point cloud generated by Studio Azimuth in 2016 [1]. For the restitution of sculptural decorative elements, data from photogrammetric surveys and high-resolution scans using a portable triangulation-based infrared system were integrated [2].

Most of the artifacts were modeled in Rhinoceros with NURBS geometry.

At the same time, sculptural decorations were processed in Metashape: high-density meshes were isolated, decimated for polygonal optimization, and retextured to restore UVW mapping lost during decimation, producing computationally sustainable meshes for AR and VR. These elements were imported into Rhinoceros, forming a hybrid NURBS-mesh model for further elaboration. The Villa della Regina environment was reconstructed from the photogrammetric survey, using NURBS modeling for walls, fixtures, shutters, the entrance door, and the floor. At the same time, the vault, including its impost molding, was imported as a decimated and textured mesh.

This methodological choice was particularly significant for AR applications, where precise dimensional correspondence between virtual and real elements is essential. Prior interpretative studies enabled the reconstruction of the original arrangement according to Piffetti's design at the Villa della Regina. The current state digital model was carefully segmented to extract the parts identified as original, which were reassembled within the Villa della Regina digital environment. The reverse process validated the interpretative transformation of the *boiseries*, demonstrating a tolerance of 10 millimeters, likely attributable to cumulative errors between digital surveys and corresponding 3D modeling (Fig. 5).

Given the high complexity of the inlays and wooden decorations, to obtain a digital model that could offer the most photorealistic fruition, texturing required meticulous processing of 2D orthophotos derived from photogrammetric surveys. Planar surfaces were textured using three orthophotos from the survey at the Palazzo del Quirinale. Single- and double-curvature surfaces necessitated specific 2D developments. For the Villa della Regina environment, orthophotos were prepared explicitly for shutters, fixtures, the entrance door, and the floor. Firstly, all 2D orthophotos underwent thorough retouching to compensate for minor gaps. Then, the elements of the composition were carefully contoured and saved separately in PNG format for use as diffuse channels in material creation.

***Figure 5:** Digital reconstruction of the original configuration of Piffetti's Library at Villa della Regina. (Modeling: E. Pupi).*

Preliminary analysis demonstrated that achieving a sufficiently photorealistic result did not require additional mapping channels, such as displacement, normals, or specular layers. The materials application was performed within the Rhinoceros workspace, targeting the original Villa della Regina configuration's NURBS surfaces since meshes retained their original textures from the photogrammetric survey processing. Texturing the NURBS surfaces allowed subsequent management of various polygon resolutions for AR and VR applications. This process employed manual UVW mapping to ensure precise texture alignment with individual surfaces, with particular attention to curved areas (Fig. 6).

Differentiated model management for AR and VR represents an established strategy in cultural heritage valorization, where varying modes of interaction require specific geometric and texture optimization. This approach enhances user experience based on the unique characteristics of each technology [16]. Consequently, the final phase involved developing two distinct models for AR and VR (Fig. 7), and the geometric transformation process for NURBS followed different criteria:

Figure 6: *The Piffetti's Library's Rendering shows the complex texturing process applied to the NURBS surfaces, demonstrating the high-fidelity material application achieved through UVW mapping. (Modeling and rendering: E. Pupi).*

- For AR, only the *boiseries* components dismantled during the library's relocation were exported, excluding the vault, fixtures, shutters, entrance door, and floor. The conversion from NURBS to polygonal mesh was optimized with a maximum deviation of 1 millimeter from the surface, prioritizing model lightness for smooth visualization (total weight 386 MB, including 358 MB of the textures and 28 MB of the 3D model, consisting of about 737,000 polygons).
- For the VR, the entire model was exported to enable comprehensive visualization of the digitized environment and a higher polygon density with a maximum deviation of 0.1 millimeters was employed (total weight 643 MB including 577 MB of the textures and 66 MB of the 3D model, consisting of about 2,600,000 polygons).

In both cases, mesh elements remained unchanged, as previously optimized. After iterative testing, the FBX export format was selected for its ability to optimize model file size. Textures were preserved at maximum quality and resolution, with potential optimizations deferred to the AR and VR application preparation phase, ensuring maximum flexibility during final processing.

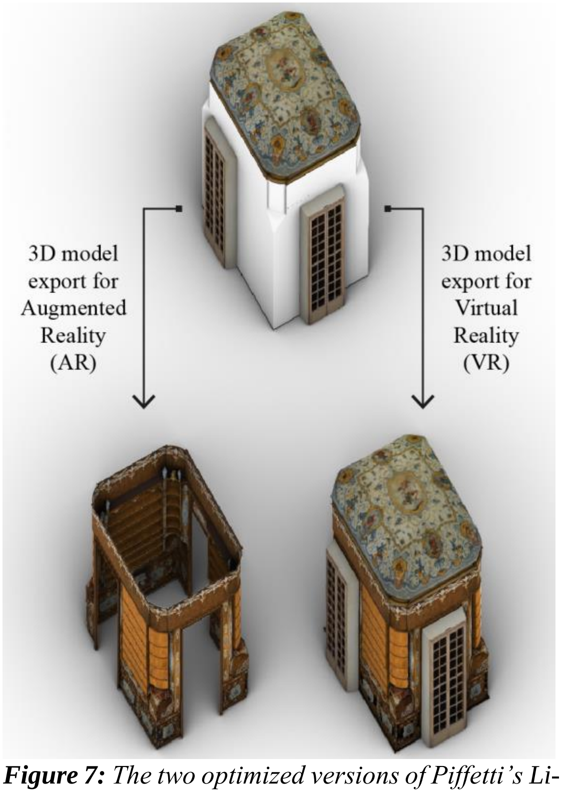

Figure 7: *The two optimized versions of Piffetti's Library model derived from the overall digital reconstructive model: the Low Poly model for AR applications, showing only the boiseries, and the High Poly model for VR applications, showing the complete digitized environment. (Editing: E. Pupi).*

8. COMMUNICATION THROUGH AR

AR has emerged as a pivotal tool in cultural heritage, offering solutions for a better understanding of reconstructed artifacts [17]. AR improves access to cultural resources by superimposing digital reconstructions onto physical environments, fostering an intuitive visualization of digital models based on interactive functions [18]. This technology has proven particularly effective in museum contexts, where it stimulates and addresses visitors' curiosity while supporting venues in promoting and strengthening audience engagement [19].
We developed an AR application using the Unity cross-platform game engine and its AR Foundation framework, a suite of tools enabling AR functionalities via platform-specific technologies like ARCore for Android and ARKit for iOS. To anchor the single 3D model produced, an image target (or "tracked image" in AR Foundation terminology) was employed, specifically a visual reference of the wooden floor (Fig. 8).

Figure 8: *Detail of the inlaid wooden floor extracted from the VR model to create the anchoring target for the AR model. (Editing: V. Palma).*

This approach leverages the natural features of the environment without requiring custom markers. AR Foundation provides extended tracking functions that record spatial data around the target and use the device's sensors to maintain the model's alignment with its initial position relative to the physical space, even when the target moves out of view.
During development, critical challenges for aligning virtual elements with the camera imagery included:

- Lighting consistency: ensuring seamless integration between virtual components and camera-captured imagery by balancing brightness levels.
- Model anchoring accuracy: maintaining precise placement of the 3D model.
- Occlusion of physical objects: addressing potential conflicts with movable room furnishings.

The lighting was configured with diffuse, fixed ambient light without cast shadows or light probes. This approach avoids lighting effects that might obscure texture details and reduces application resource demands. The room's natural light is provided by two full-height windows and supplemented by a single mobile floor lamp on one side of the space. The window orientation (northeast and northwest, shielded by another building volume) prevents direct sunlight. The natural light did not appear too intense during evaluation periods, avoiding stark contrasts between the room's interior and the digitally lightened library (Fig. 9). Artificial lighting creates noticeable shadows only on the vaulted ceiling above the thick cornice without disrupting the integration of the digital model.
The target area is large (1.54 × 2.31 meters) and effectively trackable despite the symmetry of the design, thanks to the contrasting inlays and the natural irregularity of the material (Fig. 8). This ensures precise and stable model placement. The relative position of the target and model was defined accurately during modeling, as the target image was extracted from the photogrammetric model itself. However, some inaccuracies were observed during tests, especially when using extended tracking. These deviations, typically within a few centimeters, do not compromise the application's effectiveness and can be corrected by realigning the target area within the field of view (Fig. 9). Critical alignment challenges were noted near the transition between the modeled boiserie above the shelving and the ceiling cornice, as well as around the window recesses.
The room's furniture, which will remain in place during the AR installation, can be easily repositioned to avoid obstructing the digital elements. Even if the taller floor lamp poses a minor visual challenge, its design minimally interferes with the AR experience's perspective illusion (Fig. 9).
The user experience was designed in collaboration with the museum's management, considering preservation requirements, particularly for the flooring. Visitors can step approximately one meter past the entrance before encountering mobile barriers (Fig. 10).
The model's "concave" design — intended to be viewed exclusively from within — aligns well

Figure 9: *Screenshot of the app in use. The top image displays the northwest window, allowing natural light into the room. The alignment of the model with the floor edges is shown just before restoring the ideal anchoring. The bottom image highlights the mobile floor lamp obscured by the digital model. (Editing: V. Palma).*

with the limited range of movement permitted. User interaction is primarily rotational, with restricted positional adjustments that prevent mesh "clipping" caused by close proximity to the model. However, scenarios where users step outside the room and redirect the device toward the cabinet need to be addressed. If the app remains in use, extended tracking features can maintain the model's position even when the device is moved several meters away from its anchoring location. This prompted us to design a digital 'panel' to cover the rear of the library model. This addition prevents visual inconsistencies, such as the model appearing to penetrate the room's wall when viewed from adjacent spaces.

Texture sizes were limited to reduce the overall application size and runtime resource demands, and compression was applied using Unity's build setup options. Starting from a total export size of 375 MB for the model, the memory footprint was reduced to approximately 260 MB. Texture reduction parameters were optimized empirically by evaluating the model's performance on the app running on target devices. The process of defining an acceptable level of detail was simplified by the usage constraints of the room, which prevent users from getting too close to the model's surfaces. Further reductions can be considered for the application rollout to maximize user accessibility to the service.

Figure 10: *AR application installed on the device. The image shows the user positioned near the area designated by the museum management for observing the room. The artificial lighting and the shadow cast on the ceiling by the cornice are visible, but these effects do not interfere with the integration of the digital component. (Editing: V. Palma).*

9. CONCLUSION

This experience represented an essential moment of welding between academic research and museum institutions, developing synergies between scholars belonging to the two realities that made it possible to offer the outcomes of a complex project to the community through simple and interactive modes of use. The deprivation from which the Villa suffered and the original look of one of its most valuable rooms come to light through the overlap between real and virtual.

The use of low-cost technologies and devices, ease of use, and adaptability to the museum context without the need for fixed or mobile installations offer excellent potential for the scalability of the product to other museum settings.

10. ACKNOWLEDGMENT

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Augmented Reality as a Mediation Tool in the Munich Museum of Casts: Methods and Potentials for an Interactive Museum Experience

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ABSTRACT: Augmented reality (AR) is rapidly developing into an effective tool for interpretation and education in museums. It enhances traditional presentation formats by adding digital layers, allowing for the virtual reconstruction of missing components, the visualization of original color schemes, and the contextualization of historical details. Such digital enhancements deepen understanding and significantly improve visitor interactions with the exhibits. The Munich Museum für Abgüsse Klassischer Bildwerke collaborates with the Augmented Reality Research Group at the Technical University of Munich to develop digital AR content and explore its potential for museum education. This paper presents two case studies: The "ParthenonAR" application — a virtual tour of the model of the Parthenon — and a digital comparison between the ancient portraits of Claudius and Caligula, and also comments on the opportunities and challenges posed by AR in museums.

1. INTRODUCTION

In recent times, augmented reality (AR) has become an increasingly important tool for education and interpretation within museums: It adds an extra digital layer to exhibits, often with historical contextualization, reconstructions, and additional information. AR generally creates an enriched visitor experience and provides new ways of accessing the collections beyond traditional interpretative media.

However, AR integration involves much more than simple technological adoption: It imposes new demands on exhibition design, technical infrastructure, and content delivery. At the same time, AR provides an opportunity to reach audiences who have previously had little access to museum offerings and complements traditional interpretive formats in meaningful ways.

In this respect, with more than 2,000 plaster casts of classical Greek and Roman sculptures on view, the Munich Museum für Abgüsse Klassischer Bildwerke (MfA) is an ideal place to investigate the new possibilities AR allows. AR possesses special significance for the MfA, as its utilization offers ways through which exhibits might be virtually restored and original colors and other historical or artistic features contextually realized to return the appearances of these objects to a much closer semblance of the original, thus, enabling better understanding and appreciation of the content. However, what makes AR truly valuable is its potential to provide interactive content, which allows visitors to independently engage in the exhibits at a much deeper level than has traditionally been possible.

By way of illustration, this article describes the implementation of AR at MfA through several examples, focusing on the challenges and benefits of its use. This paper introduces AR use in museums, presents two case studies, and discusses the broader opportunities, challenges, and future potential of AR in enhancing cultural heritage. The article also highlights the role of interdisciplinary collaborations, such as that between MfA and TUM, in achieving progress and innovation in museum education through AR.

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2. RELATED WORK

2.1 Augmented Reality – The Extension of Reality

AR enhances the physical world by projecting virtual information onto physical objects and surroundings in real time, thus, efficiently integrating real and virtual components. This is achieved through the displays on the screens of devices such as smartphones, tablets, or AR glasses (e.g., Microsoft HoloLens 2 or Magic Leap), which combine live camera images with digital elements such as images, 3D models, sounds, and animations. Sensors, such as cameras and AR algorithms, are used to align virtual content with the real-world environment. For precise tracking, correct identification of objects or the environment has to be performed, and some approaches to implementing tracking in AR involve using marker-based tracking, object recognition, or markerless tracking.

Marker-based tracking relies on sharply displayed visual marks, such as QR codes or specific patterns, to place digital content in certain positions. In a museum context, any prior images, historical maps, or artworks can act as markers if they possess unique features for trusted detection. *Object recognition* involves the real three-dimensional identification of objects such as sculpture or furniture by processing geometry and surfaces to determine reference positions. *Markerless tracking* provides real-time analysis of environmental features, such as surfaces, edges, and points, without any a priori defined markers, giving virtual elements full freedom with regard to positioning.

The development of AR applications also often relies on platforms such as Apple's ARKit and Google's ARCore, typically in combination with the Unreal Engine or Unity game engine and AR frameworks such as Vuforia, EasyAR, or MAXST.

As described in the following section, AR can be used to provide an interactive and immersive experience that offers museum and exhibition visitors new opportunities for discovery and interaction.

2.2 Use of AR in Museums

In recent years, AR has increasingly been implemented in museums as a tool for knowledge dissemination and a new way of interacting with cultural artifacts. Unlike static videos or audio guides, AR allows users to directly interact with exhibits, offering a dynamic and immersive experience unattainable with traditional media. AR technology provides the possibility of augmenting physical exhibits with digital information, such as text, images, videos, or even interactive 3D models. The most common applications are those related to virtual restitution: The restoration of missing or ruined components allows visitors to see how the artifact once appeared. Studies such as that by Miyashita et al. [1] have shown that AR-enhanced museum guides increase visitor participation and comprehension, fostering more meaningful connections between exhibits and audiences by encouraging curiosity and facilitating personalized exploration.

Specifically, AR enhances exhibits by superimposing digital information onto real-world objects. In this way, these objects are contextualized, reconstructed, and even rendered interactive to improve access and visualization. This use of AR technology makes artifacts, together with their historical contexts, more tangible and engaging for an audience. For example, AR can rebuild the original colors of ancient statues or take viewers on virtual tours around historic cities. It allows stories to be told, thus, creating an immersive experience, raising emotional involvement, and deepening insights [2].

Other significant educational advantages are that museum visiting becomes active rather than passive, and visitors can independently study exhibit details, comparing different reconstructions and focusing on aspects relevant for personal interest. AR allows complicated notions to be explained in a simple way, such as demonstrating how a particular kind of machine works in a technical museum. In this respect, AR bridges the gap between traditional exhibitions and the expectations of modern visitors by offering dynamically immersive environments for enhanced access to cultural heritage.

2.3 Collaboration with TUM

For many years, the MfA has been collaborating with the Augmented Reality Research Group of the Technische Universität München (TUM) on how to integrate digital technologies, in the forms of augmented and mixed reality, into the museum functions. The common objective of this collaboration is the development of concepts that allow visitors to independently engage with plaster casts. This collaboration has included research projects, theses, and internships, with results presented at special events, for example, during the Lange Nacht der Museen München. Visitor feedback supports further steps in development.

A major achievement of this collaboration has been the TUM "FAR Demo" mobile application [3, 4] for the 2019–2020 jubilee exhibition entitled "Lebendiger Gips." The app allows visitors to interactively explore selected exhibits on smartphones or tablets. Key features include the digital reconstruction of fragmented works, such as the Crouching Aphrodite (Inv. No. Th 43), combining Roman copies to create a more complete virtual representation [5, 6]. Visitors can also virtually disassemble and reassemble the Laocoön Group (Inv. No. 1051) to understand the complexity of the work. Another feature focuses on the Arch of Titus, presenting it in its historical context with 3D models, interactive highlights, and contextual maps.

In 2020, the TUM "FAR Demo" application underwent redevelopment to render it more user-friendly [7]. Major improvements included a new AR-based camera mode that allows users to place virtual displays in real-life environments and study features and dimensions in considerable detail. The app has also been extended to include exhibits such as the Column of Marcus Aurelius, which reaches a height of 40 meters. Due to its size, the museum can only display casts of its relief; however, through AR, one can see the whole column and study all its details.

In addition to the app, the exhibitions themselves have included interactive stations, as seen in the Funerary Stele of the Shoemaker Xanthippos (Inv. 484) [8, 9]. Using a tablet, visitors were given the opportunity to virtually paint the plaster cast, with their designs simultaneously projected onto the cast in real time. Evaluations, including interviews and questionnaires, showed these features enhanced visitor engagement and their understanding of the object.

The projects discussed below represent just a small sample of the successful cooperation between the MfA and TUM. In addition to these completed projects, the partnership is further developing new approaches. Two current undertakings include an interactive exploration of the Parthenon, on which Ekin Çelebi worked, and a comparison of antique portraits of Claudius and Caligula, created by Daniel Haselbeck. These are described in the case studies that follow.

3. CASE STUDY 1: INTERACTIVE EXPLORATION OF THE PARTHENON (DEVELOPED BY EKIN ÇELEBI)

One of the most important holdings of the MfA is the highly colored model of the Parthenon (Inv. No. DL 128; Fig. 1) executed on a scale of 1:20 and dating back to the 19th century. Since 2005, the model has been on display alongside some 150 other long-term loans from the Metropolitan Museum of Art in New York, thus, emphasizing the close collaboration that exists between the two museums. The museum also uses the model in academic research projects involving different dimensions of investigation, such as those related to architectural color schemes and the documentation of historical transformations.

Figure 1: *Model of the Parthenon. (Credits: MfA, Manuel Hunziker)*

For her thesis, Ekin Çelebi created "ParthenonAR," a mobile AR application for improving visitor access to the model of the Parthenon [10]. The app aims to enhance the user's understanding and interaction with the model by adding digital information to the physical display (Fig. 2). In this way, historical information related to this model becomes interactive through the use of AR, thus, converting it into a more tangible and much livelier model.

The ParthenonAR is loaded with various interaction possibilities. For instance, one can see what the pediment of the temple originally looked like through an interactive slider that compares it to the present state. The AR allows for virtual “entry” into the model by using the screen of the visitor’s device to explore a detailed representation of the physical model’s interior. This action permits users to enter the temple, the so-called *cella*, showing its particular features with regard to design and structural characteristics. At one point along the frieze with modern colors, the viewer is able to contrast it against a digitally restored ancient color scheme to gain a sense of how the Parthenon originally appeared. Golden digital markers, using AR superimposed on the temple, point out these interactive features to visitors and provide a structured way of exploring the content. All of these traits are supported with accompanying texts in both English and German.

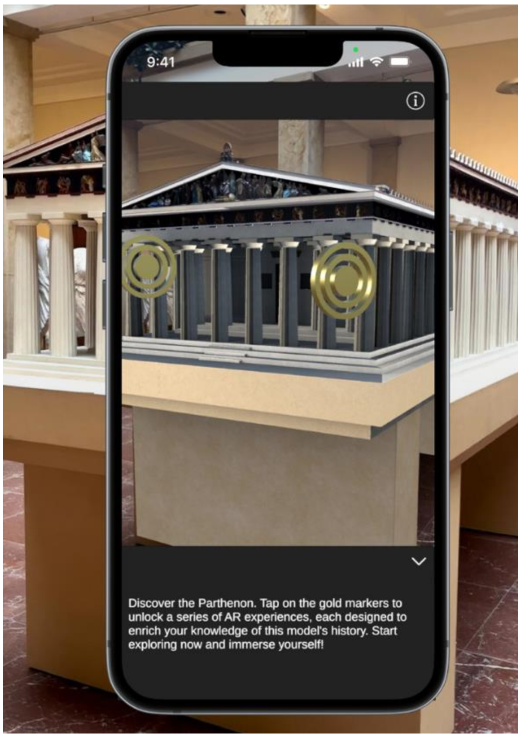

Figure 2*: App test run in the museum: The golden markers indicate interactive areas. (Credits: Ekin Çelebi)*

The technical execution of the project was addressed by using the Unity game engine in combination with the AR framework Vuforia (Fig. 3). Unity allowed for visualization and provided more interactivity, while it became possible with Vuforia to include historical representations that slide easily onto the physical model.

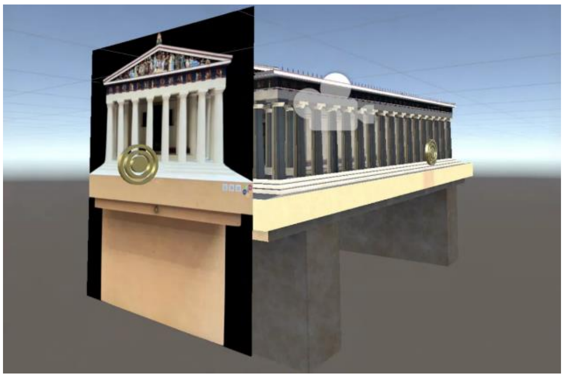

Figure 3: *Implementation of the app in Unity: The overlay is aligned with the temple. (Credits: Ekin Çelebi)*

Structure-from-motion technology, a method that creates 3D models from a series of 2D images, has been used for the digital reconstruction of the external and internal elements of the Parthenon model and the interior statue of Athena (Fig. 4). The results were further polished in 3D in Blender and imported into the Unity game engine. Among others, the largest challenges involved correctly aligning the digital content, with the physical model used as a marker, and seamlessly integrating interactive elements.

Figure 4: *Three-dimensional reconstruction of the Athena statue generated through structure-from-motion methodology. (Credits: Ekin Çelebi)*

Feedback from users was gathered by performing a structured analysis with survey participants from mixed backgrounds. The results showed that ParthenonAR considerably improved engagement with and supported better learning of the model of the Parthenon. Most participants rated the experience positively and also stated that the educational value of the architectural and historical aspects of the Parthenon was furthered with the use of the AR application. This assessment underlines the effectiveness and added value generated by the application, given it is indeed a significant addition to the physical exhibit presentation and thus constitutes a contribution to museum education.

4. CASE STUDY 2: COMPARATIVE ANALYSIS OF ANCIENT PORTRAITS: CLAUDIUS AND CALIGULA (DEVELOPED BY DANIEL HASELBECK)

The second application, developed by Daniel Haselbeck, allows users to compare ancient portraits, specifically those of Claudius (Inv. No. 560; Fig. 5) and Caligula (Inv. No. DFG 145; Fig. 6) [11]. In Ancient Rome, emperors commissioned many portraits of themselves to project their images and power throughout the entire empire. Since it would not be feasible for an emperor to model for every portrait, Ancient Roman sculptors often copied from existing statues to satisfy demand. For this reason, we can classify many of these portraits into types that share features. Additionally, in antiquity, imperial portraits were sometimes reworked from one face to another, for example, for political, cultural, or monetary reasons. Experts are able to identify such reworked statues, for instance, via the odd proportions of the different facial features, chisel and drill marks, or sudden pattern transitions between modified and untouched areas.

Comparing the unmodified and modified statues (Fig. 7) against each other in an AR context naturally highlights the differences in proportion in a much clearer way than simply viewing the statues independently side by side. The other peculiarities, such as the marks left on the statue by later modifications, can also be easily marked and annotated within the AR application. While 3D registration onto human features has been extensively studied, both in medical and commercial contexts, the underlying technical problem statement of this topic is more complex. Firstly, our data is orders of magnitude more limited than the data for the aforementioned cases, and we cannot simply create more, given that there are only so many intact antique statues that are accessible. Secondly, one of our targets has presumably been modified from its initial appearance, hence, we no longer possess its original representation, and we must assume that its facial landmarks have shifted in shape and location.

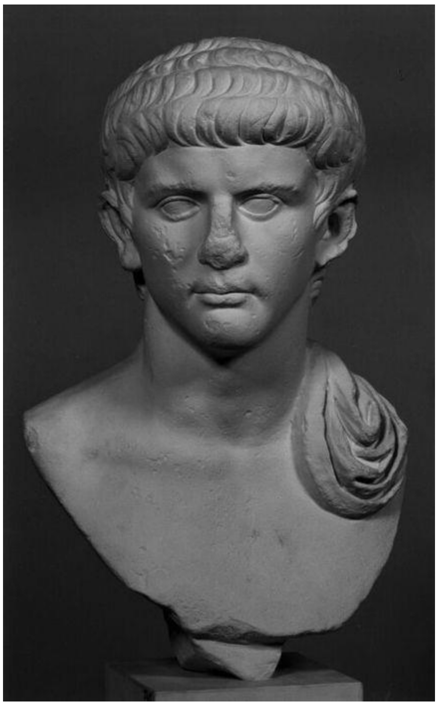

Figure 5*: Bust of Claudius (Credits: MfA, Roy Hessing)*

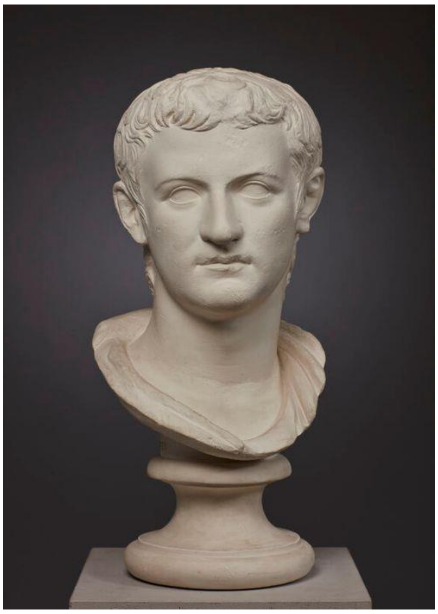

Figure 6**:** *Head of the seated statue of Caligula. (Credits: MfA, Roy Hessing)*

Since our goal was not to register the two statues onto each other but rather to superimpose them in a way that would optimally register the two originals together, conventional methods were not feasible in this context. Nevertheless, relying mostly on expert input about landmarks lying within the unmodified areas of the portrait, we managed to find a satisfactory alignment for both statues, which now serves as a basis for explaining the AR reworking phenomenon to visitors.

Figure 7: *Overlay of the heads of the statues of Caligula (green) and Claudius (blue), aligned at the ears. (Credits: Daniel Haselbeck)*

The AR application allows visitors to be engaged in a variety of interactions (Fig. 8): The overlaying of two portraits in virtual space serves to highlight differences in proportions and details. In addition, the identification and labeling of signs of subsequent alteration such as chisel and drill marks further support visitors in understanding what changes have been made to the statues. An interactive slider eases the switch between the original and its edited version, which functions as an effective demonstration of the meaning of revision. Further details have been provided on informational panels, explaining how different edits to the shape and position of facial features, such as noses and chins, have been performed.

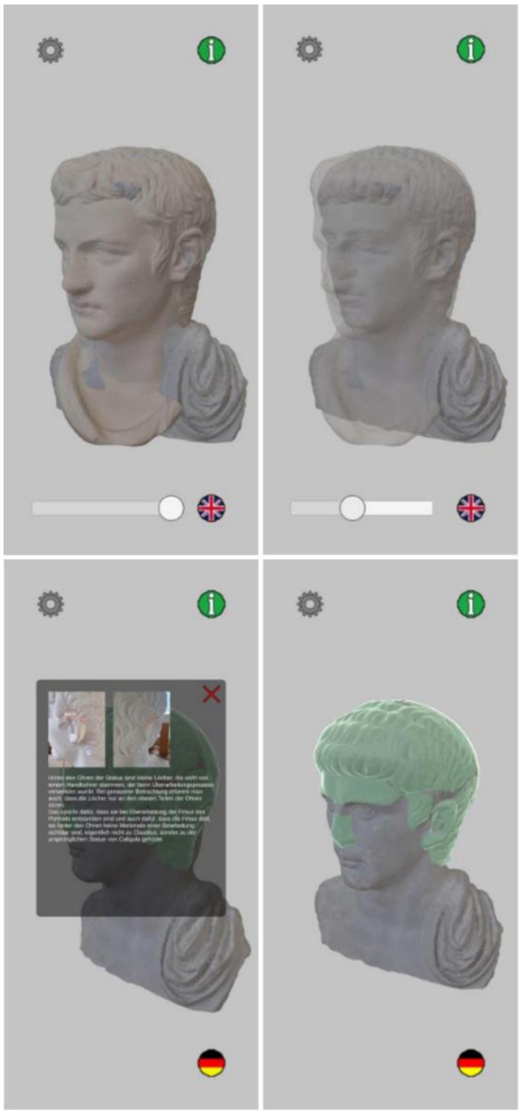

Figure 8: *View in the app: Overlays can be toggled on and off, and details can be selected.*
(Credits: Daniel Haselbeck)

Technical implementation was performed by using a Unity game engine in combination with the Vuforia AR framework. This approach utilized the physical statues as markers, allowing the AR system to recognize and track their unique geometry and surface features in real time. Digital superimposition was designed from 3D scans and facial registration algorithms developed with precision. The structure-from-motion technique was used to scan the 3D data for the portraits and then optimized in Blender. Lining up specific changed and unchanged areas of the portraits was challenging in an effort to present the portrait as it was in its original representation.

The first feedback regarding this application was received from internal sources among the museum staff. Therefore, they valued the interactive features for their ability to provide insights into the artistic and political messages of the portraits from ancient times. Consequently, the results of the evaluation support the app's potential to serve as a meaningful complement to the live museum experience.

5. ENSURING VISIBILITY OF AR CONTENT IN MUSEUMS

The application of digital content in museums is closely related to its visibility to and accessibility by a large audience. The use of AR content – at least until now – has been particularly problematic given the need for stand-alone applications. While simple AR content can be distributed via websites (WebAR), more complex applications, as in the examples shown, are not currently technically possible with this method. Accordingly, the creation of a unified application for the MfA is currently under conceptual development. This application aims to integrate all existing and future digital projects, such as ParthenonAR and the portrait analysis app, to offer users a seamless experience where it is most applicable. Instead of many diverse applications for each exhibit and function, attendees could have all the information in one place for the best possible navigation and interaction. Additionally, QR codes placed near exhibits can guide users directly to the relevant AR content.

The lead application possesses a user-friendly display platform featuring an overview of all the available AR content nearby. It will be possible to inquire about any exhibit or topic, which can easily be located through instinctive and clear navigation. The interactive functions of the application involve some of its multimedia offerings, which are already available on the website of the museum, video and audio guides, and accessible contents. Virtual tours allow the user to move around the exhibition areas and trigger AR experiences when necessary, combining the real objects with the digital/interactive content. The integration of the elements of interactivity with those of didacticism – the educational function – creates an all-round experience within the museum environment.

To further implement effective resource usage, AR content will be dynamically loaded only when really needed. Such a method allows all the data to be effectively maintained while facilitating the burden for users' devices in terms of storage. A strong Wi-Fi network at the museum will also ensure quick, uninterrupted downloading of the content.

Technically, the foundational elements for a unified mobile application are being explored using Apache Cordova. This would enable the reuse of prebuilt web frameworks such as Ember.js that are currently being used for other parts of the museum's website. Additionally, Ember.js would facilitate the implementation of the application's user interface, ensuring a consistent design and user experience. This approach would allow for the integration of current resources with minimal changes, significantly reducing the work involved and increasing the efficiency of the whole project. Previous AR applications were developed using Unity and Vuforia platforms because they offer high flexibility and powerful features for creating interactive AR content. Currently, we are evaluating other AR frameworks such as EasyAR and MAXST to investigate their integration with Apache Cordova and their potential for future AR content. The goal is to establish a homogeneous tech stack that will, in itself, be a base for future projects while, at the same time, reducing the diversity of tools used across the institution.

6. DISCUSSION: ADVANTAGES, CHALLENGES, AND POTENTIAL OF AR

AR’s introduction into museums is accompanied by a number of simultaneous opportunities and challenges. This section emphasizes the advantages and challenges of AR, and its future potential in the museum context.

Advantages of AR in Museums

As discussed in Section 2.2, AR can enhance exhibitions by including digital resources, such as interactive features, virtual reconstructions, and multimedia components. The interactive features of AR foster deeper engagement by allowing visitors to explore details, view alternate perspectives, or toggle between different stages of reconstruction. In that respect, AR may allow object modification or changes by virtually overlaying digital layers on top of the object, without affecting the original object. In this way, the displays can represent historical changes, color schemes, or architectural features without touching the actual exhibit in any manner whatsoever. These capabilities enhance understandings of complex topics, make exhibits more engaging, and strengthen emotional connections with the content.

Challenges in Implementing AR

To apply AR in museums, modern devices, possibly provided by the guests or by the museum, are needed. Visitors' personal devices would reduce the effort of maintenance: The museum only has to provide an app and some technical infrastructure, such as Wi-Fi, to allow the visitors to download the AR application directly on site. In the other case, the museum-owned devices have to be managed, which also includes providing charging stations, regular updating, cleaning, and disinfection.

Unless in-house development occurs, AR implementation quite often requires an external agency or a cooperation partner. The AR systems also need periodic updates and maintenance, especially in cases of permanent installations.

Accessibility may also be an issue, as many AR applications overlook users with disabilities or low technical proficiency. Inclusive design and adaptive features require careful planning and additional resources.

Future Potential of AR in Museums

Ongoing improvements in AR technologies are continuously making its usage easier. As a result of improvements in tracking algorithms and more intuitive tools and frameworks, AR will become much easier for developers and cultural institutions to utilize. Meanwhile, modern devices are becoming more powerful, which will allow an increasing number of visitors to smoothly enjoy AR content on their own devices. As the capabilities of WebAR are continuously growing and very likely to be further extended in the future, there will be no need for separate AR applications in the future. As a result of these advantages, acceptance and usage of AR in museums could be increased and further fuel the continued development of AR as an immersive and interactive medium, thus, providing a unique experience for visitors.

7. CONCLUSION

AR allows the possibility of integrating traditional ways of presenting exhibits in museums with the expectations of the modern, digitally active public. This paper has, through specific case studies such as "ParthenonAR" and comparative studies on ancient portraits, demonstrated how this might be accomplished using digital technologies to enhance the visitor experience within the museum.

Nonetheless, AR is not without its own thorny path of implementation – from the demand for modern technical infrastructure to designs allowing access for diverse audiences. In addition, AR requires considerable resources at all stages of its creation and implementation.

Overall, the case studies presented in this paper exemplify how progress in museum education, greater visitor engagement, and more comprehensive learning goals can be achieved through a combination of technical and academic competencies, as evidenced in the collaboration between MfA and TUM. To this end, this paper demonstrates that the strategic and inclusive use of AR has the potential to make cultural heritage more accessible, interactive, and inspiring for visitors.

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Keynote Speech

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Digital products can be useful and good if people use them in a controlled way, i.e. if we control them - instead of us being controlled by the digital tools. However, the trend at the moment - especially among younger people, but not only there - is for digital products to control us and not us them. The zeitgeist demands that we like everything that the monopolies in Silicon Valley are currently throwing onto the global market.

How does a neuroscientist and psychiatrist view this topic? The significance of the arts for people arises from the human need for interpersonal resonance. Due to their neurobiological design characteristics, people cannot develop and remain healthy if we do not experience resonance from our fellow human beings.

Interpersonal resonance has long been the subject of neuroscientific research. My friend, the sociologist Hartmut Rosa, has published a book on resonance from a sociological perspective. A few years earlier, I myself had written a book on the neuronal resonance systems of humans, which Hartmut Rosa then also referred to in his subsequent book. My book on human neuronal resonance systems was entitled "Warum ich fühle was du fühlst“ (Why I feel what you feel). It describes the inevitable reciprocal resonance processes that take place when people meet.

The starting point and trigger for interpersonal resonance is, on the one hand, the human body and, on the other, what people say. In addition to the physique and posture, the body primarily includes the gaze, facial expressions and voice. The resonance receiver is the fellow human being or fellow human beings. In the first step, the meaning of the body language and linguistic messages received by the recipient is read by special neuronal systems. In a second step, the received messages have the tendency to tune the recipient into their meaning, i.e. to infect them, as it were. Resonance processes occur quickly and predominantly involuntarily. However, they require a willingness on the part of the recipient to allow resonance in. Interpersonal resonances are reciprocal. Whoever is in the social space not only triggers resonances, but also receives them. Receivers become emitters and vice versa. Every resonance experienced changes the person.

The arts are not only involved in the many different forms of interpersonal resonance, they also play a huge role here. At the moment of their creation, the arts are human self-expression. A work of art could be described as the artist's "extended self". Like every human being, works of art have an aura and can trigger resonances in the recipient. Not only the resonance induced by another person, but also a work of art can change the viewer. Incidentally, people could - or perhaps even should - also be described as works of art. The resonances triggered by works of art will be different for each individual viewer. As a result, when works of art are perceived by many people, additional possibilities of interpersonal resonance arise, namely in that the individuals communicate their individually experienced resonances

People are therefore neurally connected to their fellow human beings. Moods, feelings and inner attitudes can be transferred from one person to another as we perceive each other. Researchers speak of "emotional contagion". People are not only connected to each other via the resonance capacity of their emotional systems, but also via the neuronal self-systems. While the emotional systems have to do with feelings, the self-systems are the neuronal plateau on which we think rationally about ourselves. Research has shown that we use our self-systems not only when we mentalize ourselves, but also when we think about other people. This overlap between "I" and "you" mainly affects other people who mean something to us, i.e. it mainly affects significant others. The neuronal overlap between I and you, between self and other, is the reason why we humans are able to change our perspective.

The arts have the potential to enliven and expand the interpersonal resonance space. Pico della Mirandola (1463-1494), an Italian philosopher of the early Renaissance, said that man is "a work of indeterminate form". From a neuroscientific point of view, this is an entirely correct statement. The arts are a space of possibility for human self-expression. They are

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a kind of test laboratory in which we can constantly try out and present anew who we humans are or who we could be. The artist's opportunity to seek new forms of self-expression is one side of the coin. The other side is the opportunity offered to the viewer of art to allow new resonances within themselves. Art is therefore always also an invitation to allow something new, something that has not yet been depicted in this way, to take effect and be understood.

The new things that art imposes on its viewers or consumers are not always met with an open response. Artists often experience rejection, even hatred and persecution, as the history of our country under fascism has shown. This brings us to the very important issue of vulnerability. Where people try out something new in their immediate self-expression or as artists, they make themselves vulnerable. The aspect of vulnerability in connection with art was not taken very seriously, as we had a predominantly tolerant social climate for a long period of time, which is now coming to an end. Even if we are only now beginning to realize this again, the potential space of the arts has always been a space of vulnerability. All people who express themselves, but especially artists, expose themselves in a very special way to the perception of others and thus to the possibility of being belittled, despised or marginalized.

Social Media

Social media are not only a huge resonance space, they could in principle also be an artistic resonance space, also a space for visual arts. Why didn't that work out? There are several reasons for this, three of which I would like to mention explicitly. The first reason is the binding or addictive effect of the systems. The platforms are deliberately designed in such a way that they do not let users go, but bind them. As has been explained at the beginning, people cannot live without experiencing interpersonal resonance. We are all in need of resonance. Network operators consciously take advantage of this fact. Social networks promise their users that they will be noticed and seen. Anyone who spends many hours a day on the networks loses time that is then no longer available for artistic projects.

A second reason why no artistic resonance space has been able to develop in social media is that social media platforms leave no space between self-expression and a subsequent response. The digital systems are geared towards a rapid succession of messages sent out and the reactions that follow. There is no space between self-expression and response in which something artistic could emerge. The resonance processes that take place in social media are far too short and therefore largely devoid of meaning.

A third reason why social media platforms have not become artistic resonance spaces is the hostile tone that is widespread there. This also has to do with the design features of the systems. A battle for recognition takes place on the platforms, which is fueled by the fact that users are constantly expected to rate each other. Those who do not receive good comments, hearts, likes, etc. experience a lack of feedback. We know from neuroscience that the feeling of not receiving enough social appreciation activates the brain's pain systems, which results in both aggression and depression. As I said earlier, people who express themselves artistically make themselves vulnerable. Art needs a tolerant space in which it can develop. Social media are the opposite of such a space. They have degenerated into platforms whose purpose is to cynically exploit users by tapping into their data, to manipulate them with advertising and political information, to keep them online for as long as possible and to bind them to the networks in an addictive way.

Artificial intelligence

Artificial intelligence is the term we use to describe computers that - in short - are able to break down and reassemble the material they are fed. Systems with artificial intelligence do not perceive the world directly as we humans do with our five senses. The text, speech or image material fed to artificial intelligence systems must be digitally processed. The fed material, i.e. texts, speech samples or image material, is broken down into small individual parts, so-called "tokens", by artificial intelligence systems. The machine can assemble something new from these individual parts or "tokens" at the user's request. In order to understand what happens, you need to know the internal structure of systems with artificial intelligence

Artificial neural networks consist of superimposed layers of chips. Each chip in an upper layer is connected to all the chips in the subsequent layer. One could speak of a kind of "digital lasagne". The top layer is the input layer, the bottom layer is the output layer, with the so-called "hidden layers" in between. The decomposed individual parts, i.e. the "tokens" of the fed material, are passed down from the input layer. The calculation engine stores the rules according to which the individual parts of the fed material are related to each other. It stores what belongs to what, what follows on from what. In the case of an image fed to it, the machine stores the rules according to which individual parts in an image fed to it are related to each other. How the machine does this in detail is not visible to the designers from the outside. The "hidden layers" are a "black box", even for the designers. All that is known is that the fed material is stored on the basis of probability calculations. Thus, if a machine has been fed sufficiently large quantities of language material, including, for example, a sufficient number of texts by Shakespeare, then it can produce a sonnet in the style of Shakespeare at the request of a user.

The majority of pupils and students now have their work written by artificial intelligence. If they are not allowed to use smartphones when writing class tests, pupils now use their smartwatch. Teachers and professors are doing the same and using artificial intelligence to prepare their lessons and assess work. The question is what this means for the user's brain. In neuroscience, the basic rule is "use it or lose it". While researchers into ageing have been telling us for years that we should use our brains to prevent dementia, we find it convenient and good that systems with artificial intelligence are now taking over our independent thinking on a broad front.

Artificial intelligence not only makes it easier for us to complete tasks. It is now also offered to us in order to experience interpersonal resonance without having to come into contact with a living person. Chatbots, i.e. talking services equipped with artificial intelligence, have now been perfected to such an extent that they pass the Turing test, i.e. they are indistinguishable from living, speaking people. Providers on the internet offer users the opportunity to configure a conversation partner whose characteristics the user can specify in advance. A growing number of people are living in a partnership with such chatbots. More and more people are also using therapeutic chatbots. These are now also on offer.

Research shows that users develop an emotional bond with chatbots, even when they know that chatbots do not have human feelings but can only simulate them. The result is an asymmetrical situation: on the one hand, a feeling person who develops a bond with their counterpart, and on the other, a machine that can perfectly simulate as if it were feeling, but in fact feels nothing. Chatbots, like all systems with artificial intelligence, are machines. They have no subject characteristics, they have no "I" and no "self". Some of them deliver excellent results and have been performing well in the manufacturing industry for years. However, systems with intelligence have no consciousness, they feel nothing and do not know what they are doing. Statements to the contrary have been and continue to be spread in order to divert attention from the real problems.

What is the relationship between artificial intelligence and the arts? And in particular to the visual arts? When fed with large enough quantities of image or film material, artificial intelligence systems can seemingly produce new images and films depending on the orders or "prompts" given to them. If Anselm Kiefer or David Hockney feeds an AI with his pictures and then instructs the machine to produce pictures with new motifs using this material, then the matter remains "in the family", so to speak. The result would be an artistic-technical hybrid product.

In most cases, however, something else is actually happening: users are using systems with AI that have been fed a huge amount of artwork, be it texts, music, photos, images or films. The fed material was protected by copyright or personal rights in many, perhaps even most cases. In most cases, these rights were simply disregarded by the manufacturers. Users can now use the systems to produce "new" material according to their "prompts". To what extent is this an artistic act? That's debatable, and it is debated, even in the courts.

Perhaps it will help us and allow us to see a little more clearly if we go back to what I said at the beginning about the role of art in the interpersonal resonance space. People express themselves artistically in many different ways. A work of art is an expression of a person to a greater extent the more the artist was personally involved in the creation of his or her work of art. Resonance can arise all the more easily in the viewer of the artwork, the more the artwork - despite all alienation - still reveals that a person was involved in the production of the work.

Let me conclude. When it comes to the question of the extent to which we shift the artistic creation process and the perception of artworks to the digital or virtual, it depends on what we want. The providers of digital products have a clear position on this, which can also be found in their philosophical manifestos. The masterminds of Silicon Valley want to shift more and more of our analog, natural lives to digital communication channels and virtual experience spaces. They say and write quite openly that they see no future for the analog world. Their vision is the metaverse, i.e. the greatest possible shift of life into virtual space. Studios, workshops and exhibitions can then also be held there. Congresses like this one will also take place there. The monopolies of Silicon Valley are interested in such a development because it fills their coffers. The crucial question is whether we want it.

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SESSION IV

"CH In Conversation"

Moderation: Eva Emenlauer-Blömers

(formerly Senate of Berlin, Department for Economics, Technology and Research)

The Antikythera Mechanism: Data Visualization by Means of Web-Based Virtual Reality

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ABSTRACT: The Antikythera mechanism is an ancient astronomical calculator, the fragments of which were discovered in 1901 near the Greek Island Antikythera. Dating back over 2,000 years to Ancient Greece, this remarkable device was used to calculate the positions of the sun, the cycles of the moon, solar and lunar eclipses, and the dates and locations of the Panhellenic Games—both for past and future dates. The advanced engineering behind the mechanism was lost to history, but modern visualization techniques have allowed researchers to analyze radiological, archaeoastronomical, and mathematical data, enabling the virtual reconstruction of the device. Our web-based Virtual Reality model provides a wider audience with access to the main fragment and an open data replica. Updates to the model based on new discoveries, such as the recently proposed Draconic cycle dial, are both time-saving and cost-effective.

1. INTRODUCTION

In 1900, a group of Greek sponge divers from Symi took shelter from a fierce storm near Antikythera, an island located off the southern coast of the Greek mainland. When the storm subsided, the divers did not find sponges, but rather the remains of a Greek or Roman shipwreck, which appeared to have sunk around 60 BCE. The following year, they recovered many artifacts from the seabed, including amphorae, bronze and marble statues, glassware, pottery, jewelry, and coins. Among these treasures, which originated from the eastern Mediterranean, was a corroded lump of bronze that seemed unrelated to the other finds. While the spectacular artifacts were displayed at the National Museum of Archaeology in Athens, the bronze fragment was set aside for later examination. Over time, in the dry air of the museum archives, the fragment eventually split open, revealing a remarkably well-preserved gear wheel, with its 1 to 1.5-millimeter-long teeth closely resembling those of a modern timepiece.

Scientists were amazed to discover a high-precision gear wheel dating back to antiquity. It wasn't until the 1950s that British physicist and historian of science Derek de Solla Price solved the mystery of the Antikythera mechanism. Price realized that the original device had been flat and rectangular, about the size of a large dictionary. A complex gearing system inside a wooden casing moved several pointers around circular dials on both the front and back of the device, displaying the positions of the sun and moon for any given date [1]. The names of celestial bodies are engraved on the mechanism [2], leading some researchers to believe it was designed also to show the positions of the five planets known to ancient Greek astronomy—Mercury, Venus, Mars, Jupiter, and Saturn—even though no parts of the corresponding gears have survived [3].

Ancient Roman literature provides evidence that the Greeks constructed clockwork mechanisms of this kind. In the 1st century BCE, Poseidonius (c. 135–c. 51 BCE), an acknowledged scholar, settled on the island of Rhodes, where he taught and contributed to the scientific advancements of his time. It was there that lawyer and later Roman consul Cicero saw a device, *"cuius singulae conversiones idem efficiunt in sole et in luna et in quinque stellis errantibus quod efficitur in caelo singulis diebus et noctibus"* ("which at each revolution reproduces the same motions of the sun, the moon and the five planets that take place in the heavens every day and night"), as he wrote in his work *"De natura deorum"* in 45 BCE [4]. The discovery of the Antikythera Mechanism

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proves that Cicero's description was meant to be taken literally.

Meticulous analyses of all 82 surviving fragments, including high-resolution computed tomography scans penetrating the metal, show that the Antikythera Mechanism was a sophisticated mechanical calendar crafted from bronze, a dedicated, gear-driven astronomical calculator. Its plates were inscribed with scales and texts detailing its various functions. One face of the device displayed a lunisolar calendar with a date indicator. A pointer, which housed a rotating black and silver ball, tracked the lunar phases. A fixed ring dial featured the 12 signs of the zodiac, while another ring marked the 354 days of the lunar calendar [5]. Closely spaced holes underneath the lunar ring appear to have been used to rotationally adjust it to the zodiac. On the opposite side of the mechanism, two large displays provided further astronomical information. The top dial, designed as a spiral, displayed a lunar calendar tracking the 19-year Metonic cycle—named after the Greek astronomer Meton of Athens—with its 235 synodic lunar months. A second spiral dial below was used to predict solar and lunar eclipses, with an embedded smaller dial indicating their approximate time of day. Finally, within the upper Metonic dial, a smaller subsidiary dial indicated the four-year cycle of the Panhellenic Games, specifying both the timing and location of the events, thus providing the only non-astronomical (but rather social and cultural) information processed by the device.

2. REPLICA IN WEB-BASED VIRTUAL REALITY

The Antikythera mechanism, with its 30 preserved gearwheels, is an extraordinarily complex calculating machine that represents a previously unknown level of scientific and technological achievement not seen again until the Middle Ages. Visualizing its operation is no easy task. Although several physical replicas exist, they are usually not accessible to the public and only represent the state of archaeoastronomical research at the time of their creation, becoming outdated as soon as new discoveries are made. Diagrams of the gearings, whether technical drawings or schematics, fail to convey the impressive physical appearance of this stunning artifact. Video animations of the mechanism's operation on the other hand are linear and non-interactive.

Our goal was therefore to create a freely accessible replica of the mechanism, including a 3D model of the iconic main fragment, accomplished through:

- the use of open web technologies,
- the use of open-source software and frameworks,
- web-based Virtual Reality (Web VR) viewable on any device, not requiring any additional hardware such as VR headsets or dedicated projection systems,
- full 3D animation and interactivity,
- a downloadable 3D model, published under an open license.

By utilizing open technologies and software, we have created a realistic VR model of the Antikythera mechanism embedded into a dedicated webpage [6], ensuring it to be freely accessible to scholars worldwide. The animated 3D model can be downloaded both from its webpage and from Sketchfab [7].

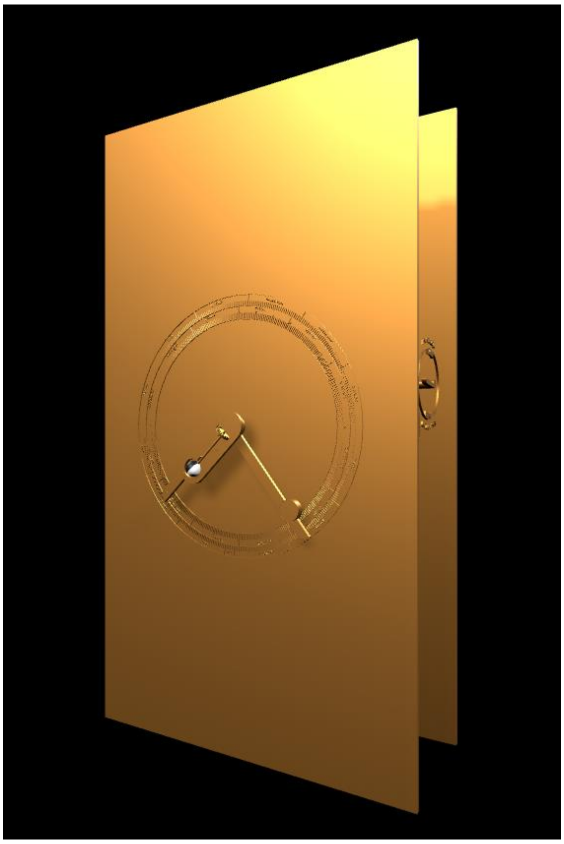

Figure 1: *VR model of the Antikythera mechanism with the solar year dial and the sidereal, synodic and Draconic moon cycle display.*

The 3D model can be freely tilted or zoomed and supports both research and educational purposes. A slider at the bottom allows for fading in or out both the iconic fragment A and the replica. The open data model is easily adaptable, enabling time-saving and cost-effective updates based on new discoveries. The following example may illustrate the process.

3. EXAMPLE: THE DRACONIC MOON CYCLE DISPLAY

Since the first replicas of the Antikythera mechanism built by Derek de Solla Price and Michael Wright [8], scientists have believed that the crown wheel a1, the only gear rotating in a *perpendicular* direction to the rest of the mechanism, and meshing with the main four-spoked wheel b1, would have been driven by an input crank or knob, through which the gearing could be manually set in motion.

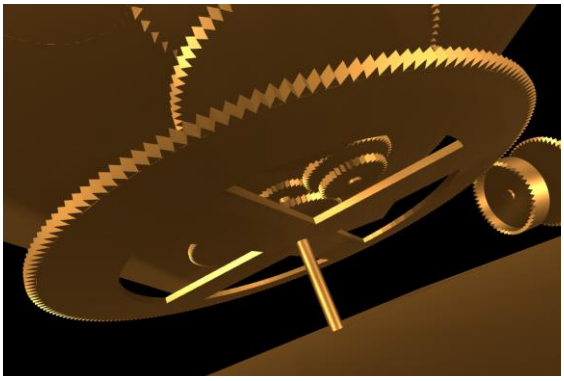

Figure 2: *Four-spoked main wheel B1 (center) with meshing crown wheel A1 (right).*

Recent research, however, has shown that this hypothesis is unlikely to be accurate. An input through pivot A would create issues with torque and movement resolution, leading to excessive wear on central components of the mechanism, a phenomenon that could not be observed in the CT scans of fragment A, within which the relevant gears were preserved. The authors of two recent papers have demonstrated that pivot A was likely designed to support a gear found in the coin-sized fragment D. This gear r1 with its 63 teeth is exceptionally well-preserved, though its function had so far remained unknown. Together with an additional, hypothetical gear with 22 teeth, gear train A would enable the tracking of the Draconic moon cycle—a feature that had so far been missing from a device otherwise focused on calculating lunar motion [9]. This hypothetical array is highly precise and produces a phase difference error of 0.00202809 days/1 Draconic pointer rotation, corresponding to only ~2.9 minutes/Draconic month (27.21222 days) [10].

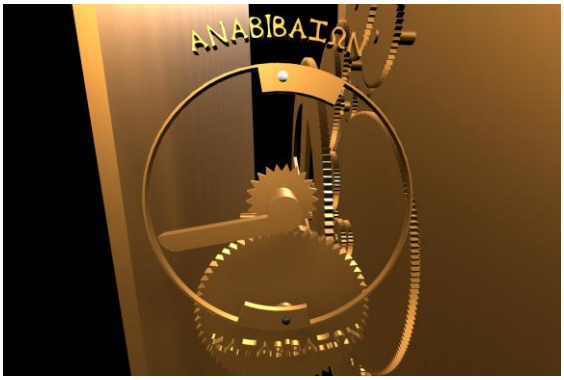

Figure 3: *Gears s1 (22 teeth, center) meshing with r1 (63 teeth, center bottom), providing a display of the Draconic moon cycle.*

With this interpretation of gear train A, the Antikythera mechanism is revealed to provide information on *all* the lunar cycles known to ancient Greek astronomy: the sidereal, synodic, anomalistic, and Draconic cycles. Furthermore, it is only with the addition of a Draconic dial that the otherwise incomplete large eclipse prediction dial on the back of the mechanism makes sense.

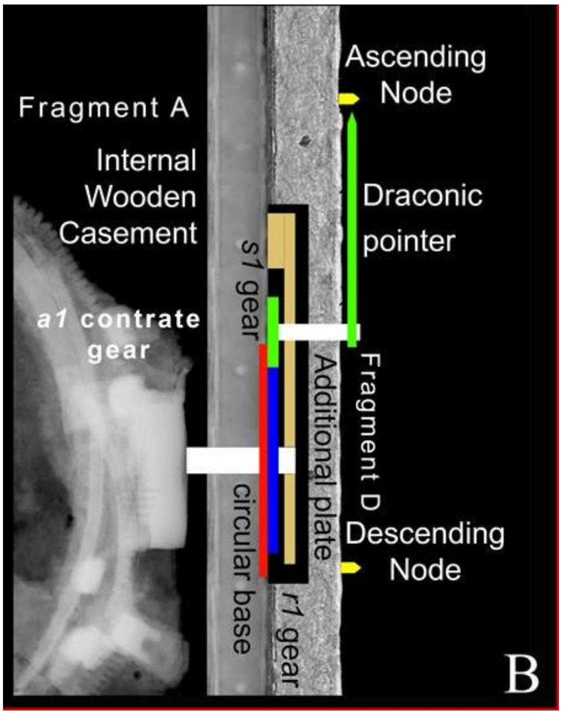

Figure 4: *Draconic gearing scheme with pivot A (white, lower), pivot S (white, upper), gear r1 found in fragment D and the hypothetical gear s1 driving the Draconic pointer. (Voulgaris, A. et al., 2022)*

Gear	Teeth	Meshing with	Driving/ driv. by	Gear ratios
b1	225	a1	—	—
a1	48	b1	r1	4.6875
r1	63	s1	a1	4.6875
s1	22	r1	—	13.4233*

Table 1: *Gearing scheme of a hypothetical Draconic cycle display.*
** Number of Draconic months per Callippic tropical year.*

Despite the stringency of this new hypothesis, most existing visualizations of the mechanism have not been updated and still feature a previously assumed input crank on pivot A. Physical replicas are difficult to modify, and outdated illustrations based on previous research continue to circulate freely online. In contrast, our model, built using the same technologies as any normal webpage, can be easily adapted. Incorporating the new findings into the existing VR model was a matter of little time, and today a working version of the proposed Draconic dial is part of our virtual mechanism.

4. CONCLUSION

The Antikythera mechanism, dating back to the 1st or 2nd century BCE, is an astronomical calculating machine of remarkable complexity and precision. Its discovery in 1901 revealed previously unknown dimensions of the technical and mechanical knowledge in ancient Greece. Visualizing the sophisticated device has always been a challenge, but open-source software and web technologies make it possible to create virtual models that allow for the interactive exploration of the mechanism, including parts that have not been preserved.
Our animated VR model of the Antikythera mechanism has been created using open-source software and web technologies only, not requiring any additional hardware components, thus ensuring free accessibility for scholars, teachers and developers worldwide. The model offers a realistic representation of the historical device, with updates—such as the recently proposed Draconic cycle dial—being quick and cost-efficient. Freely downloadable and open data, our model of the Antikythera mechanism provides free access to both a significant archaeological find and an accurate replica of a device that was 1,500 years ahead of its time.

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Broadcasting Architecture in the Age of New Media. Innovative Tools for Changing Times

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ABSTRACT: The paper explores the role of digital ecosystems in the dissemination of cultural knowledge and architecture education within a rapidly evolving media landscape. While traditional methods emphasize school as the primary learning environment, the research examines how digital media have become essential spaces for knowledge transfer, especially in the field of architecture. By surveying architecture students, the research evaluates their engagement with digital and traditional media, uncovering a paradox: while students rely heavily on the former, they still regard traditional sources as more trustworthy. This shift highlights the necessity of integrating critical pedagogies into digital environments, enabling students to actively participate in their learning processes. To remain relevant, education must bridge the gap between traditional and digital approaches. The research culminates in the proposal of LIA, an innovative platform for architecture education that leverages these insights to offer interactive and engaging learning experiences.

1. LEARNING OUTSIDE THE SCHOOL

This paper builds on the doctoral research titled *For a school Beyond the school: Phenomena, Tools, and Perspectives of Extra-Academic Transmissibility*, which I defended in May 2024. The study examines the boundaries and mechanisms of contemporary knowledge transfer, focusing on the role of digital ecosystems in cultural dissemination and architectural education.

In an age where digital tools produce and spread information at an unprecedented speed and scale, it is crucial to question which environments and mechanisms are most effective in shaping learning, particularly for younger generations. If you were to ask an educator, “Where do we learn?” they might confidently respond, “At school!” But is that truly the case? Is our learning limited to schools alone?

A closer examination of 20th-century architectural history reveals two key dimensions of learning – and, consequently, teaching. The first is school, while the second is an undefined space encompassing various knowledge-sharing initiatives organized in places and through media not formally tied to it. This includes journals, mainstream media, editorial series, television, radio broadcasts, and similar channels. Between the post-war period and the 1990s, these tools played a crucial role in constructing and disseminating architectural culture, making it accessible to audiences that were previously excluded.

This “inside-beyond school” dialectic of learning relies on the relationship between teacher and learner. At best, when this exchange becomes horizontal, a bond of mutual trust is established between the student and the teacher. A chemistry between individuals that makes knowledge capable of awakening the students’ desire through a process of seduction, leading the learner toward a greater awareness of the importance of what they are learning.

Conversely, this external realm often provides an unmediated relationship between the individual and sources of knowledge, resulting in a largely autonomous experience. For instance, readers of a specialized journal cannot directly interact with the author of an article, nor can listeners respond to a presenter on a radio program.

This was largely the case until the late 20th century, when the digital revolution creating new media alongside traditional ones sparked an anthropological shift in how people engage with knowledge.

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2. NEW MEDIA AS EDUTAINMENT TOOLS

To understand the differences between traditional and new media, it's important to introduce key concepts from media sociology. These two categories vary significantly in how individuals interact with information. In traditional media, individuals are passive participants in the communication process, consuming content in a largely hierarchical manner. In contrast, new media empower individuals to become active participants through features such as multimedia, interactivity, hypertextuality, accessibility, and intermediality. Users engage dynamically in the creation and dissemination of information. Traditional media include print, television, radio, and podcasts, whereas new media consist of social platforms, online blogs, and digital ecosystems.

If, as Marshall McLuhan famously stated, "the medium is the message" [6], then the media shape the content, which in turn influences how knowledge and information are acquired. This creates a continuous flow leading to what has been described as a true anthropological mutation [11] resulting from an increasingly complex and layered media environment. New media's ability to empower – or at least create the perception of empowerment among users – has sparked competition between traditional educational institutions and alternative platforms. The traditional school, which once excelled at enticing students, has become somewhat diminished due to excessive bureaucratization, while digital ecosystems provide innovative forms of edutainment. These ecosystems serve as catalysts for what Olimpius Istrate describes as a "pedagogy of discoveries", a compelling process that highlights the relevance and meaning of knowledge [2]. This approach encourages students to immerse themselves in learning, passionately exploring knowledge, methods, and values.

3. A SURVEY ON DISSEMINATION OF ARCHITECTURAL KNOWLEDGE

Based on these considerations, we developed a survey to assess the impact of digital ecosystems on learning and media in architecture. The survey was conducted with architecture students from their first to fifth year, who are both the main recipients of knowledge and a generation highly engaged with digital tools. Namely, today's students embody the demand for cultural content that needs to be met.

The survey included four thematic categories of questions: *Tools*, *Places*, *Awareness*, and *Perspectives*. The first three aimed to outline a phenomenology of contemporary knowledge transfer, while the fourth focused on identifying perspectives and suggestions for future projects.

3.1 SOME NOTABLE RESULTS

As expected, all four sections of the survey highlighted the dominant use of digital environments. Regarding tools, students reported that new media – websites, online platforms, social media, and search engines – constitute their primary source of information. In contrast, traditional media, including books and print journals, were consulted less frequently. This pattern reveals a striking paradox: while digital resources are the most commonly used, traditional sources are perceived as the most reliable. Thus, students acknowledge that they rely on tools they consider to be less trustworthy. Although the gap between the use of digital and print resources was anticipated, this paradox raises critical questions for the academic community, which this paper aims to address in its conclusions.

A similar trend appeared when students were asked about the places they use for knowledge transfer. The survey included the Internet alongside traditional options like schools, libraries, archives, and museums. While this may seem unusual, it highlights the core of this research and supports its premise. Indeed, the vast majority of students primarily rely on both school and the Internet, reinforcing the "inside-beyond school" dichotomy in educational experiences, which has increasingly evolved into a School-Internet dynamic in contemporary society.

Students acknowledged the benefits of online research, including multimedia content,

Figure 1: *The knowledge transfer constellation**.** The diagram analyses survey results on knowledge tools and places, displaying simultaneously indices of frequency, engagement, and reliability*

hypertextuality, and access to an almost limitless (and free) database. However, concerns about the reliability of online sources also emerged, emphasizing the need for cultural institutions to ensure quality.

While the first three sections identified trends and usage patterns, the fourth provided insights into the characteristics and types of materials considered particularly valuable by potential users. Here, the findings were equally revealing. Students expressed a strong interest in diverse and accessible digital architectural content. They particularly valued virtual exhibitions that employ immersive technologies, video lectures, thematic itineraries, and unique materials such as drawings and photographs, reflecting a preference for visual and interactive resources.

Concurrently, students prioritized features such as free accessibility, customization, and interactivity, highlighting a demand for flexible and engaging learning pathways. Overall, these results demonstrate widespread interest in digital resources, along with a clear understanding and preference for their underlying processes.

This brief commentary on the survey underscores two key points. Firstly, there is a growing disconnection between traditional educational methods and the preferences of digital natives. Secondly, discussing pedagogical innovation today necessitates addressing digital pedagogy. However, this is not merely just about utilizing digital technologies for teaching; it is essential to approach these tools from a critical pedagogical perspective involving a careful assessment of digitalities potential and limitations, while tailoring its application to serve the fundamental objectives of education [2]. As Edgard Morin noted: "Mass culture must be followed in its perpetual motion from technique to the spirit, and from the spirit to technique, like a small vessel floating throughout the entire social process. At the same time, however, it must be conceived as a keystone of that complex of culture, civilization, and history that we call the 20th century" [TBA, 7].

Although Morin's cultural framework differs significantly from today's, it remains crucial to adopt a similarly critical stance towards modern digital media culture. This involves engaging not only with the tools but also with the behavioral phenomena they generate.

4. SOME PERSPECTIVES FOR EXPERIMENTAL TOOLS

The results of the survey highlighted a crucial aspect: examining the dynamics of knowledge transfer requires addressing the relationship between traditional and digital methods of learning. Based on this premise, it was essential to derive a catalog of preferences, perceptions, and perspectives from the survey results, aiming to guide future projects. These initiatives should critically incorporate a range of fundamental actions. By defining these actions, the research aims to summarize and enhance the potential of proven tools, while simultaneously addressing trends that promote problematic or biased phenomena. These guidelines, operating along the dual axis of potentialities and criticalities, reveal six key features that will be explored in detail below: *mediation and reliability*, *cooperation*, *multimedia*, *interactivity*, *open accessibility*, and *personalization*. These characteristics provide insights into both the construction of content and the dynamics of its dissemination.

Mediation and Reliability: A process managed by experts to ensure verified, high-quality content that promotes conscious learning and intellectual autonomy through innovative language and continuously updated resources.

Cooperation: Building networks and online communities that foster social learning, stimulate user interaction, and strengthen collaborations among cultural initiatives to develop broader and more specialized resources.

Multimedia: The integration of text, video, and images to create immersive experiences that enrich the understanding of architectural works, making learning engaging and stimulating.

Interactivity: Allowing users to actively navigate content, transforming learning into a participatory and engaging process where each individual plays an active role in constructing their knowledge.

Open accessibility: The practice of making educational and academic materials freely available online, promoting equitable and inclusive access to knowledge while breaking down economic, geographical, and digital barriers.

Personalization: Providing the ability to shape individual learning pathways through playlists, saved content, and thematic choices, offering a tailored experience to meet each user's needs.

These characteristics are applicable to various tools and media. They identify a range of actions that can drive the development of diverse initiatives, such as multimedia platforms, social media, online journals, or other projects. While these guidelines do not encompass the vast array of features that a medium may possess – given the depth of experience and knowledge in the field of digitalities – they represent those deemed indispensable for creating effective and innovative tools. These principles were fundamental in shaping a specific project, which will be presented in the following chapter.

5. A PROTOTYPE: LIA, ITALIAN LESSONS IN ARCHITECTURE

From the outset, it was essential to avoid purely theoretical research. Instead, the objective was to propose a concrete experimentation of the reflections that had emerged by designing a tool capable of harnessing the potential of digital environments to offer innovative and pedagogically sound pathways. This approach led to the development of LIA – Italian Lessons in Architecture, an international multimedia platform dedicated to design culture. While the title may suggests entirely Italian content, the project aims to explore the relationship between Italian culture and international architecture, fostering a mutually enriching dialogue. This is why the platform will be fully translated into multiple languages through controlled artificial intelligence software.

Figure 2: *Homepage*

LIA serves as an innovative tool for promoting knowledge related to architecture, cities, design, and the arts, utilizing experimental digital languages. It targets a diverse audience, including students, public administrations, professional associations, foundations, archives, and cultural institutions. The platform combines various types of materials – some newly produced and others sourced from architectural and artistic archives. It is structured into five sections: *Lessons in Architecture, Online Exhibitions, Itineraries, Disputatio,* and *Open school*. The choice of these sections not only reflects the preferences expressed in surveys but also aligns with the underlying pedagogical emphasis of the platform.

Lessons in Architecture

This section functions as a streaming platform, featuring a curated selection of lectures by masters of architecture, along with video interviews, conference recordings, and seminar footage. The challenge was to design a space that blends archival content with new productions, sparking curiosity and encouraging users to explore video after video.

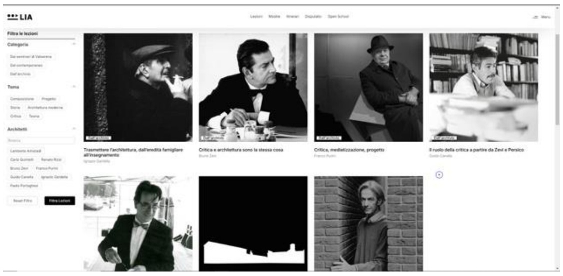

Figure 3 *Lessons: index of uploaded videos*

Figure 4: *Lesson example displaying a video and a brief synopsis*

Figure 5: *Online Exhibition example: interactive interface to access the individual rooms of the exhibition*

Videos are intentionally short, lasting 5 to 10 minutes, aligning with typical online attention spans. This format enables users to watch multiple videos in succession, navigating dynamically through an index of content or filtering them by author or theme. From a pedagogical perspective, this approach is crucial: it provides users to categorize and organize materials based on their interests, enhancing the platform's value for research.

Online Exhibitions

Rethinking how to experience online exhibitions was particularly challenging. From the beginning, the goal was to create an interactive and multi-layered experience, enabling users to navigate content based on their preferences and interests. Each exhibition consists of several "rooms" mirroring the structure of a physical exhibition, through which users can access individual pieces of content. These contents are arranged in a Warburg-style palimpsest, presenting a sequence of images that offers an overarching view, akin to a display panel. Users can click on each image to access further information. This system seeks to provide immersion, not through 3D simulation but a particular interactivity that grants users complete freedom while keeping the centrality of the artworks.

Itineraries

In *Unguided Tour* (1983), director Susan Sontag has the narrator recite, "Every tourist city is different from the others […] because there is an imaginary realm of which this city is

Figure 6: *Itinerary example: the map outlines the route, with details of each stage enhanced by images and text. Image reference: The portal of the building, 1911-1913. © The New York Public Library*

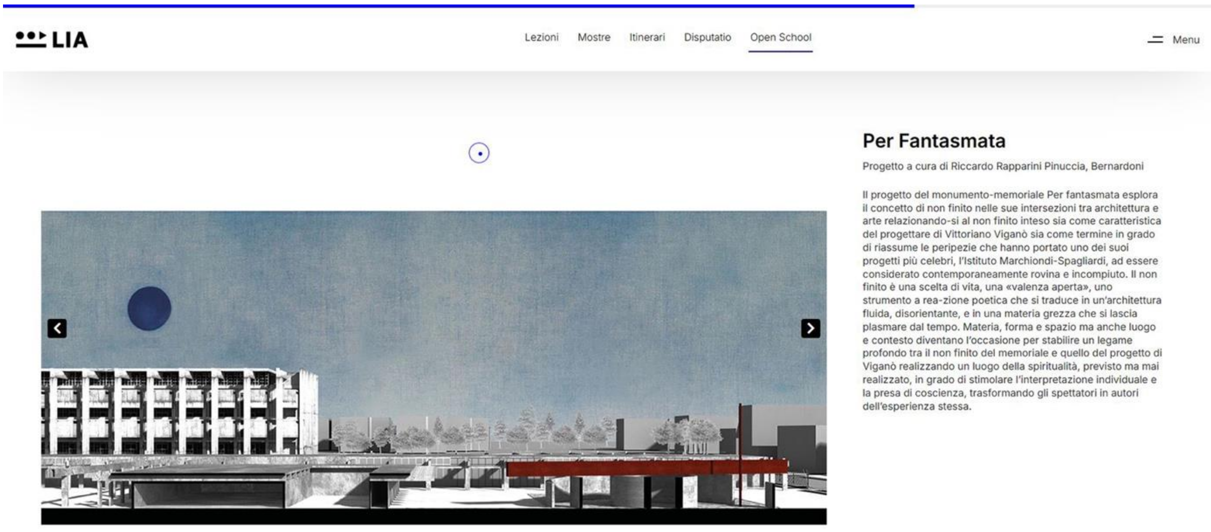

Figure 7: *Open school example: each project includes an introductory text and an image carousel within a pre-defined template*

the capital". LIA's itineraries aim to unveil this "imaginary realm" while emphasizing the importance of fostering a physical connection with architecture, even in a digital context.
Many existing online itineraries focus exclusively on architectural information. In contrast, LIA adopts a pedagogical approach derived from the Grand Tour, encouraging an interdisciplinary understanding of architecture as an exercise intersecting with the arts, cinema, photography, and literature. Each itinerary includes an interactive map designed to provide both an in-depth and an exploratory on-site experience. The first is achieved through texts and images associated with each stop, while the second is facilitated by automatic links to mapping apps on users' smartphones, enabling navigation within the selected city.

Disputatio
The Disputatio format draws inspiration from the medieval tradition, where two students debated a set topic under the guidance of a teacher who determined the winner. In this project, the format is reimagined as a live double interview addressing contemporary issues. Two participants with opposing viewpoints engage in a structured debate on a predefined topic. The screen is split into two sections, with a voiceover introducing the subject, managing time, and framing the discussion while displaying images. Each participant is allocated about one minute per response, ensuring the debate stays focused and succinct.

Open school
As its title suggests, this section aims to extend education beyond traditional boundaries by establishing an observatory on architectural pedagogy. The platform will annually select and publishes the most significant outputs from international design studio, reflecting trends in architectural education while providing reliable resources for students seeking inspiration.

* As of December 2024, the platform is still under development. The images presented are not final but represent the project's progress. In some cases, materials from past activities were used to test the platform's functionality

6. CONCLUSION

The project seeks to counter the proliferation of low-quality digital initiatives that attract large audiences through superficial yet appealing formats. LIA adopts a distinct approach, focusing on the organization and creation of research-based materials, which are shared using engaging and refined digital languages.
In its initial phase, the project aims to expand architectural education beyond traditional boundaries, fostering connections with the external world. The following step is to build an international network, establishing LIA as a platform for courses, summer schools, content calls, and interdisciplinary collaborations. These initiatives will bring together faculty and students to address critical themes, such as the integration of digital tools into education, particularly in an era increasingly shaped by generative artificial intelligence. The priority today is to equip students with the ability to

produce, understand, evaluate, select, preserve, and disseminate structured and complex content – primarily within the new digital ecosystem. This focus is on the complexities of the future rather than merely those inherited from the past [TBA, 9].

The challenge does not lie just in organizing knowledge, but in actively constructing and sharing it.

7. ACKNOWLEDGEMENTS

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Data Transformation for Narratives Context: From Scientific Research to Communication

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ABSTRACT: The contribution concerns part of the research and valorisation activities carried out by the authors at Palazzo Spada in Rome, a place where scientific culture and artistic wisdom converged between the 16th and 17th centuries. The research activities included survey campaigns, the analysis of historical documentation and the interpretation of the data obtained. The results of the different actions feed both the digital transformation process of the cultural heritage and its cultural accessibility. The transformation and optimisation of the survey data for computer graphics applications enabled the production of four videos for the exhibition 'The City of the Sun. Baroque Art and Scientific Thought in the Rome of Urban VIII' (curated by Filippo Camerota in collaboration with Marcello Fagiolo, Palazzo Barberini, Rome, 16/11/2023-11/2/2024), with the aim of presenting to the general public the theories and processes that made possible the creation of the gnomonic catoctric astrolabe (1644) by Emmanuel Maignan and the accelerated solid perspective (1652-1653) by Francesco Borromini and Giovanni Maria Bitonto.

1. INTRODUCTION

The subject of this essay is the result of part of the valorisation of Palazzo Spada in Rome, an example of the combination between scientific culture and artistic and architectural expertise testified to by its pictorial, architectural and sculptural episodes.

The working group, under the scientific guidance of Prof. Laura Farroni, has for several years been carrying out surveys and analysing historical documents to interpret the data collected, using a variety of research methods and digital technologies (Fig. 1).

The results of the actions carried out promote both the process of digital transformation of cultural heritage and its cultural accessibility, thus contributing to the dissemination of the culture of historical and artistic heritage. The production of some digital outputs displayed at the exhibition 'The City of the Sun. Baroque Art and Scientific Thought in the Rome of Urban VIII' - curated by Filippo Camerota in collaboration with Marcello Fagiolo, held at Palazzo Barberini in Rome, from 16 November 2023 to 11 February 2024 - is part of the enhancement process that demonstrates how it is possible to reproduce the culture of a physical place in another context, using theoretical-scientific connections. The aim of each product is to reveal the theories and processes [1] that made possible the realisation of Emmanuel

Figure 1: *Surveys of Palazzo Spada. A general view of the palace (left), the gallery of the catoptric astrolabe (centre), the accelerated solid perspective (right).*

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Maignan's gnomonic catoptric astrolabe of 1644 - whose sun dial is painted on the vault of one of the galleries on the piano nobile - and of Francesco Borromini and Giovanni Maria Bitonto's accelerated solid perspective of 1652-1653. Both artworks are the result of Cardinal Bernardino Spada's project to enlarge and embellish his palace in Rome.

2. SCIENTIFIC RESEARCH AND ASSUMPTIONS FOR KNOWLEDGE NARRATIVES

Palazzo Spada in Rome is an example of an aristocratic palace that testifies both to the antiquarian taste of the 16th century and to the affirmation of the relationship between art and science in the 17th century. The importance of the building is well illustrated by the numerous historical studies that have been carried out on it, which have examined numerous aspects of it, mainly based on documentary and iconographic analyses [2-5]. The activities carried out by the authors contribute to the implementation of the principles of the Faro Convention on Cultural Heritage [6], for the recognition of the tangible and intangible value of heritage, thanks to the recognition of the value and identity that societies have attributed to it over time and which they seek to unveil through scientific research. They therefore consider it appropriate to develop actions aimed at participation and access to cultural heritage for all types of audiences [7]. For this reason, diversified initiatives have been launched on the Palace over time, aimed at different audiences: the students of the Department of Architecture have been involved in learning paths on life drawing, while some have developed graduation thesis paths on cultural accessibility and on virtual reconstructions of perspective illusions, and then presented their work to a general public through guided tours organised since 2018 as part of the *Science Week. European Researchers' Night* [8].

The scientific research enabled a framework of knowledge useful for planning actions for the enhancement of the building, focusing attention on the most evocative artistic episodes and revealing the relationship between the knowledge that enabled their conception and subsequent construction. In particular, the connections between the scientific principles used in the design of the reflection sundial and those of the accelerated solid perspective have been studied, as well as the construction techniques used, and the perceptual and geometric aspects considered at the time of their realisation. These included, for example, the alignments between significant elements and the ordering axes of the interventions, theories of geometric projections such as perspective and gnomonics [9-12]. The research has led to the acquisition of large amounts of data in various surveys, implemented by the information found in archival documents, which, once processed, have allowed for certain verifications and virtual reconstructions, with the implementation of critical interpretative models that share internationally recognised recommendations for physical-digital transformation and scientific visualisation [13-14].

The elaboration of the knowledge framework was designed according to a digitisation process developed in four phases (Fig. 2):

1. The capture of 2D and 3D raw data using appropriate methods and tools depending on the object/phenomenon to be detected;
2. Data processing through computing and optimising the acquired raw data to produce 1D (text), 2D (raster) and 3D (point cloud, mesh) data;
3. The analysis and interpretative synthesis of the data, conducted through the intersection of the processed data and information

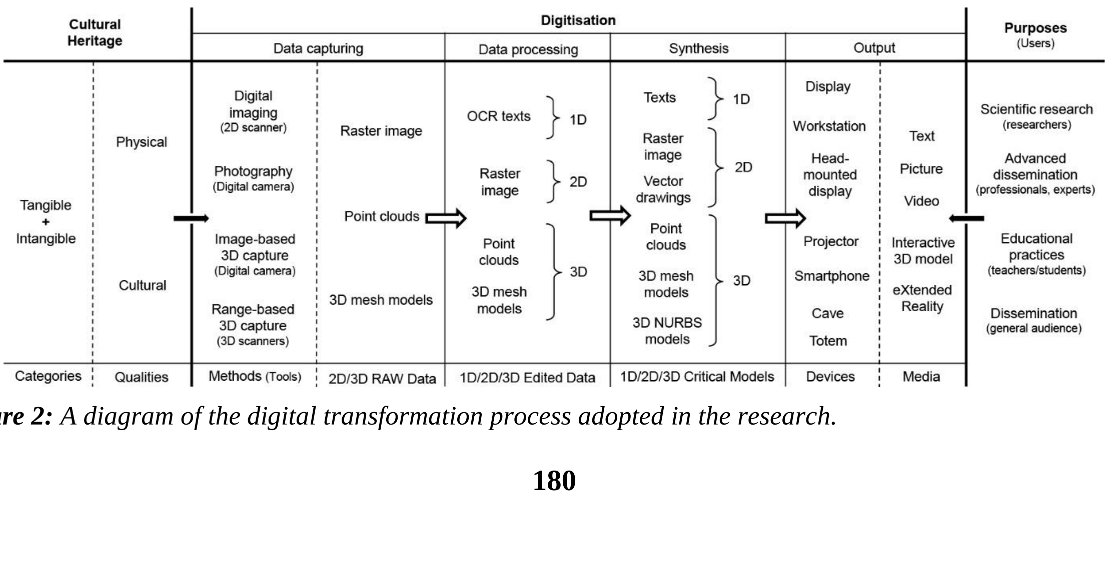

Figure 2: *A diagram of the digital transformation process adopted in the research.*

regarding the historical and cultural context of the artwork, to produce new critical 1D (text), 2D (raster and vector) and 3D (point cloud, mesh, NURBS) models;

4. The production of digital outputs using different media languages (text, images, video, 3D models, eXtended Reality experiences) and devices appropriately chosen according to the objective and the end user to whom the outputs are addressed.

In the object of this study, the results of the research were translated into video outputs, aimed at a wide audience interested in the specific theme of the relationship between art and science on which the exhibition ‘The City of the Sun. Baroque Art and Scientific Thought in the Rome of Urban VIII' was built. In particular, the four videos structured a path of knowledge on Palazzo Spada articulated from the general to the particular and deal with, respectively:

A. “Art and Science at Palazzo Spada. Geometric Projection and Perspective Illusions”, is dedicated to the presentation of the most important artistic and architectural interventions commissioned by Cardinal Bernardino Spada. The axes of development, the geometric and architectural connections and spatial configurations of the rooms through internal and external paths are highlighted;
B. “Emmanuel Maignan’s Gnomonic Catoptric Astrolabe at Palazzo Spada”, illustrating the constituent elements and geometric genesis of the gnomonic catoptric astrolabe designed by Emmanuel Maignan in 1644 and how it works;
C. “Art and Science for the Time Measurement. The Gnomonic Catoptric Astrolabe at Palazzo Spada”, to show, in detail, the elements of the astrolabe painted on the vault, revealing the compositional choices, the symbolic significance of the figurative elements and the scientific meaning of the line tracings, thus enhancing their artistic value;
D. “The Accelerated Solid Perspective at Palazzo Spada”, which is dedicated to the small architectural sculptural artefact designed by Francesco Borromini and Giovanni Maria da Bitonto in 1652-1653. On this occasion, its true form is shown with the elements that compose it, the proportional rules that determine its conformation and the principles that generate the illusionistic effect in the observer.

3. COMMUNICATION DESIGN AND IMPLEMENTATION

The communication through the videos was the result of the design of a narrative path that in the first instance considered the context in which they would be projected in the exhibition as defined by the curators of the exhibition and the technical specifications to be respected (technological devices through which the narration would be conveyed). In particular, the request for the absence of audio content and the co-presence of several video installations in some rooms led the author to the use of short texts in Italian and English within the videos to provide historical information about the artworks treated and the protagonists involved in their construction. The space dedicated to the projection conditioned the wall display on LED monitors of the three videos A, B and D (see above) and the ceiling projection of video C. In the latter case, viewing the video with an upward gaze suggested the choice of a bottom-up framing for all the animations, thus simulating the vision one has of the astrolabe when visiting Palazzo Spada (Fig. 3).

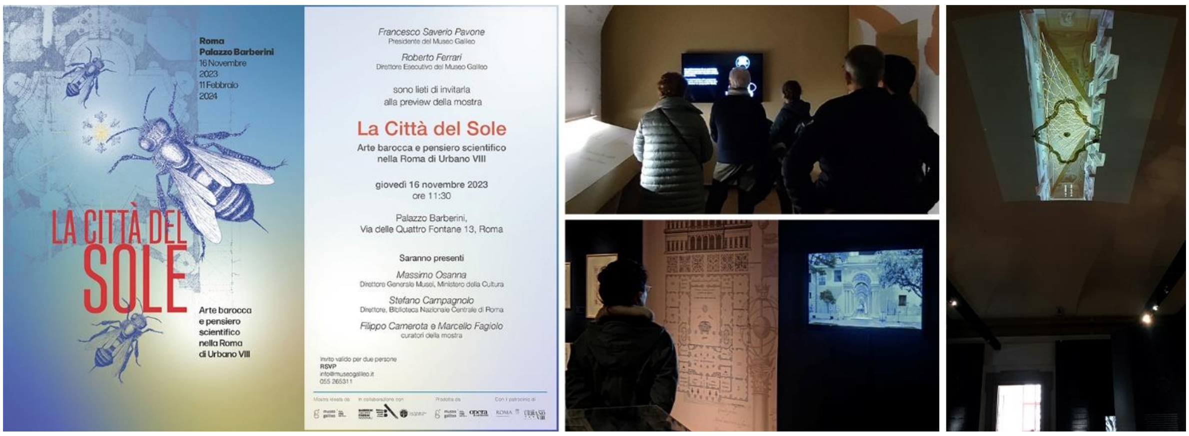

Figure 3: *A collection of picture from the exhibition.*

The entire design and realisation process was divided into four phases: a) drafting of a textual script; b) composition of a written-graphic storyboard; c) extraction and optimisation of data; d) elaborate production and editing. The first phases (a, b) correspond to the design of the videos and were developed simultaneously to ensure the coherence of the narrative path and the consistency of certain methodological choices regarding the structure of the communication and the presentation criteria. The following phases (c, d) correspond instead to the moment of data processing and the production of the necessary elaborations to produce the videos. In this way, each video was processed in turn to optimise processing times and ensure internal consistency between the different products. The consistency and objectives of the various process steps are described in the following sections.

3.1 SCRIPT

The textual script summarises the content to be conveyed in a narrative manner, selecting information and using direct language, avoiding the use of technical terms wherever possible or selecting the most commonly used terms from those available. For the videos in question, the length of the final scripts is between 1500 and 2500 characters. At this stage, a common structure was decided for all the videos (A, B, D) to be displayed on the walls. These videos always begin with the context in which the artwork was created, with the essential historical information and the people involved in its creation, accompanied by short texts outlining their respective roles and cultural contexts. This initial introduction is followed by the location of the work in Palazzo Spada and its analysis. This structure has been chosen in order to capture the attention of the visitor with the most narrative information and then to introduce the scientific and geometrical content.

3.2 STORYBOARD

The storyboard translates the script into visual terms by identifying essential keyframes that relate to the content to be presented and the transitions between one content and another [15]. The design is based on a grid that takes into account the required aspect ratio (16:9) and allows the design of the framing, the camera movements (summarised by the opening and closing frames and a selection of significant frames), the duration of animations and blocks, and the type and duration of transitions between blocks (Figs. 4-5). At this stage, a number of graphic decisions are made that are common to all videos: the characters involved are presented through their portraits; the localisation of the intervention inside the building is done through an animation that shows the position of the work from above and then descends inside the spaces, accompanying the viewer; the analysis of the work is done through hybrid models, in which the point cloud represents the real consistency of the works and the 2D/3D critical-interpretive models illustrate the scientific-geometric contents; the videos alternate between dynamic animations, which show the consistency of the sites in a more engaging way, and static images, on which the animated geometric constructions are superimposed, allowing time to read them without the potential visual disturbances associated with camera movement; the videos show both realistic views (static perspectives and dynamic paths), which

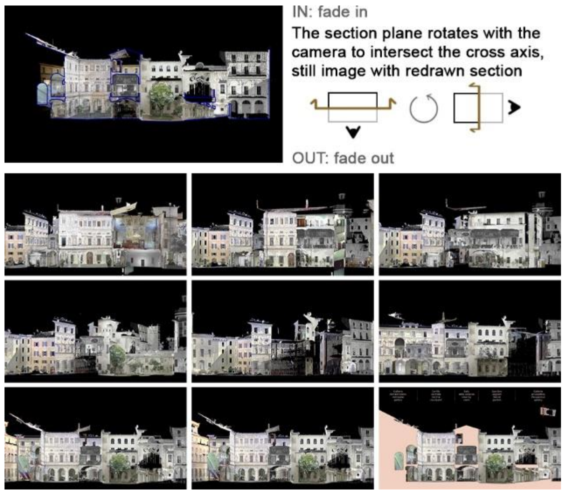

Figure 4: *An example from the storyboard and a selection of the corresponding frames from the video.*

Figure 5: *An example from the storyboard and a selection of the corresponding frames from the video.*

simulate the presence of the visitor on site, and abstract views (building sections and axonometries), which place the interventions in the building, reveal their imperceptible geometric relationships and describe their geometric properties.

3.3 DATA EXTRACTION AND OPTIMISATION

The extraction and optimisation of two-dimensional data (images and vectorial drawings) and three-dimensional data (point clouds and geometric models) involves selecting, from the data produced by the scientific research, the materials to be used to realise what has been prefigured in the storyboard, according to the final output envisaged. At this stage, the operations to be carried out depend on the type of data being considered. For two-dimensional work, it is necessary to check file formats, size and resolution, as well as the presence of overly technical or specialised content. Three-dimensional work, in addition to the process just described, requires further checks depending on the type of model: the density and total weight of the point clouds must be controlled and adjusted through sampling

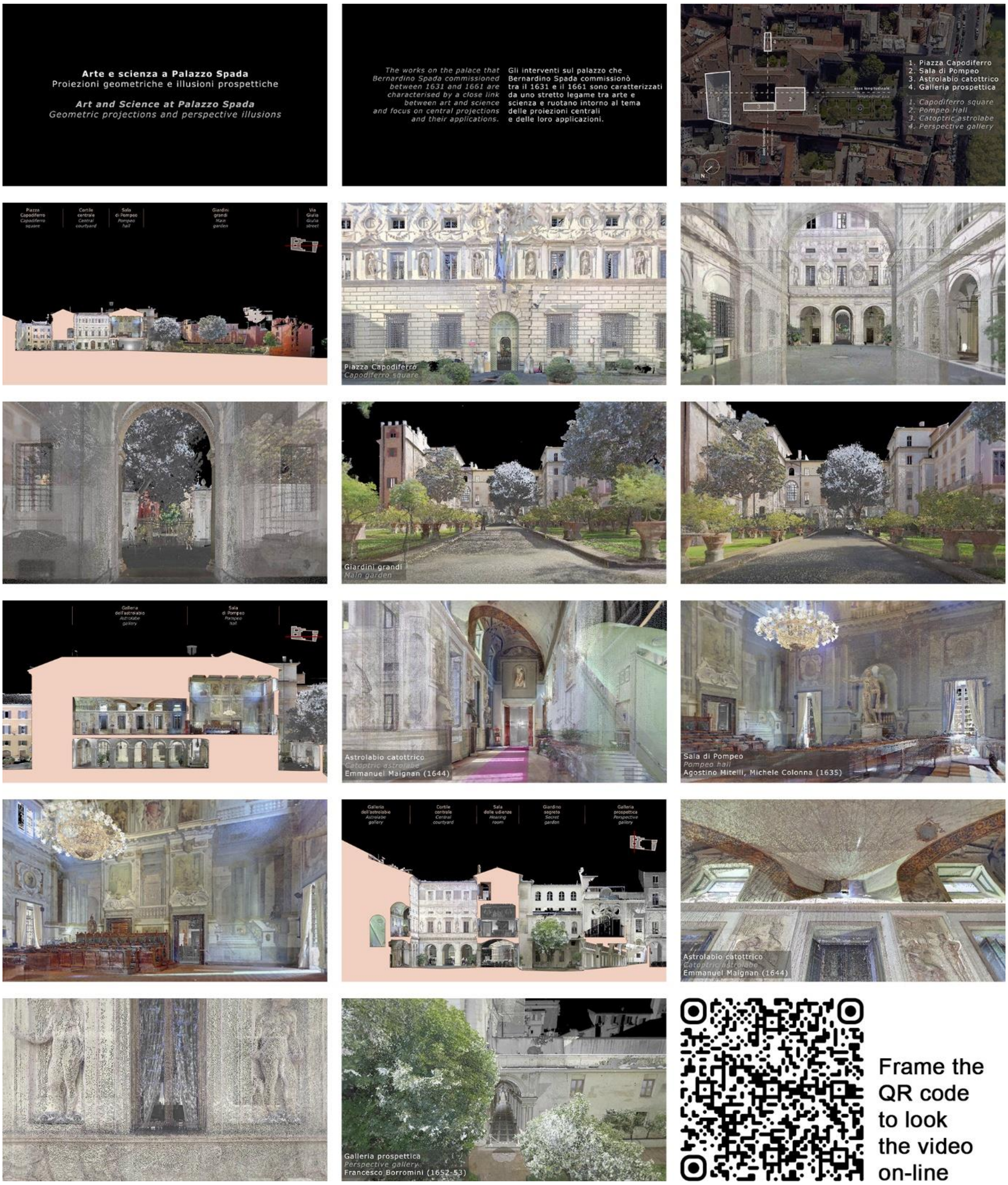

Figure 6: *Frames from the video "Art and Science at Palazzo Spada. Geometric Projection and Perspective Illusions".*

operations and the removal of undesirable elements; the type of surfaces (mesh or NURBS) of the geometric models must be evaluated in terms of interoperability and total weight, with the necessary conversions and possible topological simplifications. The aim of this phase is to prepare materials for the transition from software environments dedicated to highly specialised technical-scientific applications to software environments designed for computer graphics or general graphics applications.

3.4 DATA PRODUCTION AND EDITING

The production of materials for the assembly and final editing of the videos (Figs 6-9) involves the production of all the materials that will make up the videos using specialist computer graphics software, which allows greater control over aspects such as lighting and framing. At this stage, all footage is produced in formats, sizes, resolutions and weights compatible with video editing environments. This step results in a reduction in the number of spatial dimensions of the data, as even 3D data

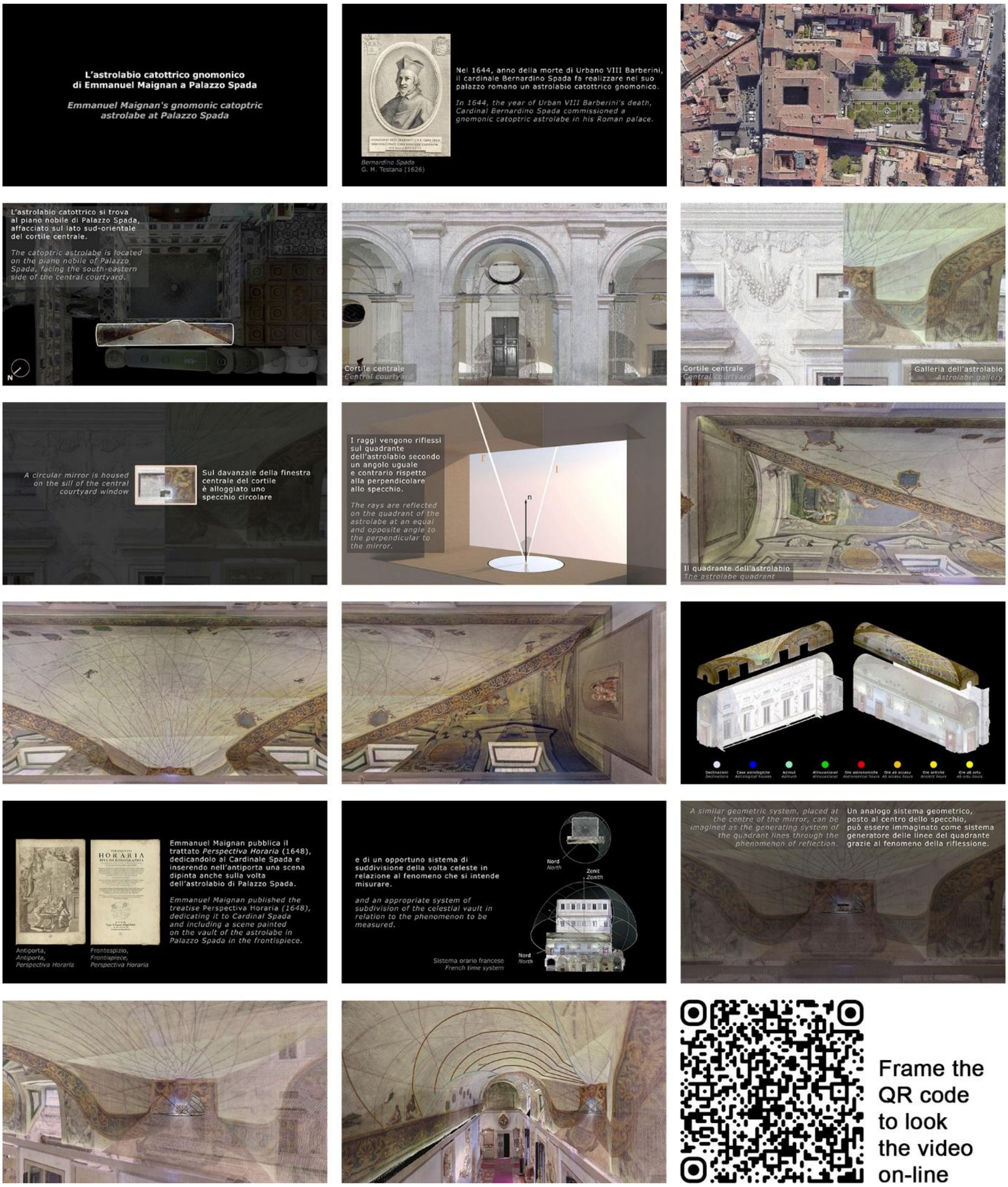

Figure 7: *Frames from the video "Emmanuel Maignan's Gnomonic Catoptric Astrolabe at Palazzo Spada".*

is ultimately converted into two-dimensional (static or dynamic) images. This phase is carried out by refining the storyboards for both the export of images and animations (shots, camera movements) and editing (transitions). This phase includes the creation of motion graphics elements to animate the geometric constructions, as well as all the retouching and video editing, such as: colour correction, brightness and contrast adjustment, and the introduction of vignetting and depth of field to improve the visual quality and accentuate the sense of depth of the images, concentrating visual attention in the centre of the frame. The duration of the videos is between 3 and 4 minutes, including opening and closing titles.

4. CONCLUSION

The design and production of digital products described above illustrates how scientific research can be used to develop content suitable for non-expert audiences. Several fundamental aspects are thus highlighted: scientific research must be carried out with rigour and method in

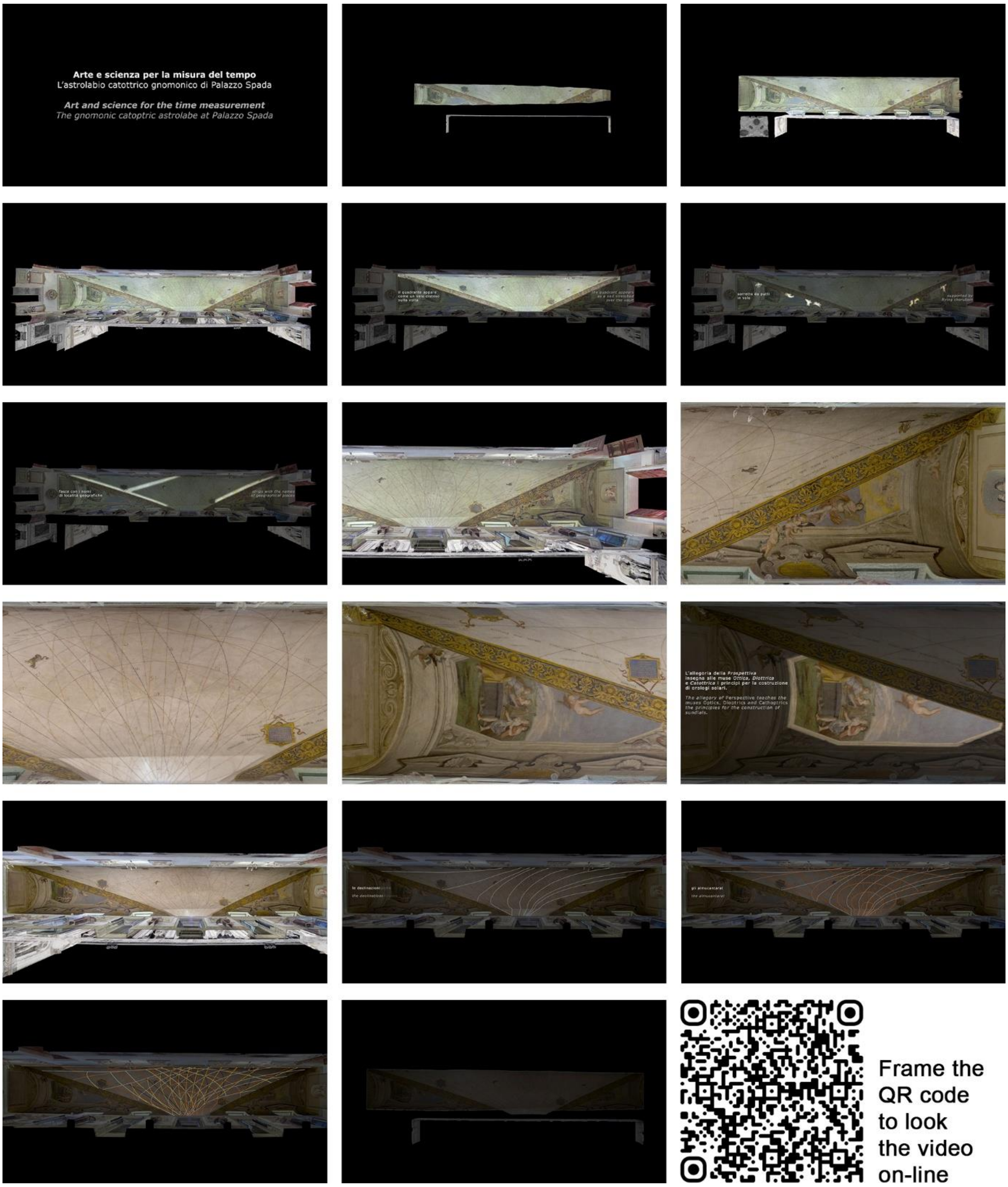

Figure 8: *Frames from the video "Art and Science for the Time Measurement. The Gnomonic Catoptric Astrolabe at Palazzo Spada".*

order to guarantee the accuracy of the content, which is then disseminated in different contexts; digital technologies must be used according to need, with clear and transparent objectives, highlighting where the data is the result of interpretation or a primary source; digital technologies open up unexplored areas for cultural exhibitions, allowing, as in this case, the transposition of magnificent works of art to other sites, where they can be integrated because they are linked by the thematic framework of the exhibition.

The experimentation of the digital transformation process of the research results in the context of the Palazzo Spada activities, aimed at dissemination initiatives, made it possible to test the flexibility of the possible solutions - static images, animations, 3D printing - and also to assess the appreciation through the constant presence of the public in the initiative.

Future developments planned by the authors include experimentation with experiences related to eXtended Reality (XR), with a focus

***Figure 9**: Frames from the video "The Accelerated Solid Perspective at Palazzo Spada".*

on Augmented Reality (AR) for its ability to create hybrid communication and learning environments that enrich spaces with information without breaking the perceptual link with the material reality of the asset being enhanced. At the same time, tactile experiments for the blind are also open, through the optimisation of data on inaccessible sculptural apparatus in the building. In conclusion, the research world must also take advantage of the possibilities offered by technological innovation to promote knowledge and disseminate results in order to contribute to the creation of identity awareness.

5. ACKNOWLEDGMENT

The research on Palazzo Spada is coordinated by Laura Farroni within the framework of the agreement between the Italian State Council and the Department of Architecture of the Roma Tre University (scientific head, Laura Farroni). The creation of the videos for the exhibition 'The City of the Sun. Baroque Art and Scientific Thought in the Rome of Urban VIII' is implemented within the framework of the agreement between Museo Galileo - Institute and Museum of the History of Science (contact person, Roberto Ferrari) and the Department of Architecture of the Roma Tre University (contact person, Laura Farroni).
The authors declare that they agree with the methodology and results presented in this paper and the following attributions: Laura Farroni edited paragraphs 1. Introduction, 2. Scientific Research and Assumptions for Knowledge Narratives, 3.2 Storyboard; Matteo Flavio Mancini edited paragraphs 3. Communication Design and Implementation, 3.1 Script, 3.3 Data Extraction and Optimisation, 3.4 Data Production and Editing; Laura Farroni and Matteo Flavio Mancini share paragraph 4. Conclusions.

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The Famedio by Leone Savoja at the Monumetal Cemetery of Messina

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ABSTRACT: Built following a competition announced in 1854, the Famedio by the architect Leone Savoja is an important testimony in the field of 19th-century monumental funerary architecture. Inaugurated in 1872, the Famedio had not yet been completed when, in 1908, an earthquake damaged several parts of it. Since then, the Famedio has remained as a ruin in the funerary landscape of the cemetery. The reconstruction process, started on the basis of the plan kept at the Damiani Almeida archive in Palermo, was verified thanks to the execution of a digital survey of the surviving structures. After the survey has been carried out, first phase saw the redrawing of the building. The plans, elevations, sections were drawn and the architectural details were studied in 2D. The next phase involved the three-dimensional modeling of the structure. In the contribution presented here, the images relating to the three-dimensional model modelled in a CAD are presented for the first time; some images relating to the analogue model printed in 3D during public exhibition occasions are also shown.

1. INTRODUCTION

Built in the 19th century, the Famedio designed by Leone Savoja, is an important testimony in the field of monumental funerary architecture. Inaugurated incomplete in 1872 it is a late neoclassical construction that includes elements of 19th-century eclecticism. The word Famedio is a modern term, coined in 1869 from the Latin *fama-aedes*, temple of fame. This kind of building became an architectural typology adopted – with reference to Italian territory – not only in Messina, but also in the contemporary monumental cemeteries of Milano, Mantova, Padova, Torino e Ferrara.

The project was drawn up as part of a competition open to all architects of the Kingdom of the Two Sicilies, announced in 1854, a competition that Savoja won together with his collaborators C. Beccalli, G. Bottari and G. Fiore. The *Gran Camposanto of Messina* is the most famous building built by Savoia.

This monumental cemetery is considered one of the most important in Europe for its grandeur and for the artistic level of the works it housed. Savoia conceived the cemetery with a remarkable scenographic and naturalistic layout, creating a true open-air museum, a museum of the dead for the living. The cemetery is built to the south of the city, on a hill that slopes down towards the sea, thus offering visitors the opportunity to admire the combination of architecture and landscape.

It is the history of the building itself that has determined its current state of incompleteness.

The building had not yet been completed when, in 1908, the earthquake that affected the two banks of the strait damaged several parts of it, including the roofs and particularly the so-called northern basilica, making its restoration inappropriate, also due to the new anti-seismic regulations. At the time of the earthquake, the base, featuring semi-hypogeal rooms, the north wing of the gallery, and the section orthogonal to it, called the basilica, were completed.

1.1. THE ROLE OF DOCUMENTATION

Archive documentation plays a central role in the process of graphic analysis and digital reconstruction of inaccessible, unbuilt, partially or totally destroyed architecture. The acquisition of archive graphic documentation represents an essential source for the reconstruction of the building in its entirety.

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The relationship between archive documentation and three-dimensional reconstruction of lost buildings is a relationship combines history with graphic representation techniques. The aim is to preserve and study the partially or totally lost architectural heritage and that which was never built. Historical sources, such as drawings, engravings, photographs, textual descriptions and maps, are essential to develop the reconstructions. This information is collected, analyzed and subsequently transformed into digital models, thanks to tools such as 3D modeling software. If traces of the structures under study remain, techniques such as digital photogrammetry and laser scanning can be used to verify the reconstructions and integrate the data.

The process develops in several phases: from the collection and analysis of the sources, to the creation and verification of the 3D model, up to its dissemination through different final products. This practice offers great advantages, including the possibility of studying and reviving lost buildings, preserving their cultural memory. These products can also have an educational purpose, being useful for disseminating the studies conducted to the public. In this sense, technology becomes a bridge between past and future, opening new opportunities to enhance our cultural heritage.

2. THE DOCUMENTATION STUDIED FOR THE RECONSTRUCTION OF THE FAMEDIO BY LEONE SAVOIA

The main archival sources relating to the field of graphic representation - corresponding to the original project by Savoja - are contained in the Damiani Almeida archive in Palermo.

The Damiani Almeyda archive in Palermo holds a copy of the documents drawn up by Savoja, transmitted to the engineer and architect Giuseppe Damiani Almeyda (1834-1911) as part of a correspondence aimed at illustrating the architectural solutions adopted in the Messina monument.

Giuseppe Damiani Almeyda was interested in addressing the issue of designing a cemetery in an academic context. The archive holds eight prints with a dedication from Savoja to Almeyda, depicting the main elevation and the perspective representations. There are also two drawings on cardboard, made by Almeyda, from the author's originals, depicting respectively the general plan and the plan of the building accompanied by a perspective (Fig. 1).

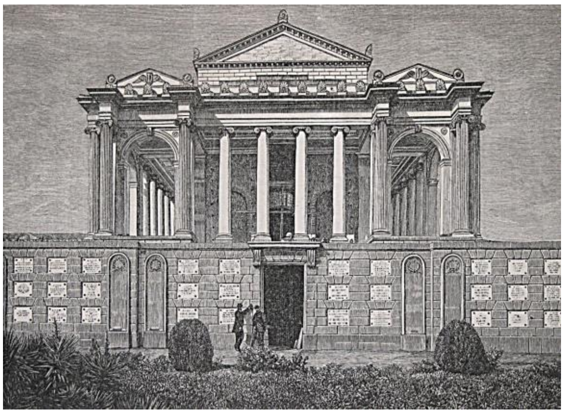
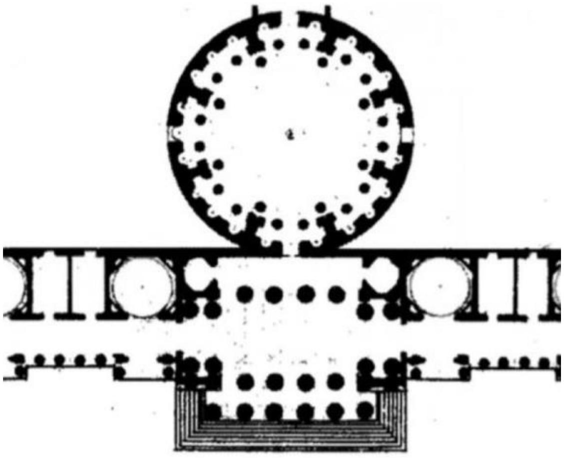


Figure 1: *Perspective of the east front of the portico and the gallery, published in 'Illustrazione popolare' on 30 October 1887. The engraving is based on the perspective present in Plate XXV kept in the Damiani Almeyda archive.*

Also dating back to the period preceding the great destruction of 1908 are several illustrations, photographs, postcards, etc.; these are precious documents useful for understanding the original state of the building. Among these documents it is interesting to note the presence of stereoscopic cards (Fig. 2). This photographic technique, invented in 1832, is able to transmit the illusion of three-dimensionality, and can be partly considered as an anticipation of the three-dimensional virtual fruition through the use of headsets.

Following the air raids of 1943, the cemetery suffered several damages, therefore a project for the repair, reconstruction and completion of the Monumental Gallery was drawn up by the engineer Enrico Fleres; these documents are kept at the State Archives of Messina. The documentation offers useful information to understand the state of the structure following the bombings, integrating graphic documents aimed at its repair and completion. The architect Fleres proposes his own original solution for the construction of the central pantheon, simplifying the solution conceived by Savoia (Fig. 3).

Figure 2: *The pillared halls of Campo Santo in a stereograph from 1899. See: https://www.loc.gov/item/2020684019/*



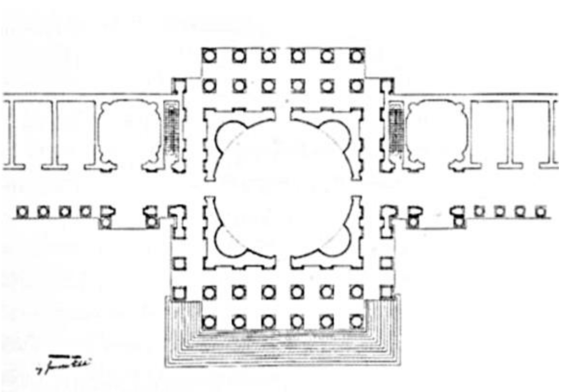


Figure 3: Comparison between the architectural solution adopted by Savoja (top) and the proposal by Fleres (bottom) for the resolution of the Pantheon.

3. THE DIGITAL SURVEY

The architectural survey operations were aimed at providing updated documentation of the current state and verifying the metric correspondence between what can be obtained from the archive graphic documents and what has been built. The integrated operations were aimed at providing both an overall view of the area and detailed surveys.

A laser scanner survey and an aerial photogrammetric survey by UAS were conducted. A FARO 3D focus x330 laser was used to carry out the laser scanner survey (Fig. 4). Nine scans were performed, with particular attention to the main elevation. A DJI Mavic 3 unmanned aerial vehicle (UAV), equipped with a 4/3 Hasselblad CMOS camera, was used to carry out the survey using aerial photogrammetry techniques. The photographic shots were taken following a double grid scheme: the first for the acquisition of nadir photographic images and the second, aimed at better definition of the elevations, with the optical axis inclined by 45°. The acquired data were processed using the Agisoft Metashape software.

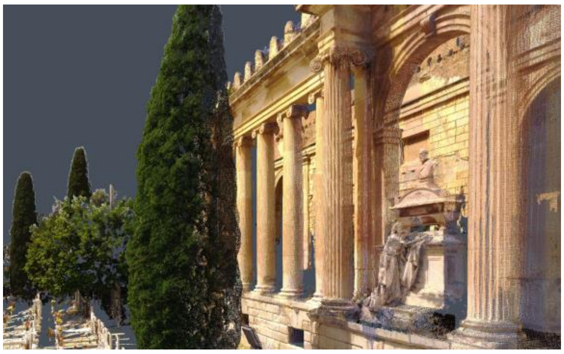


Figure 4: *Dense point cloud, perspective view of the main elevation.*

226 photos were acquired, thanks to which the following were calculated: a sparse point cloud composed of 193,414 points; a dense cloud composed of 22,807,447 points. The survey documents allowed us to verify the correspondence between the Savoja project and the surviving structures. The plan was drawn following a grid with a 1.2 x 1.2 m module. The intercolumniation between the columns positioned within the projecting gables is equal to 4.8 m, while between the columns in axis with the floor level is equal to 2.4 m.

4. THREE-DIMENSIONAL MODELING

The reconstruction process was verified from both a metric and morphological point of view, thanks to what materially emerged from the survey of the surviving structures.

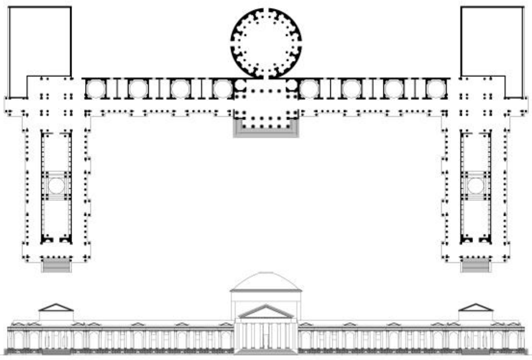


Figure 5: *Plan and main elevation (Drawings by the autors).*

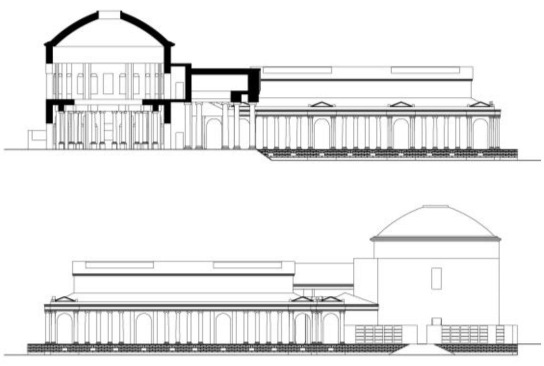


Figure 6: *Cross section and lateral elevation.*

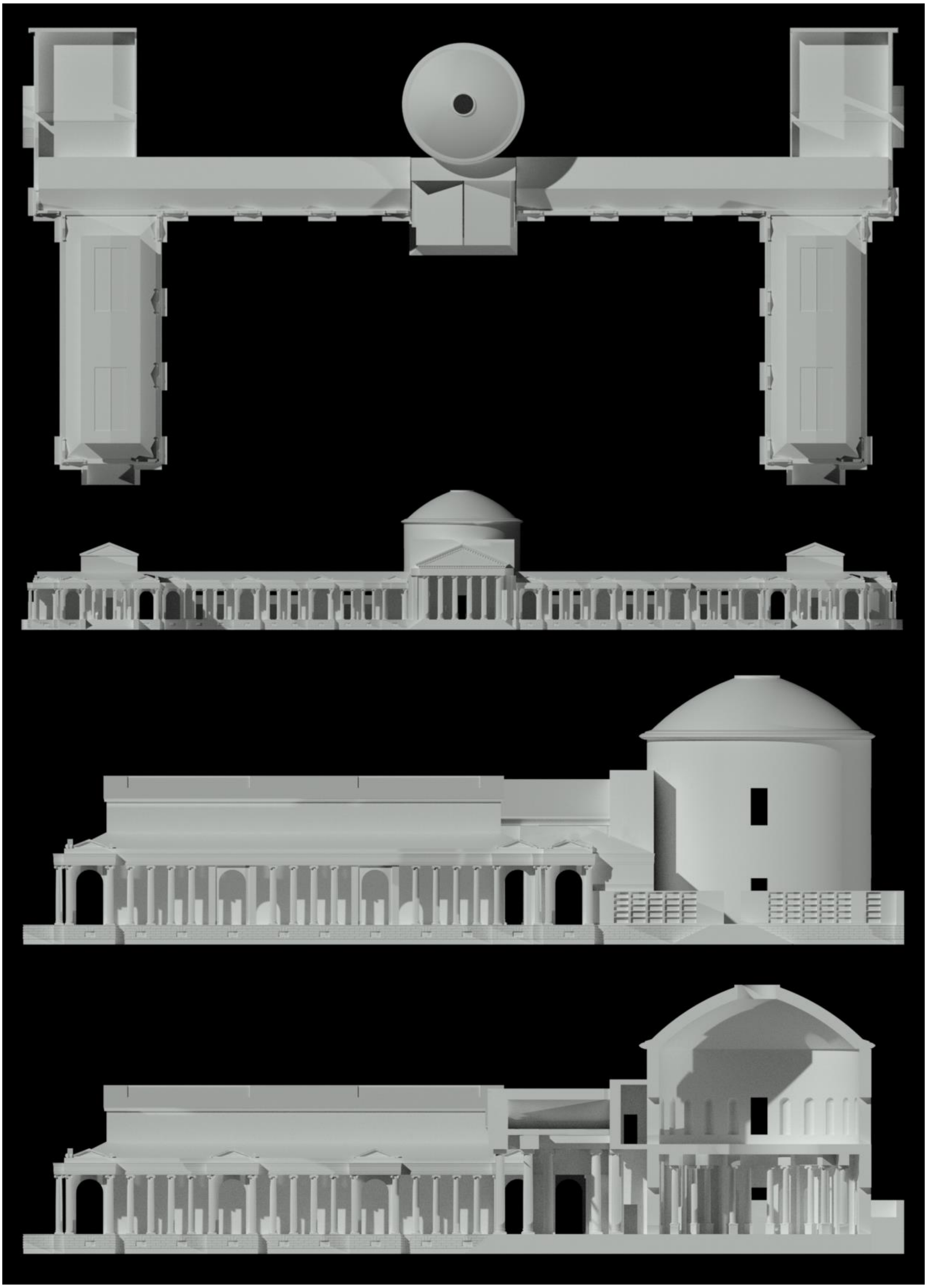


Figure 7: *Rendered views of the model (Modeling and rendering by the autors).*

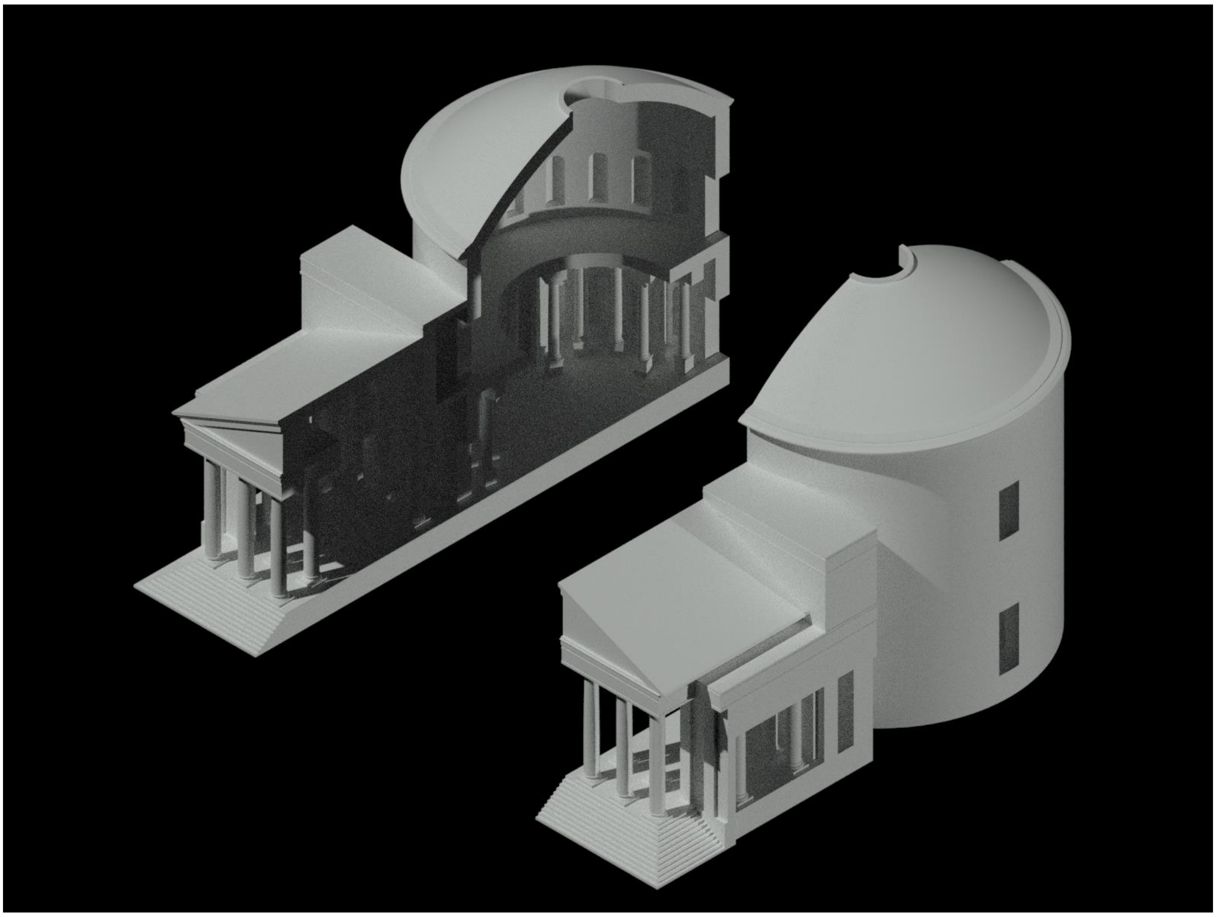


Figure 8: *Aaxonometric section of the model of the Pantheon (Modeling and rendering by the autors).*

A first phase saw the redrawing of the building, carried out in a CAD environment (Figg. 5-6). The plans, elevations, sections were drawn and the architectural details were studied in 2D.
The next phase involved the three-dimensional modeling of the structure (Figg. 7-9); it was decided to propose a model of the famedio relating to that entirety never possessed, and pertinent to the original project prepared by Savoja. This determination led, among other things, to taking into consideration, for the reconstruction of the pantheon, the circular model with internal colonnade, planned by the architect.
This architectural solution, which has reached us in plan, can only be partially perceived in elevation, so much so that, through observation of the same, one can find an almost exact adherence to a subsequent solution, relating to the mid-20th century reconstruction project prepared by the architect E. Fleres.
This second version of the pantheon involved the construction of a simplified portion of the building, based on a quadrangular plan, and expressed by the juxtaposition of a dome to a parallelepiped. In any case, limited to this portion of the building, the choice made inevitably determined a certain degree of freedom in the reconstruction itself. This interpretative freedom is determined in particular by the lack of further graphic drawings, such as sections and plans at higher levels, of the structure as conceived by Savoia. Furthermore, there is the material absence of traces since this portion of the building has never been built. This shows some of the limits and merits of virtual reconstructions; three-dimensional reconstruction is always a scientific process, which is not limited to the reproduction in three-dimensional, but is rather an operation whose scientific and artistic value lies in the process of interpretation of the individual who carries it out.

5. 3D PRINTING

The digital model aimed at producing the analog model through the use of a 3D printer, was produced according to a criterion of simplification of the decorative apparatus, and of all those details not visible at a scale suitable for printing. The reduction ratio considered most convenient for the creation of the analog model was set at a scale of 1:200.

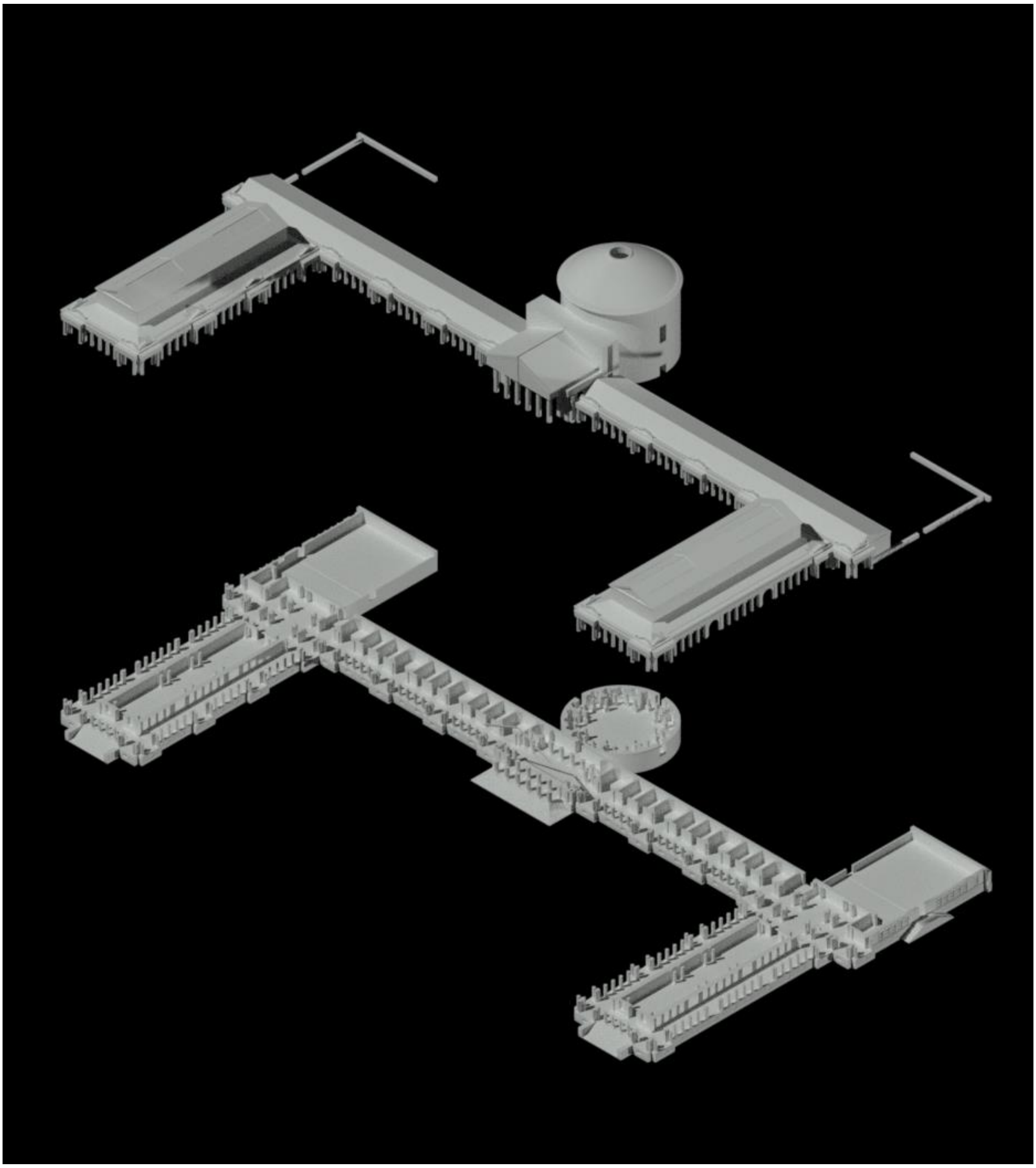


Figure 9: *Axonometric plan section rendered of the model (Modeling and rendering by the autors).*

Printing was performed using UltiMaker S5 3D printers, powered by white PLA with a diameter of 2.85 mm, and capable of managing print volumes of 330 x 240 x 300 mm.
The overall printing time, exceeding 50 hours, was reduced thanks to the simultaneous use of three printers.The model was divided into 12 sections, subsequently assembled on a wooden support measuring 60x120 cm divided into two 60x60 sections (Fig. 10). Considering the main axis of symmetry that divides the pantheon, the part of the building falling to the left of this axis was printed from the base to the roof, differently the portion falling to the right of the same axis was printed 'in plan', that is, sectioned horizontally at the actual measurement of 120 cm above the raised floor level (+ 230 cm) defined by the base. The right portion thus obtained can be considered usable by the blind, haptically revealing the plan.

6. CONCLUSION

The model has been exhibited on more than one occasion, achieving the goal of arousing interest in a little-known monumental architecture that is irremediably reduced to a state of ruin.
In the age of digitalization, analog models, although created through digital processes, still

represent an irreplaceable means of communication in the field of architecture.

Among the open perspectives, the possibility of optimizing the virtual model for loading into a virtual reality (VR) system is highlighted. The 3D printed model could also be useful in the field of augmented reality, becoming a target to be framed through a mobile device with the aim of reaching its virtual analogue loaded onto a web platform accessible to the public.

The proposed experience, inserted within a research context much explored within the disciplinary fields of drawing and representation, but more generally of architecture and archaeology, has allowed the construction, albeit on a small scale, of a particularly evocative architecture, which never before - albeit on a small scale - had been able to reach an effective completion.

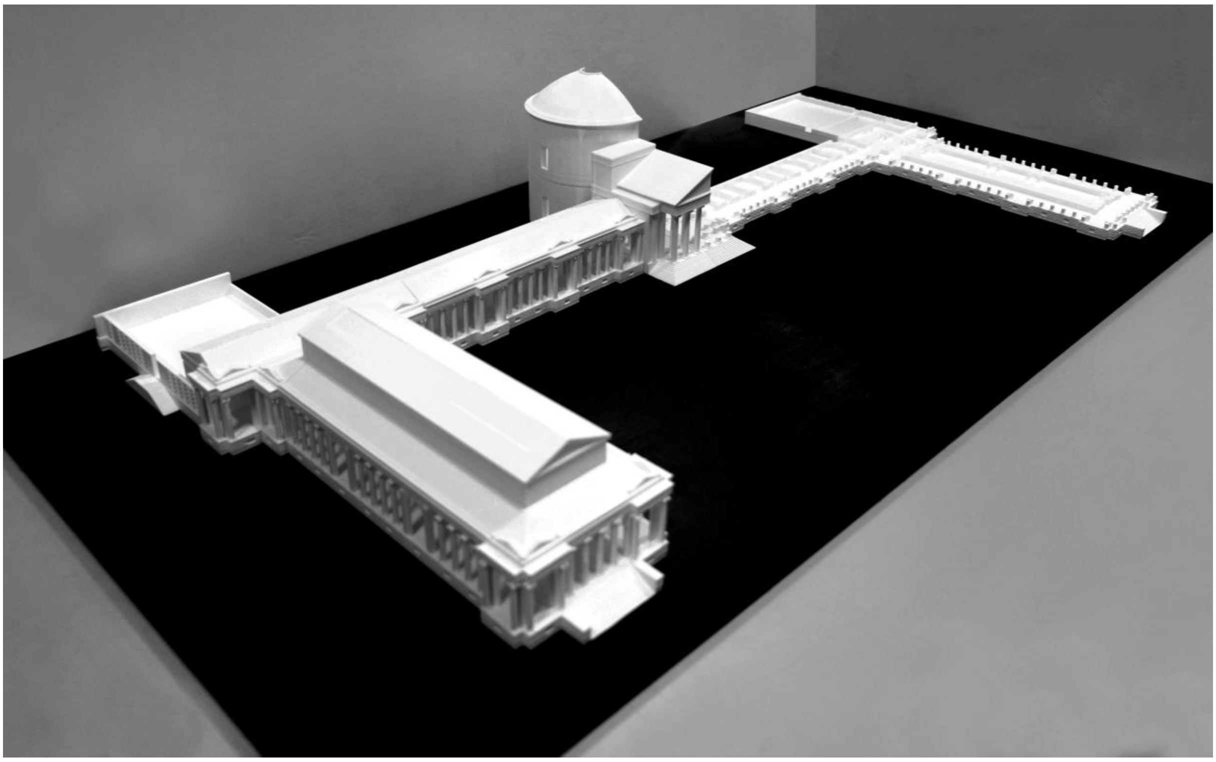


Figure 10: *Photo of the 3D printed model (3D printing and photo by the autors).*

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DAY III
“Hybride Realities”

Friday, March 14, 2025

SESSION I

“Knowledge Architectures”

Moderation: Prof. Dr. Andreas Bienert
(form. Staatliche Museen zu Berlin)

Authority Files for Search and Filter Options in the German Digital Library

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ABSTRACT: A successful search in portals such as the German Digital Library is not a matter of course. Especially for museum objects, bringing them together in the digital space poses significant challenges. This is not surprising: museums use different databases, apply diverse vocabularies and catalogue their collection objects in a very heterogeneous manner. In view of this, the question arises: How can the retrievability of museum objects in the German Digital Library be improved through better use of authority files and controlled vocabulary in metadata? This paper highlights preliminary project results of the research project "*Authority Files for Search and Filter Options in the German Digital Library"*, based at the Institute for Museum Research. It comprises a symptom analysis, a causal analysis focusing on certain limiting factors and the identification of possible solution approaches.

1. INTRODUCTION

The research project *Authority Files for Search and Filter Options in the German Digital Library*, based at the Institute for Museum Research, has already been presented in a very early phase of the project at the EVA Conference 2023 [1]. Now that the project is gradually coming to an end, preliminary results will be presented at the EVA Conference 2025. The following question is addressed within this project: How can the search function in the German Digital Library be optimised through the more consistent inclusion of authority files and controlled vocabulary in metadata? In other words, the research project investigates how more consistent use of authority data can enhance the retrieval of museum objects in the German Digital Library, thereby improving search accuracy through optimised filter options in the portal. The German Digital Library is primarily to be seen as an important showcase: It undoubtedly represents a central platform for access to digitised cultural heritage in Germany and links over 50 million cultural heritage objects across cultural sectors. However, the results of the study are not only relevant for the German Digital Library but can also be applied to other collection portals.

As already emphasised in my contribution to the Eva Conference 2023, a special feature of the research project is that it starts with the data source itself: the collection in the museum - including the database structures used for cataloguing, the underlying controlled vocabularies and the heterogeneity of object cataloguing in museums. A particular added value of the research project is that project results can contribute to the operational work of the German Digital Library through close cooperation with the museum department and other relevant actors and that project results can flow directly into the operational further development of the portal.

The starting point of the project has been a stakeholder workshop that took place on 20 September 2023 at the Institute for Museum Research and brought together selected experts in museum documentation and representatives of the museum community to discuss crucial questions about the characteristics of museum data and their consequences for data exchange (figure 1). The project is also based on an article produced as part of a joint publication project at the Institute for Museum Research in which the special features of data elements in museum object cataloguing are compared with those in libraries and archives [2].

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Figure 1: *Stakeholder workshop at the Institute for Museum Research (20 Sept. 2023). Photo: Chiara Marchini.*

2. SYMPTOM ANALYSIS

In the context of the symptom analysis, it is investigated to what extent certain types of search (faceted search, free text search, etc.) can be impaired for certain entities (object type, person, place, etc.). The focus of this analysis lies on the faceted search, in which a list of results derived from e.g. a simple standard search is restricted by the use of search filters.

The faceted search can be impaired in various ways: On the one hand, it is possible that additional synonymous filter values and/or more generic terms must be selected when restricting a list of results by using a search filter to obtain all the desired hits. In information science, this phenomenon is referred to as ‘reduced recall’. On the other hand, it is also possible that the same filter value conceals different terms, places, people etc. that are not disambiguated by homonym additions. Consequently, users of the portal do not exclusively receive those objects as filter results that are really relevant to them. This scenario is described as 'low precision' in information science [4].

In addition, it is crucial that search filters only contain values that align with the intended content and semantics of the respective filter. Otherwise their 'intension' is not fulfilled. This is the case, for instance, whenever image content (e.g. “Straßenansicht”), object genres or subject categories [5] are included in the values of the filter object type. Last but not least, the same terms should not be scattered across different search filters. However, this issue arises, for example, if some institutions that supply data to the German Digital Library via the coin portal KENOM record ‘Brandenburg’ as a place, but others record it as an organisation (with minting rights): As a result, identical cataloguing information is distributed to two different filters.

The FAIR principles require that (meta)data contain qualified references to other (meta)data [6]. In the German Digital Library, a navigational search via object links can be carried out via entity pages for persons or corporate bodies: A mouse click takes you to all objects that were produced, worked on, acquired or used by the person (category: ‘Has participated in’), or in which the person is depicted, mentioned or thematised (category: ‘Is thematised in’). Cultural heritage objects can thus be linked across institutions and even across disciplines if the same person or corporate body is linked to them. However, this is only possible if identifiers from the Integrated Authority File (GND) are delivered for the respective persons and corporate bodies. Otherwise, if no identifiers are supplied from the GND, it is not possible to create or link to entity pages. By supplying persistent identifiers from the GND, additional information is also made available that is displayed even though it is not included in the metadata of the linked objects, such as vital data and name variants of the person in question.

3. CAUSAL ANALYSIS

Based on the symptom analysis, selected limiting factors that impair information retrieval in the German Digital Library are identified and explained within the causal analysis. To make cultural heritage objects digitally accessible in portals such as the German Digital Library, some basic requirements must already be fulfilled on the delivery data side – beginning with the choice of a cataloguing database.

3.1 DATABASE MODEL

The quality of object data in museums rises and falls with the possibilities offered by the databases used for cataloguing. Museums work with very different database models: Each of them has different advantages, but also different limitations. In some databases, free text entries are possible, individual lists can be integrated or further terms from a separate list can be made available for recording in addition to terms from controlled vocabularies, whereas other database systems only accept terms from controlled vocabularies. Certain information cannot be recorded at all in certain systems because certain data elements are not even available. One system allows typifications of entities, in another system no typifications are permitted. The defined mandatory fields can also be very different in different databases - deviations from the requirements for the delivery data of the German Digital Library (e.g. concerning the object type) are possible [7]. Contrary to relevant recommendations, many databases do not support event-based recording (or at least event-based data modelling when creating the LIDO export). This can lead to serious misinterpretations when delivering data to the German Digital Library.

3.2 CONTROLLED VOCABULARIES

Another important factor that might negatively affect search in the German Digital Library in various ways is the controlled vocabularies used for cataloguing museum objects. Depending on the entity to be recorded or on the academic discipline, one vocabulary may be more suitable than others for different reasons.

Some vocabularies like the GND and the AAT are curated by an editorial team according to strict criteria. Others, such as Wikidata, follow a crowd-based approach, which offers the advantage of a higher degree of currency. For some vocabularies, such as the Dewey Decimal Classification (DDC) recommended, despite certain reservations, by Lindenthal (who has recently been developing a concept on a cataloguing system for the German Digital library) for subject categories [8], there are some technical reservations. Frequently, they are not linked open data vocabularies and are only available as PDF files without machine-readable URIs. Their usability in the sense of the FAIR principles is then limited by the fact that the terms cannot be addressed via globally unique, persistent identifiers. Other controlled vocabularies are not suitable for the retrieval in search filters due to the presence of term strings and due to reasons of syntax.

3.3 CATALOGUING PRACTICES

As Stefan Rohde Enslin points out in an article that was written as part of the joint publication project mentioned at the beginning of this article, this applies in principle: Object cataloguing in museums is primarily carried out for internal use; data exchange is generally not the focus of attention in museum work [9].

The heterogeneity of museum data and the very different cataloguing practices in the individual museum disciplines have concrete effects on recall and precision when data from different institutions is brought together in cultural portals: The cataloguing of synonyms, generic terms etc. as additional subject keywords as well as the different naming of identical places leads to a low recall. This is also the case if one museum records the historical place name and the other the modern one. Moreover, merging cataloguing information in scientific jargon with more generally understandable terms reduces the recall.

In parallel, the recording of chains of terms such as 'coin, medal, means of payment', which is common practice in some museums, leads to low precision. Other museums do not consider it to be necessary to disambiguate possible homonyms due to their specific focus or academic background, which might also reduce the precision.

3.4 LACK OF DATA PREPARATION FOR EXPORT REASONS

Data quality that is not available at the time of cataloguing is difficult to incorporate later on. Nevertheless, there are still certain procedures to ensure the required level of data quality for the various types of searches in the German Digital Library. These procedures include data enrichment, for instance in OpenRefine, subsequent typification of entities as well as certain XSLT mappings. But far too often, museum data is delivered exactly as it was recorded in the database, without being subsequently prepared for data export and, if necessary, enriched afterwards with authority data.

4. SOLUTION APPROACHES

To address these limiting factors, possible solutions are presented. The main levers are to be adjusted, in particular through a more appropriate use of authority data. The goal is to enable a sustainable improvement in the retrievability and linkage of museum objects in the German Digital Library.

One first approach is to collaborate closely with aggregators (and museums able to create their own data exports). This also includes the joint development of data exports with agreement on the sensible handling of authority files. Specific data quality problems can be addressed systematically by using e.g. XSLT mappings, concordance lists, and data enrichment.

A further lever is the mediation of authority data and the communication of their significance for information retrieval in portals. An important contribution to this is made by the Minimum Record Recommendation [10] (figure 2), which will be presented at the EVA Conference 2025 by Stefanie Götsch and Angela Kailus [11]. A central component of its data elements is vocabulary recommendations, a selection of controlled vocabularies that are suitable for online publication, whereby data delivery to the German Digital Library and Europeana are explicitly taken into account as an important showcase.

The development of an example record focussed on controlled vocabularies [12] should also be seen as a way of authority data mediation. The aim is to illustrate at which point in the Lido export which authority data should be integrated in the form of URIs to support information retrieval in the German Digital Library in the best possible way. The example record likewise serves as a supplement to the DDB-LIDO application profile [13].

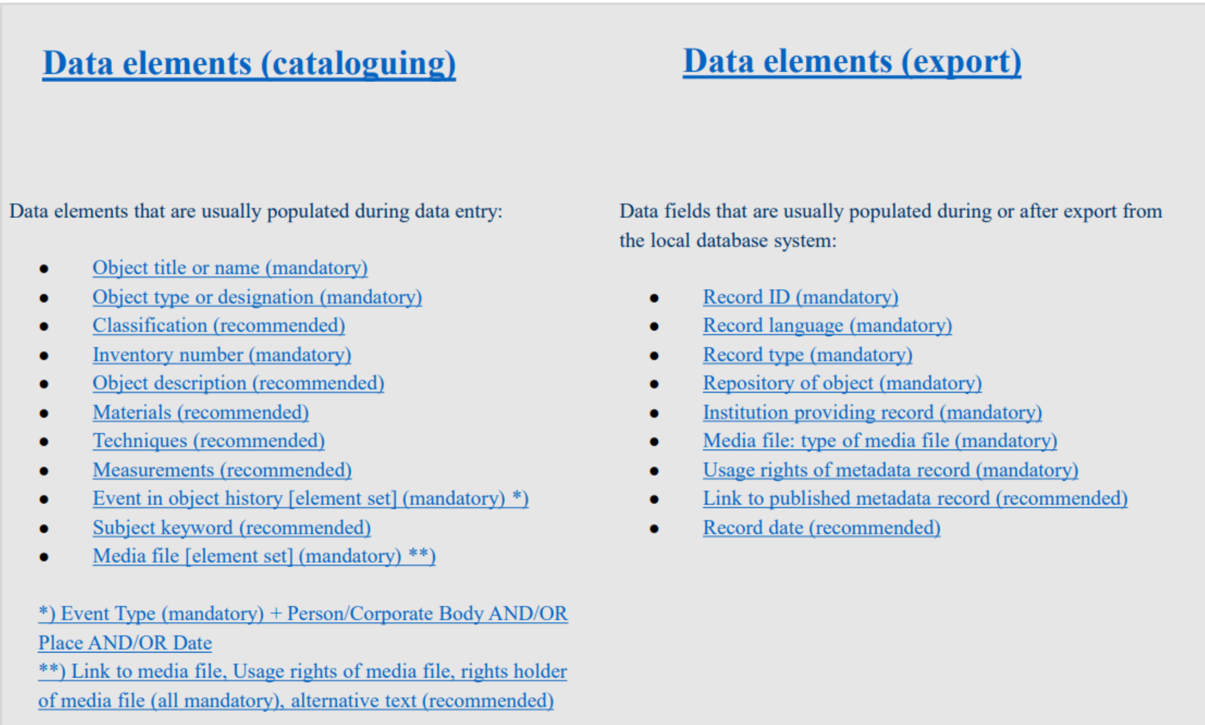

Figure 2: *The data element set as the centrepiece of the Minimum Record Recommendation. The illustration was taken from a slide in the following presentation:* [*https://doi.org/10.5281/zenodo.14162731*](https://doi.org/10.5281/zenodo.14162731).

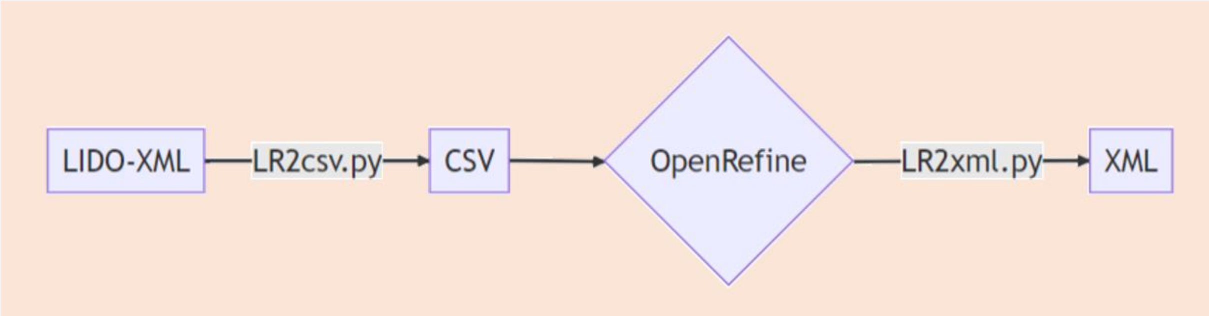

Figure 3: *The Python-based LidoRefine (developed by digiS Berlin).*

Another approach aims to use specific tools to facilitate subsequent data enrichment. Museum staff can use OpenRefine to individualise certain entities retrospectively by enriching controlled vocabularies. Raising awareness of this tool among museum staff and introducing them to the use of this tool would therefore be an important step. If, despite this, no authority data were delivered in the LIDO files, there are already initial theoretical considerations regarding the subsequent enrichment of authority data by the Museum Desk of the German Digital Library: digiS Berlin has developed LidoRefine [14] (figure 3), a Python-based tool that makes it possible to extract specific element paths from the LIDO XML and convert them into the CSV format. The CSV file can then be downloaded and enriched with authority data via OpenRefine. The enriched file can then be uploaded again in a Python environment, and the new path can be written back to the correct location of the LIDO file. LidoRefine has not yet been implemented in the operational work of the German Digital Library. However, it is worth keeping at it and weighing up the benefits, limitations and potential risks of subsequent data enrichment.

4. CONCLUSION

It should have become clear in which ways the information retrieval in the German Digital Library can be impaired. It has also been shown which limiting factors negatively affect recall and precision when searching in the portal or have other negative effects on information retrieval. It is worthwhile to adjust certain levers and to pursue some solution approaches further: Close cooperation with aggregators, including an agreement on the sensible handling of authority files, intensive mediation of controlled vocabularies (e.g. in the context of the Minimum Record Recommendation) as well as the subsequent enrichment of authority data was emphasized. In the future, AI-supported applications could potentially lead to further solution approaches. Finally, it should be emphasised once again that the German Digital Library should be rather regarded as an important showcase, but that the outcome can also be transferred to other collection portals. The results will be published in a few months, a preprint is already available on Zenodo [15].

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Minimum Record Recommendation for Museums and Collections

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ABSTRACT: More and more museums and collections are realising the benefits of publishing and sharing data about their objects on the Web. However, the FAIR Principles, the complexities of exchange formats, and portal-specific requirements pose significant challenges for collections staff. To address these, the Minimum Record Recommendation for Museums and Collections has been developed as a practical guide to ensure consistency and sufficient data quality at a core level. It specifies the smallest possible intersection of key data elements for the online publication of object information across disciplines and museum types.

This article presents the Recommendation. It also discusses the motivation, the priorities and the approach in its development, then describes some practical application scenarios and its reception by the professional community since its publication in May 2024.

1. BACKGROUND AND MOTIVATION FOR DEVELOPING THE MINIMUM RECORD RECOMMENDATION

Museums and collections are more and more interested in presenting themselves and their collections in the digital space. They are not only using their own web databases for this purpose - cultural heritage portals of various specialisations, which bring together object description data from different institutions, are becoming increasingly attractive. In the German-speaking countries, the Deutsche Digitale Bibliothek (German Digital Library) is the largest and most diverse in terms of content, linking the digital assets of German museums, archives and libraries and other cultural heritage institutions. The more heterogeneous the incoming data, the greater the challenge of qualified searchability of the content for the user and thus also for the portal provider who wants to offer a good service.

Why is the heterogeneity of data a particular challenge in the field of museums and collections? In contrast to the library and archive sector, there has traditionally been a lack of overarching organisational structures to support the digital transformation with central recommendations or directives on the use of indexing standards and with appropriate training. The wide range of collection profiles, the diverse conditions and resources of the more than 7000 museums and collections in Germany must also be taken into account.

Many museums are now cataloguing their collections digitally, but practices vary widely. This applies not only to the software systems used, but also to the cataloguing methods employed by museums, which often use self-developed data field catalogues and vocabularies. The Institut für Museumsforschung's annual statistical survey of 2021 shows the heterogeneous and still very much improvable state of progress in the digital indexing and online publishing of collection objects, as well as in the use of authority data [1].

However, there is a growing awareness among collections that they face similar challenges. They are beginning to realise that they can benefit from others' contributions and they can achieve more by working together. In recent years, there has been a tendency towards standardised solutions and joining collaborative net-

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works. LIDO (Lightweight Information Describing Objects) [2] has emerged as a metadata harvesting format that allows data to be successively converted into an interoperable format. LIDO is one of the standard delivery formats for the Deutsche Digitale Bibliothek and Europeana. It will also be a vehicle for the future integration of collection data into the emerging Common European Data Space for Cultural Heritage [3].

2. OBJECTIVE: IMPROVING DATA QUALITY ACCORDING TO FAIR AND CARE

What is data quality? In the context of data publishing, however, the term is often used to refer to the FAIR Principles [4]. Since their publication in 2016, they have become an important, internationally recognised framework for research data management that aims to make data findable, accessible, interoperable and reusable for humans and machines alike. The real challenge here lies in the requirement for machine interpretability. This includes the ability to analyse and link data across the boundaries of individual databases, disciplines and countries. The digital, regionally distributed and interconnected knowledge base to be created will increasingly be processed and analysed by algorithms. They are also responsible for the positive experience of human users with web offerings.

A concept of data quality derived from the FAIR Principles refers primarily to the functional purpose of the data (fit-for-use). The requirements of the users and the context of use determine whether the quality of the data meets the requirements of the portal - to make it easier to find relevant items in the portal, to improve search results, to enable further scenarios for searching, filtering and navigating, and to clearly communicate to users what they can do with the data.

It is not yet widely recognised that data about a collection’s holdings is also research data. It provides the historical context of the collection objects through research and makes the physical artefacts digitally findable, accessible and linkable. It forms the basis for further research that is increasingly independent of the original purpose of the data collection. In its position paper Sammlungen als multimodale Infrastrukturen [5] the German Council for Scientific Information Infrastructures (Rat für Informationsinfrastrukturen, RfII) emphasises the importance of collections as a "major research resource" for which "open use of collections at the highest level of quality" must be ensured. According to the RfII, the great opportunity of digitisation lies in opening up interdisciplinary and transdisciplinary perspectives on collections. The ICOM Museum Definition of 2022 “ ... [museums] operate and communicate ethically, professionally and with the participation of communities, offering varied experiences for education, enjoyment, reflection and knowledge sharing.” [6] also conveys that data quality is not an end in itself, but helps museums to fulfil their educational mission.

Data quality assurance is a requirement for all stages of the data lifecycle. While certain FAIR requirements for findability and accessibility are often implemented by the portal service provider (availability of data through various interfaces, accessibility over defined periods of time, access management in accordance with licensing), the foundation for effective interoperability and reusability is primarily laid during the creation and curation of the data in the local system. On site, a professional description, classification and contextualisation of the object is created based on the physical artefact present and available sources. The course for later publication of the data should be set at the cataloguing stage, taking community standards for knowledge representation into account, in order to enable later machine interchangeability, interpretability and recombinability of the data. This means that local data field catalogues and cataloguing instructions for export to standard metadata formats should be aligned at the design stage. Defined core fields must then be populated in a consistent manner. Wherever possible, standard vocabularies should be used for the most commonly searched entities and terms (persons, organisations, places, dates and generic terms). The main purpose of these data quality measures is initially to improve the precision and recall values for database searches in the portal, but also to provide data that can be better analysed using semantic technologies.

The discussion about provenance research in colonial contexts has opened up another complex field of action for collections. Many have only just begun to reassess their colonial heritage. There is a demand for the ethical handling of information, as called for in CARE Principles

[7]. In order to support collections in providing high-quality and differentiated data on issues relevant here, the Deutsche Digitale Bibliothek has developed detailed cataloguing guidelines [8] for its subportal Collections from Colonial Contexts.

3. TARGET GROUPS AND USAGE SCENARIOS

Many collections feel overwhelmed by the pace of digital development and the complexity of the task of implementing a successful and sustainable digital strategy for their collection data. Often a great deal of individual effort is required for a museum to make progress with its digital presence. Frequently, there is limited or no access to staff with relevant skills in these areas, or the financial means to employ them. In this context, collections need to prioritise which digitisation or data quality management activities they wish to prioritise. In particular, institutions with limited resources are reluctant to meet what are perceived as (too) high requirements.

However, a good presentation of holdings in portals should not only be feasible for large museums, but also for medium and small collections, for institutions that are just starting to publish digitally or that have not yet built up expertise in FAIR data management.

The Minimum Record Recommendation shows them where they can start to ensure the sustainability and future viability of their data. It is therefore designed as a low-threshold recommendation for those elements of object information on which quality management has the greatest impact. More specifically, it is aimed directly at museum staff, as well as museum consultants and those involved in education and training who are actively communicating standards for online publication of object information. It is also explicitly addressed to database software providers. By incorporating the Recommendation into their software products and services, they can ensure that the online publication of object data is technically supported in accordance with the standards.

4. OVERVIEW OF THE MINIMUM RECORD RECOMMENDATION

The Minimum Record Recommendation [9] outlines the essential data elements for the online publication of object information from museums and collections and provides guidance on how to complete these data elements. The Recommendation defines the smallest possible set of elements that are relevant to most disciplines and different types of collections. More detailed levels may be included where this is necessary to cover other documentation priorities.
By ensuring compatibility with relevant standards and emphasising the use of controlled vocabularies, the Recommendation ensures a basic level of data quality and value for users. The LIDO harvesting format provides the basis for identifying the key data elements for online publication, thus guaranteeing LIDO compatibility.

In LIDO, only a small selection of elements is mandatory. At the same time, it allows for a detailed, in-depth description of the object, suitable for a wide range of documentation focuses and aspects. The resulting structural complexity of LIDO is the reason why some collections find it difficult to work with it.

As a LIDO application profile for a specific purpose, the Recommendation is limited to a subset of LIDO elements, while still conforming to the generic LIDO schema. It summarises the core documentation requirements of various specialist disciplines and different types of museums and collections. These have been derived from relevant standards and database models in the field. At the same time, the Recommendation aims to ensure low-threshold access by providing a simple and understandable approach. Its practical implementation results in consistent coverage of the main data elements for identifying and describing objects, as well as the most commonly used search criteria.

The Minimum Record Recommendation consists of two groups of data elements.
Elements that are usually populated during data entry:

- Object title or name (mandatory)
- Object type or designation (mandatory)
- Classification (recommended)
- Inventory number (mandatory)
- Object description (recommended)
- Materials (recommended)
- Techniques (recommended)
- Measurements (recommended)
- Event in object history [element set] (mandatory)
    - Event type (mandatory)
    - Person/corporate body (conditionally mandatory)
    - Date (conditionally mandatory)
    - Place (conditionally mandatory)
- Subject keyword (recommended)
- Media file [element set] (mandatory)
    - Link to media file (mandatory)
    - Usage rights of media file (mandatory)
    - Rights holder of media file (conditionally mandatory)

Alternative text (recommended)
Elements that are usually populated during or after export from the local database system, often (semi-)automatically:

- Record ID (mandatory)
- Record language (mandatory)
- Record type (mandatory)
- Repository of object (mandatory)
- Institution providing record (mandatory)
- Media file: type of media file (mandatory)
- Usage rights of metadata record (mandatory)
- Link to published metadata record (recommended)
- Record date (recommended)

Each data element is presented on a separate page. The pages are consistently structured to allow the reader to quickly understand a data element and find information at a first glance.

A short definition describes the meaning of the data element. Other common field labels used for the element are listed, to illustrate its applicability in different cataloguing systems. This is followed by information on the expected value type (controlled vocabulary, URI, text). Mandatory elements must always be filled, recommended elements should always be filled if information is available. Recording notes give detailed information on how to populate the element, and address common issues that may arise here.

If controlled vocabulary should be used for the element, a selection of recommended vocabularies qualified for Linked Open Data (LOD) application scenarios follows. These include the Art & Architecture Thesaurus, Wikidata, the Integrated Authority File (GND) and more. Other specialist LOD vocabularies may also be applied, although they are not explicitly mentioned in order to keep the Recommendation concise. Terminology advice is accompanied by examples, indicating preferred terms and URIs appropriate for the data element.

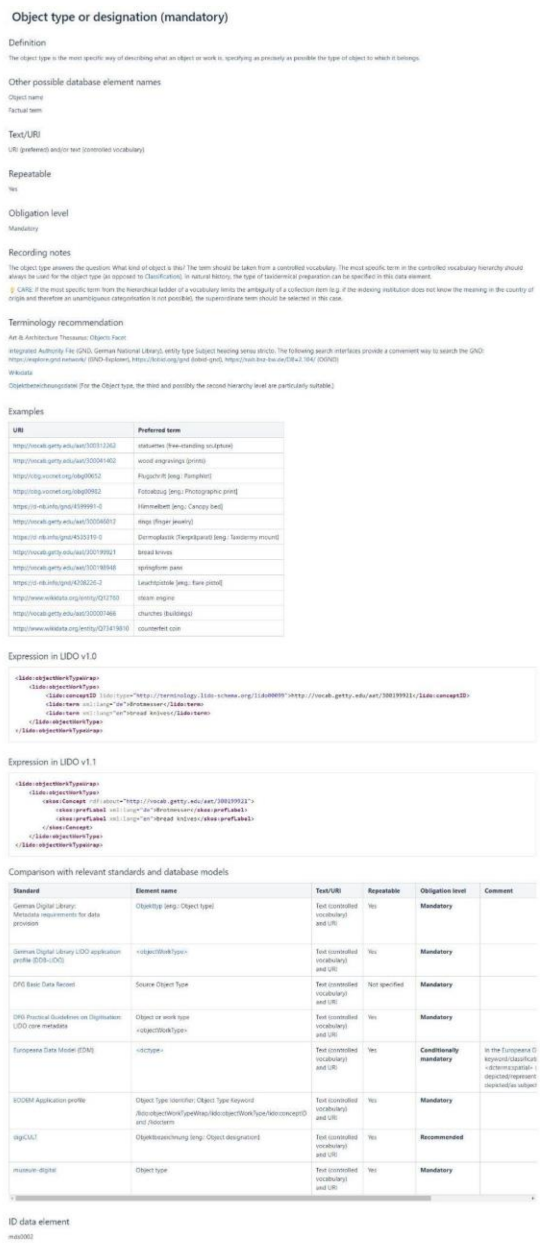

***Fig. 1:** Example of a data element page: Object type or designation*

The expression of the data element in LIDO v1.0 and v1.1 is illustrated by XML snippets taken from sample records. Finally, each data element page includes a concordance table at the end, allowing the element to be compared with how it appears in other standards. These include the Metadata Requirements for Data Provision of the Deutsche Digitale Bibliothek [10], the DFG Basic Data Record [11], the DFG Practical Guidelines on Digitisation: LIDO Core Metadata [12], Europeana Data Model [13], and the data dictionaries of the two major federated databases digiCULT and museum-digital.

Supporting museums and collections in applying the CARE Principles is an important objective of the Recommendation. Cataloguing instructions for the relevant data elements ensure transparent and adequate documentation, taking the circumstances of the objects' acquisition into account, which are often characterised by contexts of injustice and loss of information. In the course of collecting and researching, objects were and are subjected to interpretations - these are now themselves the subject of documentation. On this basis, updated findings from collaborative research with representatives of the societies of origin will also be incorporated into the digital provenance documentation, facilitating further exchange with these groups.

As public institutions in the EU have a legal obligation to ensure the accessibility of their digital offerings on the web, accessibility plays a central role for museums. Several data element pages therefore provide practical advice on how this can be achieved.

In addition to the catalogue of data elements, the Minimum Record Recommendation offers several resources to facilitate its implementation, including a sample record (XML and CSV/XSLX) and a mapping table. The Research and Competence Centre for Digitisation Berlin (digiS) provides a freely available LIDO Validator [14] with an XSD schema file for the Minimum Record Recommendation, allowing validation of data in order to check that a LIDO record conforms to the rules and restrictions specified in the schema.

Recently the Minimum Record Recommendation has been translated into English to make it available to museum professionals on an international level. Accordingly, international standards will be included in the Recommendation to facilitate international applicability.

5. DEVELOPMENT OF THE MINIMUM RECORD RECOMMENDATION

The working group behind the Minimum Record Recommendation consists of various representatives from German cultural or research institutions, bringing different perspectives, backgrounds and experiences to the table.

The idea of developing a concise recommendation to support museums in applying documentation standards and preparing their object metadata for online publication originated from members of the Museum Desk of the Deutsche Digitale Bibliothek and representatives of the museum associations of the federal states of Germany.

In 2022, the Minimum Record Recommendation Working Group was founded by the Museum Desk and the Media Desk of the Deutsche Digitale Bibliothek, the Working Group on Digitisation of the Konferenz der Museumsberatungsstellen in den Ländern (KMBL) and digiS Berlin. Since then, other key players in the field of collection documentation have joined the group, namely the Institut für Museumsforschung (Staatliche Museen zu Berlin - Preußischer Kulturbesitz), the Documentation Section of the German Museums Association (DMB), the Coordination Centre for Scientific University Collections in Germany (Hermann von Helmholtz-Zentrum für Kulturtechnik, Humboldt-Universität zu Berlin), digiCULT-Verbund eG, museum-digital Deutschland e. V., the consortia of the German National Research Data Infrastructure NFDI4Culture, NFDI4Memory and NFDI4Objects, the

Fig. 2: *Organisations and initiatives participating in the Minimum Record Recommendation Working Group*

Museum für Naturkunde Berlin - Leibniz Institute for Evolution and Biodiversity Science, Berlin and the Übersee-Museum Bremen.

Rather than developing a new framework, the focus was on summarising and highlighting the key requirements of existing metadata standards in a clear, easy-to-read online guide.
In order to achieve the key objective of a widespread adoption of the Minimum Record Recommendation, it was necessary to understand the target audience and their specific needs. The Europeana Impact Playbook [15] provided key insights here, in particular its Impact Design phase, which was quickly incorporated into the planning process of how to structure the Recommendation.

The group also used the Change Pathway exercise of the Impact Playbook to identify potential stakeholders, resources, activities and outcomes. This helped to provide a framework for the project. Subsequently, one sub-working group focused on analysing existing standards and developing the element set of the Recommendation, while a second group looked at planning outreach and dissemination activities to ensure the intended impact. Stakeholders were categorised as users (museum professionals, consultants), disseminators (training providers, academia, museum associations), software providers and consumers who benefit from high quality cultural heritage data. Once the first draft was completed, feedback was collected from all stakeholders. This was incorporated into the beta version of the Recommendation, which was published in October 2023. Interviews with key software providers in German-speaking countries, prompted by the Empathy Map exercise of the Impact Playbook, have also provided valuable feedback to refine the development process.

The first full version of the Minimum Record Recommendation was published in May 2024. Since then, it has been presented at a number of national and international conferences relevant to the documentation, publication and re-use of collection data. The initiative has recently been formally accepted as a working group of the Documentation Section of the German Museums Association.

6. COMMUNITY RECEPTION

The response from the museum community has been very positive. Because of its clear structure and practical applicability, the Minimum Record Recommendation has been widely welcomed by different types of collections - from smaller regional museums to large institutions. By focusing on the essentials first, it helps them to review their cataloguing practices and to prioritise and improve their data curation workflows. Sometimes this makes online publication or data delivery to a major portal feasible for the first time.

A number of software providers have already successfully implemented the Minimum Record Recommendation [16]. Some have integrated it into existing data quality checking tools, others have reported a significant simplification of communication with their customers when negotiating the requirements for a software application.

The Recommendation has also proved useful in more technical contexts. As it covers core information about cultural heritage objects, it has been adopted as a starting point for mapping and transforming LIDO to RDF along the lines of the Conceptual Reference Model (CIDOC CRM) [17], a requirement for integrating LIDO data into the knowledge graphs of NFDI4Culture and NFDI4Objects. This will provide a framework in various implementation contexts and ensure their semantic interoperability.

7. OUTLOOK AND FURTHER DEVELOPMENTS

The Working Group is actively engaged in an ongoing dialogue with the museum community and other key stakeholders. This continuous exchange ensures that the Recommendation remains relevant and effective in meeting the needs of the museum community. Museum advisory services play a crucial role in the implementation of the Recommendation by using it in their daily consultations. This direct interaction provides valuable feedback that is constantly fed into the ongoing development of the Recommendation.

In the coming years, communication formats will be further enhanced to facilitate a more efficient and effective exchange. In addition, the Working Group is expanding its engagement with the international museum community. The planned inclusion of other international standards, such as Spectrum [18] and Categories for the Description of Works of Art (CDWA) [19], will ensure that the Recommendation remains aligned with best practice and contributes to the wider development of museum data standards.

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Virtual Models in First-Person Perspectives. A Development Towards Comparative Perception.

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ABSTRACT: In video games, the viewer's perspective is shifted to a virtual world. The reference to real space is faded out. In a presentation of lost architectural monuments via augmented reality, devices such as smartphones or tablets are used simultaneously as a recording and playback instrument to convert signals via image recognition software to control the visual world of experience. For the app 'Monumente 3D' of the Staatliche Schlösser und Gärten Baden-Württemberg, we georeferenced 3D-models of cultural monuments and defined the possible viewing planes and surfaces for viewers in order to be able to take on a new level of perception. The extensive areas can be explored on site from a first-person perspective, whereby the reconstruction of the site is perceived in real time in a 1:1 juxtaposition to the real space. Visitors are localised and their position in the extensive complex is precisely adapted to the respective model section, allowing viewers to experience the entire space in comparison between the medium and reality.

1. INTRODUCTION

As part of the state of Baden-Württemberg's 'Digital@BW' digitalisation campaign, the Staatliche Schlösser und Gärten Baden-Württemberg launched a project in 2018 for the virtual reconstruction of individual cultural monuments in the state.

The aim is to virtually reconstruct lost and historically significant castles, palaces and gardens as closely as possible to the original based on scientific research and using engineering methods. The resulting 3D models will be used for modern and innovative cultural mediation and for scientific purposes. The use of digital formats is intended to appeal to younger visitors in particular. So far, three cultural monuments are offered in the Monumente 3D app for mobile devices. These are: 1. the Hohentwiel Fortress on Lake Constance, 2. the Heidelberg Palace Gardens 'Hortus Palatinus' and 3. the Watteau Cabinet at Bruchsal Palace. An app for Dilsberg Castle on the Neckar will follow in spring 2025 and the digital reconstruction and app for a dining room in Weikersheim Palace later in the year.

An essential element of the project work is the search for and use of innovative methods for the virtual representation of space and the search for new possibilities for model-orientated communication. In the course of the scientific reconstruction and through the handling of the models, the objectives are constantly receiving new impulses that lead to the development of new features. At the same time, innovative approaches and perspectives in the field of visual mediation emerge through the use of the medium of mobile devices. The mobile phone is utilised in its many possibilities and the content is designed accordingly. A development that is constantly gaining in importance is emerging here, which was already formulated in the early days of media theory. ('The medium is the message', Marshall McLuhan, The Gutenberg Galaxy).

2. SCIENTIFIC RECONSTRUCTION – SOURCES AND METHODS

The 3D reconstructions completed to date are the Hohentwiel Fortress, the Hortus Palatinus (the historic palace garden in Heidelberg) and the Watteau Cabinet in Bruchsal Palace. While on the one hand there are two large monuments with extensive areas whose reconstruction is based on the representation of an exterior space, the Watteau Cabinet is a small interior space whose reconstruction must be carried out under different conditions.

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All models are based on a high-precision survey of the existing inventory using TLS and SFM. In the case of Hohentwiel and Hortus Palatinus, the spatial data framework is supplemented by Lidar data in order to take changes in the terrain structure into account. The data obtained in this way is generated into an as-built model and also serves as the basis for the subsequent additions and the visualisation of different construction phases. The knowledge of these phases is provided by the scientific research team via a pool of historical plans, views, historical descriptions and other sources, e.g. on the building materials used. The resulting spatial models are initially created as mass models and then supplemented and refined according to the sources. The shape and dimensions of the buildings are checked in various work phases and textured according to existing documents. The subsequent integration into the national geodata network takes place via various measuring points. Matching and integrating the generated spatial data into the real measured national geodata is a prerequisite for the subsequent localisation of app users on the precisely aligned 3D model.

Figure 1: *high-resolution reconstruction of the Hortus Palatinus, c. 1620*

Different conditions apply to the reconstruction of the Watteau Cabinet, a cabinet room in Bruchsal Palace measuring just 22 square metres, and the task also differs from the first-mentioned monuments. This is a room that was sumptuously painted between 1756 and 1759 and furnished with over 50 panel paintings by the painter Januarius Zick, which was destroyed during Second World War. Its virtual reconstruction is based almost exclusively on historical black and white photographs, which often document the individual paintings in a highly distorted, blurred and colourless manner. In order to reconstruct the Watteau Cabinet, these photographic documents were rectified in several stages and the colours were recreated according to the pattern of existing paintings. The small-scale internal organisation of the room, which was not documented by plans, also had to be reconstructed virtually by rectification and rasterisation. While the model of the fortress and palace garden focuses on the spatial data-supported reconstruction and visualisation of the historical state of large-scale buildings in open terrain, the Watteau Cabinet focuses on the experience of an interior space viewed from close up.

3. CUSTOMISATION OF THE MODELS AND TRANSFER TO THE UNITY ENGINE

The performance of the user's end device is decisive for the aesthetics of the models and the texture of their surfaces within the app. This results in a technical discrepancy between the requirement to create the virtual reconstruction as true to the original as possible and, on the other hand, to display its polygon-rich surfaces for the app in a mobile way. Consequently, our reconstructions have 3D models in high-resolution (fig. 1).

Figure 2: *Reduced and optimized model of Hortus Palatinus for usage on mobile devices*

These then have to be reduced in their data volume for transfer to the Unity engine (fig. 2). The large overall models of the Hohentwiel and the Hortus Palatinus are strictly reduced in the total number of polygons. Model versions with a richly textured surface cannot be displayed as an interactive model due to the lack of capacity of the devices but can be displayed in the content area of the app as static images or as a film. On the one hand, this reduction in detail of the reconstruction means a loss. Unlike the original high-end version, the interfaces appear simplified. On the other hand, this gives the app its own aesthetic, which relativizes any claim to realistic object representation in an advantageous way.

4. STRUCTURE OF THE APP

The overall models of the respective monument are of central importance in the app. They are interactive in many ways. Important individual buildings and places are equipped with interfaces, the points of interest, in the overall model. They lead to content and explanatory illustrations. Thanks to the precise and geodata-compliant integration of the model and the satellite positioning, visitors can recognise their respective local position as a blue dot on the screen. Users can choose between three views for the Hohentwiel and Hortus Palatinus apps: Satellite view, bird's-eye view and first-person view.

Additional information can be found under 'Things to know' under the tiles organised according to different subject areas. This encyclopaedia section is supplemented by AR models and 'speaking images'. This feature is based on the basic idea of Ali Mitgutsch's hidden object books for children, in which a large number of individual small picture stories populate a large overall picture. In the speaking images, individual scenes or elements of a picture surface are arranged in isolation as a gallery of individual pictures. The user selects an individual scene, the image mechanics control the corresponding point in the overall image and an audio narrates a corresponding fictional story. The individual audios of a speaking image are dramaturgically linked and provide a playful access to the background of the events.
Figures should be numbered consecutively from Fig. 1 onwards. Tables should be numbered Table 1 onwards.

5. DEALING WITH SPACE

In the course of the project work, the handling of the spatial aspect of the models also develops. As a result, the viewer's perception of space soon becomes particularly important in the mediation process. It becomes apparent that the perception of space changes considerably with different locations, which has an impact on both the mediation and the scientific knowledge of the reconstructed sites.

One example is the first-person perspective: this view can currently only be used in the app on site, i.e. at the respective monument, as the location is linked to the model in its position in the geodata network. The first-person perspective makes it possible to walk through the model like in a video game. Depending on the viewer's location, the appropriate model view appears on the screen of the end device in real time. In this way, the visual environment of a historical observer can be simulated on the end device. On the screen, the original structures of the building and past buildings are perceived, while in reality the viewer is surrounded by the ruins. The comparison with the former state of the complex is interesting.

Today, some areas of Hohentwiel Fortress appear as places with a wide view of the landscape, while the model shows visitors a narrow area shielded by a wall, such as the steep path leading to the Upper Fortress. The experience of the comparative view reveals to visitors that the active period of the fortress was by no means romantic. The view of the Hegau mountains and the panorama of the Alps, praised by hikers there today, had no meaning before the fortress was destroyed.

The spatial experience that visitors can have with the app in the Watteau Cabinet at Bruchsal Palace is also astonishing. Until its destruction at the end of the Second World War, the cabinet was considered a precious gem within the suite of rooms on the Beletage of the palace.

Figure 3: *Watteau Cabinet, historical photograph, c. 1940, view of the western entrance*

After that, viewers are only able to gain a vague impression of the surviving photographic documents (**fig. 3**). This has changed with the recently presented reconstruction of the entire room. Instead of isolated views of individual wall areas, it is now possible to perceive the individual panel paintings by Januarius Zick in context and thus understand the pictorial references. The possibility of perceiving the overall space on the end device as a congruent environment moving in real time creates a new understanding of the relationships in the spatial structure. Pictorial themes are juxtaposed in a meaningful way. Figures depicted in different paintings appear to communicate with each other and the phenomenon of the privacy of a cabinet room only becomes apparent when individual spatial and pictorial elements are perceived in context.

Figure 4: *Watteau Cabinet, digital reconstruction. View to the south with mirror and painting above, "Drunkard".*

The relationship between a large mirror and the painting of a drunken man above it is one of the aspects that has so far remained hidden from research. We know that the man who commissioned the work, Prince-Bishop Hutten, drank a lot. And so the combination of the mirror and the painting of the drunkard above it, which is almost hidden due to its high position, appears to be a reference to Socrates' "Know thyself" (**fig. 4**).

From Landscape to Fragment.
Survey, Analysis, Digital Dissemination for The Cultural Industry.

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ABSTRACT: The focus of this article is methodological and is based on a reflection that has at its core the notion of scale. The research carried out, in fact, concerns objects of different dimensions: large portions of non-urbanized territory, historical centers, squares and urban spaces, blocks, single buildings, monumental fountains, sculptures, museum works, archaeological fragments. Obviously, for each context investigated we had to adapt the flow of actions that goes from preliminary knowledge to the formalization of the digital communication product. What are the methodological and procedural variants? And what are the elements that remain unchanged both in the knowledge phase (documentation, survey, graphic analysis) and in the communication phase (modeling, rendering, cataloging and archiving, presentation, educational entertainment)? The examples presented offer the starting point for a reflection on the tools and the procedures currently available to those who deal with knowledge, protection and communication of artistic heritage. Artificial intelligence, the diffusion of digital archives and access to open data further expand an already complex scenario, allowing an ever-greater interaction between those who process the information and those who are intended to use it.

1. INTRODUCTION

This article reports some experiences carried out by researchers at the Laboratory of Survey and Representation of the University of Reggio Calabria, to which the authors of the essay belong. The experiences are related to research projects funded by very different bodies and institutions (EU, Ministry of Cultural Heritage, Local Authorities), but having as a common denominator the survey, graphic analysis and digitization, aimed at cataloging and preserving information.

The focus of this article is methodological and is based on a reflection that has at its core the notion of scale. The experimentation carried out, in fact, concerns six objects of different dimensions: a large portion of non-urbanized territory (*Pietra Cappa,* Aspromonte National Park), a medieval historical center (Gerace, Metropolitan City of Reggio Calabria), some squares and urban spaces (located in the town of Mandanici, Sicily), an Arab-Norman church (*St. Peter and Paul in Agrò*, Sicily), the sixteenth-century *Orion fountain* in Messina, an archaeological find belonging to the *Acrolith of Apollo Aleo* (440-430 BC).

Obviously, for each context investigated we had to adapt the flow of actions that goes from preliminary knowledge to the formalization of the digital communication product. What are the methodological and procedural variants? And what are the elements that remain unchanged both in the knowledge phase (documentation, survey, graphic analysis) and in the communication phase (modeling, rendering, cataloging and archiving, presentation, educational entertainment)? We will try to answer these questions through the following graphs and reflections.

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2. TERRITORIAL AND LANDSCAPE SETTING

The area involved is the *Vallata delle Grandi Pietre*, a geosite of significant historical and landscape interest located in the northeastern part of the Aspromonte National Park. The site is characterized by the presence of rocky emergences shaped by weathering. They show themselves as landmarks that attract perceptual attention and characterize the area. The landscape expresses relevant emotional capacities and presents itself as an ideal place for the practice of cultural trekking: a form of slow tourism that allows the enjoyment of a rugged and forgotten territory. The predominant geological element in the valley is the monolith of *Pietra Cappa*, after which the entire area is named. It is considered the largest monolith in Europe, but in reality, geologically speaking, it is a huge polygenic conglomerate. *Pietra Cappa* covers about 4 hectares and a height of about 140 meters. The lowest part of the monolith is at an elevation of about 700 meters and the summit at 829 meters.

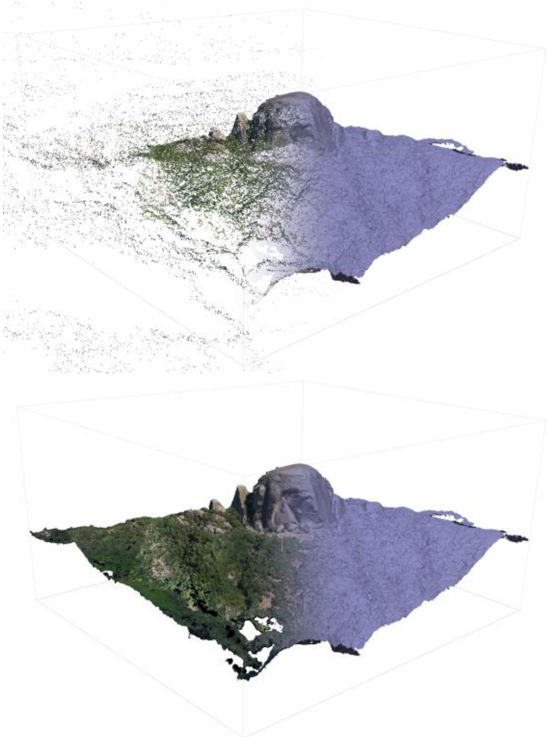

Figure 1: *Two phases of data processing from the photogrammetric survey of Pietra Cappa.*

Pietra Cappa is not the only emergence in the valley. In fact, it is possible to identify other geological signs that characterize the area. Among them, a little more than 1,500 meters southward as the crow flies, is the striking *Pietra Lunga*, which vertically marks a point of perceptual attraction and an opportunity to practice short climbs. To the northeast of *Pietra Cappa*, about 850 meters as the crow flies, is instead the Miocene conglomeratic complex of the *Rocche di San Pietro*, which among its sculptural promontories hides rock cavities that housed small hermit communities of Byzantine rite. Historian Domenico Minuto hypothesizes that the asceterio was frequented in a very remote age, presumably around the 7th or 8th century [1].

In addition to its obvious naturalistic and geological relevance, the *Pietra Cappa* area also has relevant anthropic features that are now in a state of ruins. The remains of the ancient Byzantine fortification of *Pietra Castello* stand out on a promontory chiseled with spectacular inlets that are proposed as spontaneous naturalistic viewpoints. Finally, of significant importance are the ruins of the *Church of San Giorgio* (730 m a.s.l.). They are nestled in a forest of centuries-old chestnut trees, about 500 meters west of *Pietra Cappa* as the crow flies. The ruins are what remains of an ancient Byzantine church, built according to the quincunx typology, a planimetric scheme widely used in Greece and the periphery of the Empire in the middle and late Byzantine period. In 1953 archaeologist Gennaro Pesce carried out an excavation campaign and hypothesized a 10th-century date [2]. Architectural historian Arnaldo Venditti also proposed a similar dating [3]. More recently, studies by Domenico Minuto and Sebastiano Venoso have proposed a date between the 7th and 8th centuries [4].

The landscape and architectural elements were surveyed with image-based and range-based techniques, using laser scans and aerial shots from Unmanned Aircraft System (UAS). The remote surveys were carried out with phase difference laser scanner Faro Focus X 330, using spherical targets with a diameter of Φ 140 mm for the alignment of the point cloud. The two survey data were subsequently integrated and processed for two different purposes: graphic and morphological analysis for professionals and production of digital models for interactive use.

In particular, for the second purpose, the 3D models obtained were optimized in order to minimize the number of graphic primitives. Models related to architectural emergencies were reduced to 50,000 faces, those related to landscape character to about 100,000 faces. This resulted in 3D models suitable for web and mobile app use. In addition, a hiking route was recorded in GPX (GPS Exchange Format) format that can be used on simple GPS navigators or mobile trekking apps.

Finally, we designed the logical scheme of a mobile app that would be able to exploit all the digital materials acquired in order to create a cultural trekking route for a slow and reflective mode of enjoyment of the landscape and the architectural and cultural emergencies present.

3. URBAN AREA

We have carried out a study focused on the multi-scalar investigation process applied to the medieval historical center of *Gerace* (about 13.5 hectares). The work is part of a larger research project (GENESIS - Seismic Risk Management for the Touristic Enhancement of the Historical Centers of Southern Italy). The main objective of the project is to offer support for the safe and conscious visit of cultural heritage in seismic areas, starting from the knowledge of their history and their morphological and construction characteristics, of the architectural and artistic emergencies, of the potential on which to leverage - also through innovative forms of management, based on the use of new media - to insert them into wider tourist circuits.

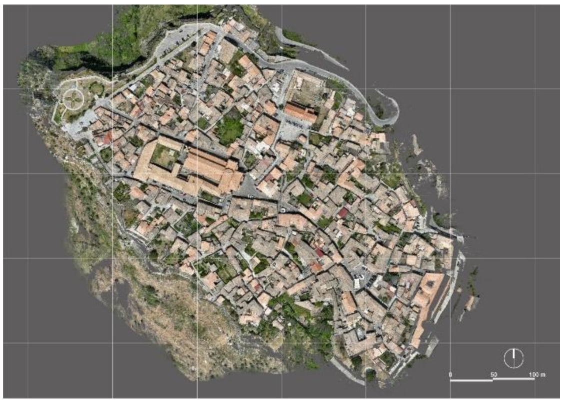

Figure 2: *Aerial photogrammetric plan of the surveyed urban fabric, point cloud, Gerace.*

The first operation carried out consists in the aerial photogrammetric survey of the compact historical nucleus, aimed at drafting documentation and analysis graphs. The survey allowed us to obtain a 2D/3D, multi-scale, multi-precision model, navigable with different visualization modes (point cloud, mesh, solid model and textured model). It also allows for the detailed analysis of numerous aspects: metric data (volume-area-length), elevations and differences in level, georeferencing, orthogonal views, horizontal and vertical sections.

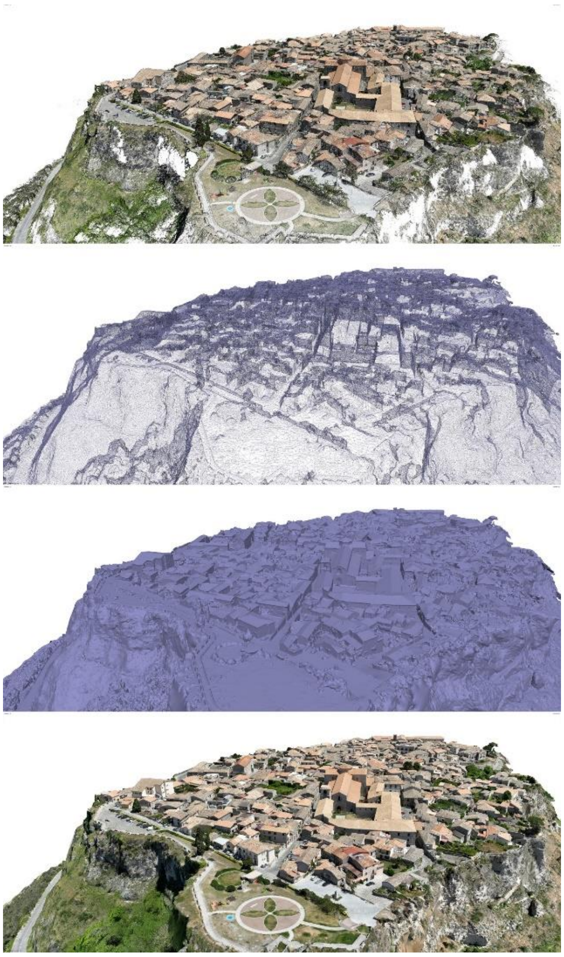

Figure 3: *From top to bottom: point cloud, TIN mesh, solid mesh, textured mesh.*

The model obtained from the photogrammetric survey was integrated with data from the instrumental terrestrial survey. The model obtained through the integration of these two techniques was optimized for insertion into a GIS platform, with the aim of obtaining metric, morphological, qualitative and quantitative information (geospatial, topographic, orthophoto cartographic, from sensors, etc.). Integrating point cloud data with GIS enables better planning across various applications and provides a combination of spatial analysis, visualization, and decision support, enabling more informed and efficient workflows. The point cloud derived from the model can be further integrated into a BIM environment for the execution of Heritage-BIM procedures, or integrated and explored in AR/VR environments, or used as a basis to produce videos and other communication materials [5].
The studies carried out in different fields (both in terms of representation scales and thematic insights) have been merged into an IT platform capable of systematizing the collected data, simulating damage scenarios useful for managing emergency situations, promoting new

ways of enjoying them based on the renewal of the offer and the valorization of new historical-artistic destinations.

The work carried out on the historic center of *Gerace* shows some of the potential offered by the tools currently used for the survey and representation of the historical heritage. Artificial intelligence, the spread of digital archives and access to open data allow an ever-greater interaction between those who process the information and those who are intended to use it.

4. PUBLIC SPACE

The urban public space is delimited by the vertical walls of architecture, buildings, churches and winds through the city. It is a hollow space, an 'empty' in terms of architecture but a 'full' with regard to the enjoyment of urban centers. In small centers, such as *Mandanici* (eastern Sicily), the square gathers a large part of social life, it is the constant setting of the life of the inhabitants. The documentation of the material and immaterial component of these places is, in our opinion, one of the new frontiers that representation aimed at the cultural industry must deal with.

The small village of *Mandanici*, founded around the 9th century by the Arabs, has in its surroundings the monastery of *S. Maria Annunziata*, founded by monks of the Eastern rite. The presence of the monastery testifies to the importance of the center during the 10th and 11th centuries. *Mandanici*, in fact, is located along one of the historic paths that connect the Ionian coast of eastern Sicily with the Tyrrhenian coast. The Byzantine routes, in this territory, wind along the rivers that draw protected and flat paths on the slopes of the Peloritani.

The town is located at the confluence of three rivers: the *Dinarini*, to the west; the *Miceli* torrent, which divides it into two parts; the *Cavallo* torrent, which borders it to the north. The ancient and articulated *via Fabrizi* follows the orographic trend and insinuates itself into the building fabric to flow into the small square of the main church. Here the urban space seems crystallized: protected from vehicular traffic because it is difficult to reach, it is at the center of numerous streets that define divergent directions.

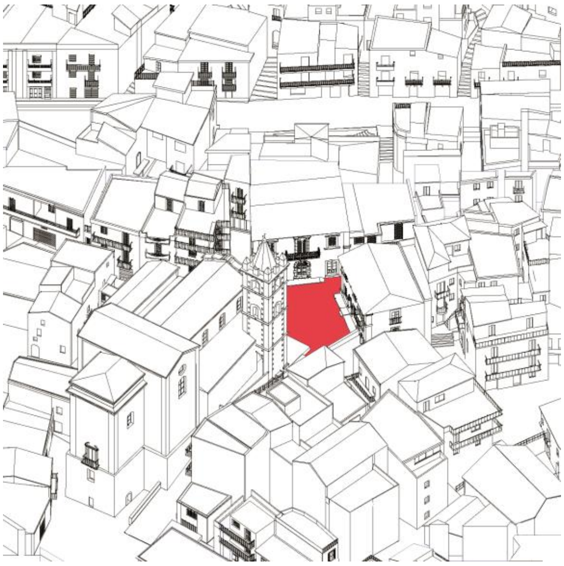

Figure 4: *Santa Domenica square.*

The square is an irregular pentagon that develops on different levels. The architectural backdrops that define it are the facade of the church of *S. Domenica*, and the *Mastroeni-Longo* palace, built between the 16th and 17th centuries with finishes and materials homogeneous to those of the church. Closing the backdrops of the small square is the *Scuderi* palace, contemporary with the *Mastroeni-Longo* one and decorated with the same architectural language.

Figure 5: *Survey of Santa Domenica square.*

The square was surveyed in 2012 with the Faro Focus CAM 2 laser scanner. 15 scans were performed around the perimeter of the external walls of the church. The church was surveyed with seven internal scans. The instrumental survey allowed the restitution of the internal facades of the square. The small size and height of the buildings, in fact, do not allow for optimal viewing. The use of the instrumental survey also allowed us to verify the correspondences between the stylistic elements present on the facade of the mother church and those of the neighboring buildings.

The survey would have been more effective by integrating aerial shots from an Unmanned Aircraft System (UAS) but in 2012 the photo modeling techniques with drones were still in an experimental phase.

5. ARCHITECTURE

The Arab-Norman architecture that dot the coast of the north-eastern tip of Sicily is a widespread and little-known heritage. A documentation and enhancement project involves the creation of a virtual network capable of narrating the phenomenon and promoting the digital dissemination of architecture that represents the most authentic roots of this territorial area. Here we illustrate the documentation of the church of SS. Pietro e Paolo di Agrò, built in 1117 by Byzantine and Arab workers in the Norman era.

The church, today, appears as the perfect syncretism between three different cultures. The plan is a cross between the central-plan church, typical of the Eastern church, and the three-nave church characteristic of the Latin rite. The wall decorations, obtained with the *cloisonné* technique, are clearly of Byzantine origin. The domes and the connection between the drum and the span are clearly of Maghreb inspiration. In fact, the small domes placed as a signal on the central span and on the bema are extradosed of small dimensions and made without resorting to centering. The church is therefore the ideal field of investigation to verify some hypotheses on the collaboration in the Sicilian territory of three different cultures and craftsmen.

The instrumental survey of the church of *Saints Peter and Paul* allows us to obtain a digital twin of the building. The purpose of instrumental analyses is multiple. On the one hand, we aim to document a state of affairs, to crystallize a situation in the process of modifying the state of conservation of a building. On the other hand, the analyses allow us to travel back in time. They allow us to hypothesize, by identifying the geometry and measurement of the building in each of its parts, the methods of tracing the morphological and structural parts and, therefore, to retrace the construction phases.

The buildings constructed in this period by the craftsmen present in Arab Sicily in the 11th century, just conquered by the Normans, present numerous imperfections in the tracing. Often the basic figures that give rise to the building's layout are visibly asymmetrical or present significant alterations from the ideal geometry. The instrumental survey, combined with the knowledge of the practical geometry manuals of the time and the construction customs, allows for further in-depth analysis.

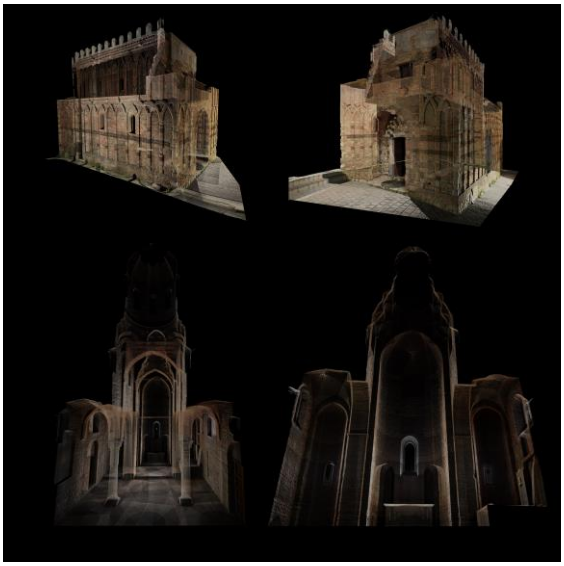

Figure 6: *Survey of SS. Pietro and Paolo.*

The survey of the church was carried out in May 2018 with a Faro Focus 3D laser scanner. 17 external and 18 internal scans were performed. The uncertainty of the instrument is equal to UcRanging = 0.496 mm. The scan alignment process involved the creation of two groups: external and internal, the average stresses in the external scan alignments are equal to 1.9922 mm; the average stresses in the internal alignments are equal to 2.2704 mm. The alignment between the two groups generates average stresses equal to 6.3607 mm. We can therefore say that the average precision of the survey is equal to ± 6.361 mm. It should be noted that the accuracy of a survey is not to be attributed solely to the instrument used but also to the conditions of the building to be surveyed. The church in question is no longer plastered, the internal walls are made of bricks while the external ones have a considerable quantity of different materials. It can therefore be assumed that an uncertainty of ±10 mm, certainly greater than that related to the instrument used.

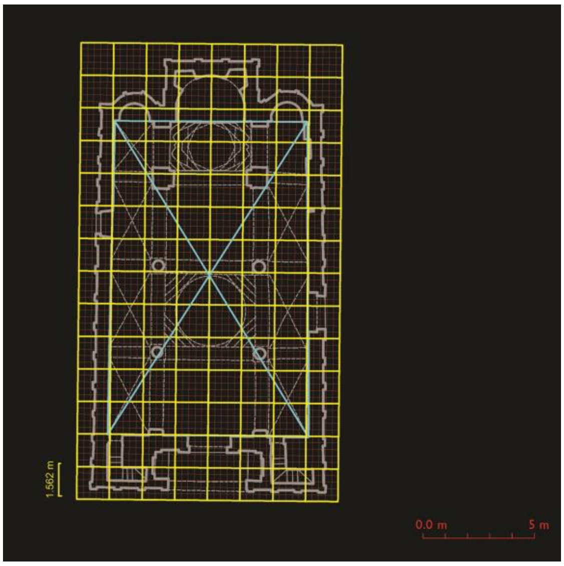

Figure 7*: Regulatory layout. Byzantine foot, cm 31.25.*

Through the survey it was possible to identify, using the unit of measurement of the time - the Byzantine Foot - the regulatory path underlying the geometry of the plan. Through the digital twin, managed in a CAD environment, it was possible to carry out horizontal sections at the level of the floor level: as shown in the image 7, the hypotheses on the tracing appear fully verified.

6. ARTWORK - SCULPTURE

The methodology of surveying and communicating artistic heritage can be exemplified in a work carried out on the sixteenth-century *Orion fountain* in Messina, by Michelangelo's pupil Giovannangelo Montorsoli. *Orion Fountain*, defined by Bernard Berenson as "the most beautiful fountain of the sixteenth century in Europe", was designed in 1553 to celebrate the construction of the first Messina aqueduct. Montorsoli did not simply designed the fountain: his work extended to the redesign of the entire square. In fact, the fountain had to be considered as a parameter to measure the hierarchy of the built-up space, leading to interpretation [6].

The fountain is not in the centre of the square, but in a secluded position: nevertheless, it represents a microcosm linked to the universality of the water element, personified by the Nile, Tiber and Ebro rivers and by the *Camaro* stream. The *Orion fountain* is also a visual goal for the square; from any position, it stands in the foreground against the background of the surrounding palaces [7].

Figure 8: *View of the fountain in the Piazza Duomo area.*

Figure 9: *Survey data processing phases. From point cloud to textured mesh.*

Figure 10: *Orion Fountain. Two-dimensional and three-dimensional views of the digital model.*

The method used for survey was terrestrial and aerial photogrammetry survey. The survey of the fountain was scheduled assuming a scale of 1:20 graphic rendering, with insights up to the

1: 1 scale. The survey of the urban space was performed through the employment of a laser scanner (in some cases to be integrated with a photogrammetric method). The survey of the urban space was scheduled assuming a scale of 1:200 graphic rendering, with insights up to the 1:100 scale. The survey phase was followed by the execution of the 2d and 3d representation (horizontal and vertical sections, elevations), scale 1:50, 1:20, 1:10, 1:5; similarly, the representation in 2d (plan, profiles) and in 3d of the urban space (1: 200, 1: 100).

The survey problem was solved in a fairly simple way using an image-based technique; more complex was the analysis of the relationship between the monument and the context which, due to repeated disastrous events, has changed several times over time, modifying the perception of the monument.

7. ARCHAEOLOGICAL FINDS

The digitized finds, housed at the *Museo Archeologico Nazionale* di Reggio Calabria (MArRC), belong to the *Acrolith of Apollo Aleo* (440-430 BC). They were found in 1923 during the reclamation of the *Punta Alice* marsh near Cirò Marina. The finds were among the remains of a temple that archaeologist Paolo Orsi, following excavations between 1924 and 1929, identified as the *Temple of Krimisa*, dedicated to *Apollo Aleo*.

Originally, the statue had a height of just over two meters. It is one of the rare examples of acrolithic technique in Magna Graecia. The acrolith was a sculpture of which only the extremities were carved in marble: the head, hands, and feet. The body, instead, was made of a wooden structure, covered with cloth drapes. The findings of the *Acrolith of Apollo Aleo*, available to date, are: a head, 41 centimeters high, whose eye sockets are hollowed out; the two feet, with holes in which the wooden support structure was inserted; and a fragment of the left hand.

There are some traces on the remains that suggest the presence of elements that are missing today. On the head was a wig probably made of gold foil or gilded stucco, as inferred from the holes into which it was grafted. The eyes were made of bone and glass paste, while the eyelashes were made of bronze foil. Finally, there are small holes on the feet through which sandals were attached.

In 2016, the National Archaeological Museum of Reggio Calabria decided to make an installation with a hypothesis of the original configuration of the acrolith [8]. At the time of Paolo Orsi, immediately after the discovery, a copy of the head had already been made, which is still in the possession of the Museum today. For the realization of the installation it was necessary to make prototypes of the two feet and the hand fragment, with high reliability of the morphological and chromatic characteristics. Therefore, the Museum asked the *Mediterranea* University of Reggio Calabria to make digital copies and prototypes of these artifacts.

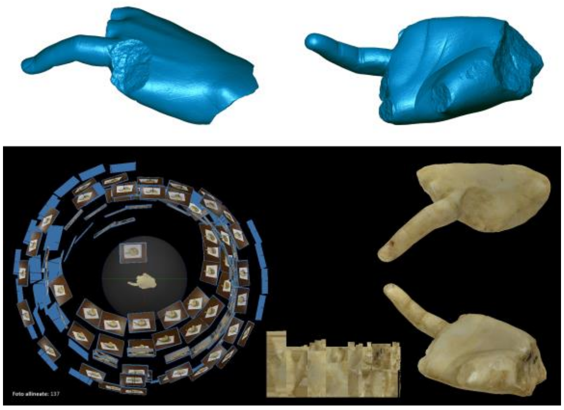

Figure 11: *Acrolith of Apollo Aleo. Processing phases of the survey, digital model and reproduction by 3D printing.*

On this purpose, a two-stage digital survey was carried out: the high-precision survey (with 0.02 mm resolution) carried out one with Faro CAM2 ScanArm monochrome scanner-laser was later supplemented with a SfM (Structure from Motion) survey. In fact, the scanner-laser used provides very high accuracy but allows obtaining 3D (high poly) models without color. Therefore, a second digital surveying process with SfM was carried out. The datasets derived from an accurate photographic survey were subsequently processed using digital photogrammetry software (Metashape). Thus, we obtained a second set of digital (low-poly) models with lower accuracy but with data on the color characteristics of the surfaces. Then, we extracted the texture and UV mapping of the (low-poly) models and, after appropriate color corrections, applied them to the scanned (high-poly) models. The resulting textured 3D meshes were optimized by reducing them to about 1 million faces, the optimal size for prototyping with the 3DSystem ZPrinter® 650 printer.

The prototypes were used by the museum to set up an installation that reproduces a hypothesis of what the *Acrolith of Apollo Aleo* must have originally looked like. Thus, while preserving the integrity of the original artifacts, it was possible to create a dissemination system with educational purposes that brings museum visitors closer to the origins of the artifacts and prompts them to learn more about the acrolithic techniques of classical antiquity.

8. CONCLUSION

The six examples presented offer the opportunity to reflect on the tools and procedures currently available to those who deal with surveying for the knowledge, protection and communication of artistic heritage. We have compared surveys of objects of different sizes, with consequent restitutions at equally different scales; the physical-geometric characteristics are also varied, as they range from large natural elements (Pietra Cappa) to geometrically defined architectures, up to stone elements characterised by accurate details. The tools used are the same, the techniques are identical (terrestrial and aerial photogrammetry, laser scanner). The substantial difference consists in the design approach towards the survey and the subsequent processing.

The digitalization of cultural heritage is a crucial activity to promote accessibility to historical, artistic and documentary heritage, thanks also to the opportunities offered by new technologies. It is a powerful tool, capable of preserving the historical-artistic heritage, making it accessible and enhancing it while safeguarding our identity.

Today it is easy to make leaps in spatial and dimensional scale and verify increasingly sophisticated vision and representation systems: thanks to augmented, mixed, immersive reality, we can appreciate the material consistency of things through the immaterial of the virtual, identifying with works of art, making them accessible thanks to open, inclusive and democratic modes of fruition.

Artificial intelligence, the spread of digital archives and access to open data further expand an already complex scenario, allowing for ever greater interaction between those who process information and those who use it.

9. ACKNOWLEDGMENT

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The drone surveys of *Pietra Cappa* were carried out between September and October 2023 by forester Dr. Francesco Manti with UAS/drone Dji Mavic 2 Pro, with the collaboration of Dr. Elvira Castiglione; the remote surveys were carried out by Domenico Mediati and Paolo Sergi.

This research about the historical settlement of Gerace is supported by the GENESIS (GEstioNE del rischio SISmico per la valorizzazione turistica dei centri storici del Mezzogiorno) Project, code ARS01_00883; the graphic documents were drawn up by Lorella Pizzonia.

The survey and graphic renderings of the *Orion fountain* were made by Miriam Ferrara and Ilaria Fiumara.

The surveys and elaborations of the *Acrolith of Apollo Aleo* were carried out by Francesca Fatta, Domenico Mediati and Andrea Marraffa.

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SESSION II

“Digitally Reproduced”

Moderation: Dominik Lengyel
(BTU Cottbus-Senftenberg)

Optimizing Inference Conditioning Techniques in Image Generation for Participatory Urban Transformation

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ABSTRACT: Generative Artificial Intelligence (GenAI) is emerging as a transformative medium for democratizing participatory urban design, potentially bridging the gap between citizens' conceptualizations and professional representations. While current GenAI tools are divided between professional-grade platforms and accessible solutions for non-experts, technical challenges persist in generating precise and contextually relevant visualizations. This research investigates the optimization of inference conditioning techniques through an open-source approach, implementing an integrated framework within ComfyUI that leverages local computing resources. The methodology combines three key enhancements: prompt engineering through Large Language Models (LLMs), fine-tuning through Low-Rank Adaptation (LoRA), and structural control through ControlNet implementations. Testing this framework on two case studies in Pisa's historical center and suburban area demonstrated how the synergistic combination of these techniques significantly improves the quality and contextual relevance of generated visualizations. Results suggest that advanced conditioning strategies can effectively balance accessibility and precision in participatory urban design tools, supporting the development of more inclusive and sustainable urban transformation processes aligned with the UN's 2030 Agenda goals.

1. INTRODUCTION TO GENERATIVE AI FOR PARTICIPATORY PROCESSES

In recent years, more and more cities have shifted toward the smart city paradigm [1], adopting digital technologies to analyze complex social, economic, and environmental phenomena at an urban scale and pursue the optimization of public investment, service management, and urban development.

Generative Artificial Intelligence (GenAI) plays a key role in this shift. Recent reports on this topic [2, 3, 4] highlight the flexibility with which GenAI can be applied in urban management and planning. Research explores its application in energy management, mobility management, healthcare, hydraulic management, climatic concerns, and biodiversity studies. In Architecture Engineering Construction (AEC), GenAI is increasingly applied at both architectural and urban scales and may offer the potential to develop cross-scale tools and databases.

It is important to understand how digitizing assets and processes in urban management and planning should be oriented toward achieving the Sustainable Development Goals of the United Nations [5]. A UN-HABITAT report highlights the risks and challenges in applying GenAI in urban studies, and applications must consider the importance of a human-centered approach when confronting contemporary and future city challenges [2]. This approach is based on Sustainable Development Goal (SDG) 11, promoting safe, inclusive, resilient, and sustainable cities.

GenAI can facilitate data acquisition, data management, data analysis, data visualization, and predictive modeling in urban environments, tackling different tasks with different purposes. One relevant aspect of fulfilling SDG 11 is the role of GenAI in participatory processes.

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Existing literature shows GenAI supporting participatory processes by enabling the acquisition and processing of extensive qualitative data, converting it into quantitative data for visualization and interpretation [6], and leading to the development of predictive models [7, 8]. One interesting research focus is the analysis of relationships between urban environments and individuals' emotional well-being. Emotional response is fundamental for efficient involvement in participatory processes.

Recent research [9] emphasizes using Large Language Models (LLMs) to interact with citizens, collect and analyze textual data, and support urban planning and design. In the developed framework, LLMs refine prompts for image editing using Stable Diffusion. Prompts act on image portions with features that negatively affect emotional well-being. The images are acquired from street view databases and are edited to simulate renewal interventions. Recent literature on environmental psychology uses street view imagery to evaluate well-being measurements, achieving quantitative comparisons between environment metrics and psychological data, strengthening the scientific reliability of results [10].

However, relying solely on street view imagery risks diverting focus from user engagement to predictive models, limiting community involvement.

Visualization tools are key communicative mediums between professionals and communities in a top-down framework in participatory processes. Instead, it is possible to highlight how image generation can be part of co-design or bottom-up frameworks [11], engaging communities in generating diverse visions of urban development.

2. RECENT ADVANCEMENTS IN AI-BASED TOOLS FOR URBAN REGENERATION

Recent advancements in GenAI image processing enable the development of high-fidelity visualization tools for non-experts, allowing effective representation of human imagination in urban regeneration. GenAI has the potential to bridge the gap between citizens' conceptualizations and professional representations [12]. These visualizations can enhance individual satisfaction and engagement in participatory processes.

The unprecedented progress in image processing, particularly with Diffusion Models (DMs), has shown remarkable capabilities in generating, modifying, and manipulating visual content with increasing photorealism and contextual consistency [13]. Stable Diffusion marked a milestone, offering an open-source alternative to democratizing access to powerful image generation capabilities.

In the current landscape, multiple tools leverage GenAI for urban transformation processes, which can be categorized into two macro-groups based on their focus and target users.

- Professional-grade tools: Designed for sector experts and offer advanced urban design and analysis functionalities. Examples include Autodesk Forma, ArcGIS CityEngine, CITYPLAIN, and Digital Blue Foam. These platforms provide detailed analytical capabilities and support complex design processes.
- Tools for non-expert users: These aim to enhance bottom-up processes in urban design by offering intuitive interfaces and accessible functionalities. Examples include the CityScope project and the UrbanistAI platform.

These applications demonstrate how GenAI transforms professional work and citizen engagement in urban design processes. Professional tools focus on detailed analysis and advanced functionalities, whereas tools for non-expert users emphasize accessible representation and public participation.

While these tools focus on facilitating public participation, several challenges remain. The lack of prompt engineering expertise may limit the precision of generated visualizations. Using unoptimized DMs for specific urban contexts reduces image fidelity and relevance. Moreover, the iterative process of selective image modification, primarily limited to inpainting, restricts flexibility in adapting visualizations.

The convergence of advanced GenAI capabilities creates new opportunities for developing accessible yet sophisticated urban visualization tools [14]. These technologies can transform participatory urban design, enabling non-expert stakeholders to generate high-fidelity representations of their ideas. While professional tools advance precision and analytical depth, platforms for non-expert users democratize the process, fostering inclusivity and engagement. However, challenges remain, particularly in ensuring high-quality visualizations and meaningful community involvement.

3. GENERAL AIM AND RESEARCH-SPECIFIC OBJECTIVES

This research aims to investigate and optimize the application of advanced inference conditioning techniques within existing GenAI frameworks for participatory urban design (Fig. 1). This field of inquiry exists at the intersection of technological innovation in architectural representation and the development of participatory urban transformation processes [15]. Adopting an open-source approach represents a strategic choice aimed not only at ensuring the accessibility of developed tools but also at promoting the collaborative and transparent evolution of the implemented technologies.

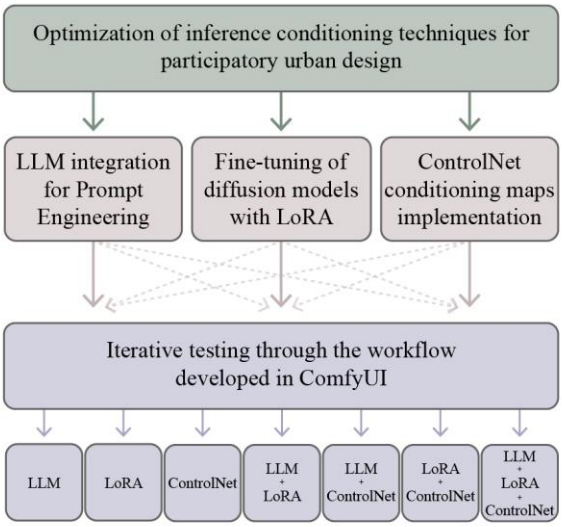

Figure 1: *Hierarchical methodological diagram illustrating the research structure: the first tier presents the general scope, the middle tier delineates specific research objectives focused on three inference conditioning techniques, and the bottom tier demonstrates how these objectives are pursued through iterative testing. This structured approach comprehensively evaluates each technique's contribution and synergistic effects.*

Integrating advanced GenAI capabilities with participatory urban design aligns with the emerging smart cities paradigm and the sustainable urban transformation objectives outlined in Agenda 2030 [4]. The accessibility to advanced visualization tools and the maintenance of high accuracy and contextual relevance standards catalyze more inclusive and effective urban planning processes.

The specific research objectives are articulated along four main directions. Analyzing and implementing the integration of LLMs in the prompt engineering process to overcome limitations due to non-expert users' lack of specific expertise. This approach aims to significantly improve the accuracy of generated visualizations through a natural and intuitive linguistic interface.

Evaluating the effectiveness of Low-Rank Adaptation (LoRA) in fine-tuning open-source DMs. The goal is to develop an efficient method for adapting generative models to specific urban contexts, producing visualizations that faithfully reflect local architectural and cultural characteristics.

Experimenting with ControlNet-based maps, particularly exploring the use of Depth Maps, Canny Edge Maps, and HED Maps (Soft Edge maps). This objective focuses on ensuring precise and flexible control over visual elements in proposed urban transformations.

Assessing the effectiveness of interpolating implemented techniques in generating visualizations that accurately reflect user intentions and coherently integrate with the existing urban fabric, maintaining a balance between design innovation and contextual accuracy.

4. APPLICATION METHODOLOGY OF PROCESS TESTING

In the context of the proposed methodology for optimizing inference conditioning techniques in image generation for participatory urban transformation, ComfyUI has been selected as the tool for experimenting with the synergistic integration of various methodological components (Fig. 2).

ComfyUI is an open-source graphical interface that utilizes a node-based system for executing custom workflows. Its modular architecture proves particularly suitable for implementing the proposed methodological framework for several reasons. The node-based interface enables the construction of complex pipelines that integrate LLMs for prompt engineering, implement workflows for fine-tuning through LoRA, and incorporate ControlNet conditioning maps.

Local computing, supported in this specific case by an NVIDIA® GeForce® RTX 4090 with 24GB GDDR6, allows for documenting and replicating methodological processes accurately and precisely. Computational autonomy ensures the ability to manage model fine-tuning with specific datasets and complete control over the generation process.

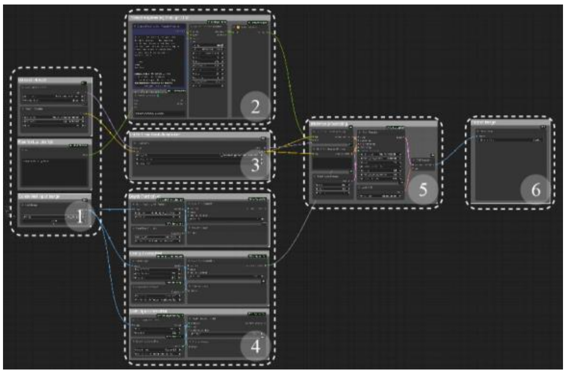

Figure 2: *Comprehensive visualization of the ComfyUI node-based workflow architecture. The diagram showcases how LLM prompt engineering, LoRA fine-tuning, and ControlNet implementations are orchestrated within a single computational pipeline running on local hardware (1 – Input as DM, raw prompt, and source image; 2 – LLM cluster; 3 – LoRA custom node; 4 – ControlNet cluster; 5 – Inference process; 6 – Output).*

ComfyUI's open-source approach facilitates research replicability and the framework's adaptability to different urban contexts.

4.1 PROMPT ENGINEERING THROUGH LARGE LANGUAGE MODELS

Prompt engineering is a relevant strategy in image generation through DMs, given the direct relationship between the quality of textual instructions and the accuracy of visual output [16].

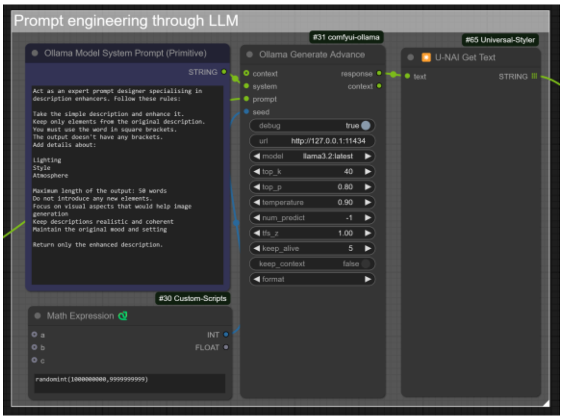

Figure 3: *LLM-based prompt engineering system, showing the integration of Meta's Llama 3.2 3B model through the Ollama custom node.*

In this context, integrating LLMs in the prompt engineering process emerges as a methodological solution to bridge the gap between users' natural expressions and the technical specifications required by DMs, enabling automatic refinement and optimization of textual prompts.

Local computing capacity constraints have significantly influenced the implementation phase, particularly VRAM availability. This consideration guided the selection toward Meta's Llama 3.2 3B, which balances efficiency and performance. This choice consciously differs from heavier alternatives such as Llama 3.3 70B and Llama 3.1 405B, which are incompatible with the adopted local processing approach.

The implementation architecture is articulated through the local installation of the Ollama framework. Integration into ComfyUI occurs through a specific custom node for Ollama, where the prompt engineering system is structured according to a precise architecture (Fig. 3):

- Role definition as an expert prompt designer for descriptive enhancement.
- Operational constraints, including the preservation of original elements, respect for terms in square brackets (essential for activating the LoRA functionality in use), and the 50-word limit.
- Focus on visual aspects such as lighting, style, and atmosphere.
- Qualitative criteria such as realism, coherence, and maintenance of the original mood.

4.2 LORA FINE-TUNING OF THE OPEN-SOURCE DIFFUSION MODEL

DM fine-tuning represents an important methodological element for achieving contextually relevant results [17]. The current ecosystem of fine-tuning techniques offers various paths, including DreamBooth for detailed learning of specific subjects, Textual Inversion for acquiring new concepts through textual embeddings, and Hypernetworks for selective modifications to the model's behavior. However, LoRA stands out for its optimal balance between efficiency and performance.
Both technical and practical considerations guided the choice of utilizing LoRA. From a computational efficiency perspective, this technique requires significantly fewer hardware resources than alternative methods, making it possible to fine-tune models on consumer-grade GPUs while maintaining high-performance inference. The architectural implementation of LoRA presents additional advantages: it

integrates with ComfyUI as an independent conditional node (Fig. 4), preserving the integrity of the base model and enabling the composition of multiple adaptations while facilitating selective application of fine-tuning during inference.

Figure 4: *LoRA integration within the ComfyUI environment as an independent conditional node, enabling selective application of contextual fine-tuning during the inference process.*

The preparation of necessary datasets for fine-tuning is characterized by accentuated operational efficiency. Acquiring images focuses on selecting representative elements of the target urban context without requiring extensive pre-processing, focusing on contextual relevance. Dataset annotation was automated using Microsoft's Florence-2 vision foundation model, which generates accurate descriptions automatically through its multi-modal capabilities.

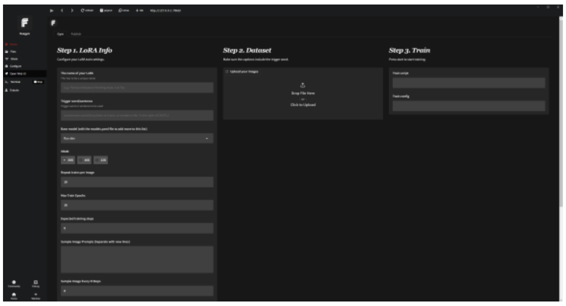

Figure 5: *Fluxgym web UI showing the elements for managing LoRA fine-tuning processes. The interface displays parameter controls, dataset management tools, and training progress monitoring features.*

The practical implementation of fine-tuning leverages the web UI Fluxgym, with the system architecture combining a frontend derived from AI-Toolkit (Fig. 5) with a backend powered by Kohya Scripts. This approach offers several implementational advantages: an intuitive interface for controlling the process, efficient resource optimization, and seamless integration with ComfyUI's comprehensive workflow.

All training utilized the Flux.1-dev as the base model, utilizing the following parameters:

- 20 GB of VRAM
- 10 repeat trains per image
- 16 max train epochs
- Resized dataset images at 512px

Combining LoRA, optimized datasets, and efficient tools represents an optimal balance between accessibility, computational efficiency, and result quality.

4.3 IMPLEMENTATION OF CONTROLNET CONDITIONING MAPS

The ControlNet architecture introduced a significant innovation in image generation, providing a reference framework for inference conditioning through various control channels [13]. In the context of this research, this technique plays an essential role in preserving specific architectural and spatial relationships.

In this case, implementation was based on the Flux-controlnet-collections nodes developed by XLabs-AI, focusing on three primary types of control maps, each with distinct characteristics and functionalities.

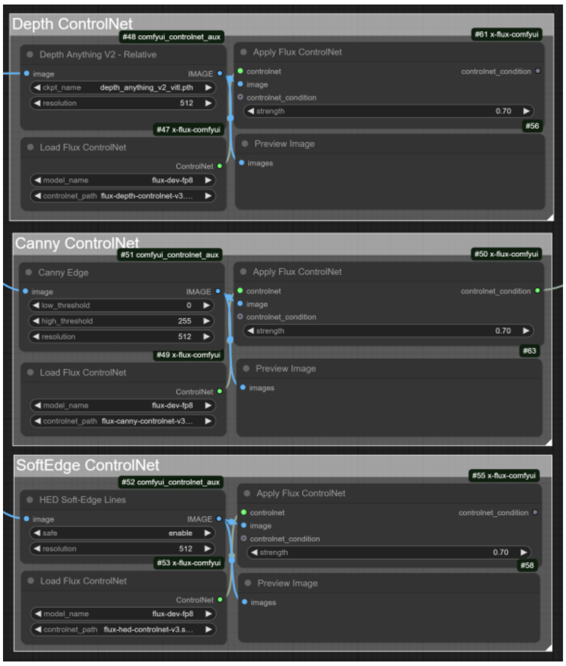

Figure 6: *ControlNet conditioning implementation, showing the integration of multiple control maps (Depth, Canny Edge, and HED). Different control maps are processed and could be combined to maintain structural coherence in generated images.*

Depth Map ensures the preservation of spatial and volumetric relationships, guaranteeing coherence and accurate proportion control.

Canny Edge Detection emphasizes line contrast, preserving architectural details and clearly defining spatial boundaries.

Holistically-nested Edge Detection (HED), or Soft Edge Detection, operates through hierarchical border detection, capturing structural details at various scales and improving overall visual coherence.

The implementation process follows a structured methodology that unfolds into three main phases. First, the system needs to acquire the base image through a photograph of the urban context's current state, then generate specific control maps and calibrate parameter settings for detection. Then, map processing involves generating the three map types, with manual optimization of specific parameters leading to the validation of the quality of overall structural control. Lastly, the system can be integrated into the comprehensive pipeline, where maps are combined in ComfyUI workflow, balancing their influence and proceeding with iterative refinement (Fig. 6).

This component ensures that generated visualizations maintain a consistent structural coherence with existing urban contexts. Properly utilizing diverse control maps enables achieving an optimal balance between generative creativity and architectural constraints, producing spatial contextually relevant results.

5. SELECTED CASE STUDIES

The area identified for this research phase is the city of Pisa (Tuscany, Italy). Considering the current research and findings in the field, within our previous work, the results are strongly influenced by the coherence between the image generation process and the characteristics of the built and natural environments in the specific context.

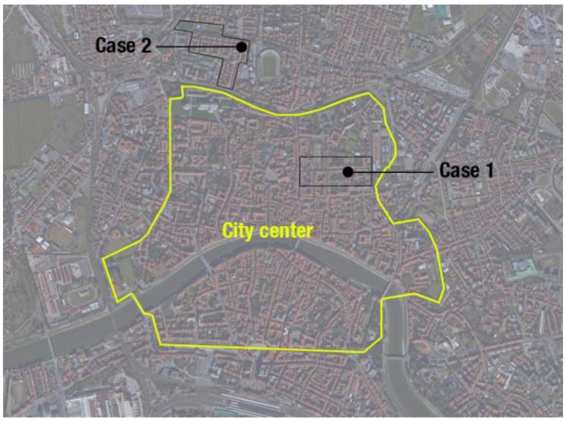

Figure 7: *The general plan of Pisa highlights the two selected case study areas: the historical city center featuring Palazzo Nissim (Case 1) and the suburban residential district of Via Piave/Via Rindi (Case 2). The map emphasizes the contrasting urban morphologies of selected areas.*

Deep knowledge of urban patterns and architectural features is fundamental for identifying areas of focus. Preliminary data collection is essential for the inference conditioning testing phase, especially when working with LoRA training.

Our analysis revealed two main areas of interest: the historical city center and a suburban residential area (Fig. 7). The distinct urban characteristics between these two areas will significantly impact the experiment's outcome.

The city center is characterized by narrow streets with tall buildings and reduced open green spaces. Only a few isolated criticalities can be localized in this area and identified as redevelopment opportunities. These emergencies are typically abandoned buildings, expressing the representation potential at the architectural scale.

5.1 FIRST CASE STUDY: HISTORICAL CITY CENTRE

The first case study is an abandoned building in Via San Lorenzo, also known as Palazzo Nissim (Fig. 8). This building has stood vacant for over two decades due to a long-standing dispute between public and private interests. However, despite the uncertainty, a resolution is within reach, potentially paving the way for revitalization.

Figure 8: *The current state documentation of Palazzo Nissim in Via San Lorenzo shows the abandoned historic building's facade. The image is the base reference for testing the inference conditioning framework in a heritage conservation context.*

In this case, the research tool under study could serve as a medium enabling users to imagine alternative scenarios and envision how the building might look if development were possible. Due to heritage conservation constraints, only limited renovations or restorations are permissible in this case. The experimental tool could foster inclusive and sustainable decision-making by incorporating heritage considerations.

The input data used in the generation process processed in ComfyUI are described below:

- Raw prompt: New life to the [ruined building San Lorenzo] with a conservative restoration project design through new finishes and overall urban redevelopment. The building is again in use with social and accommodation functions
- DM: flux1-dev-fp8.safetensors
- LoRA dataset: 39 images
- Inference step: 20
- Ratio: 1.1 it/s
- Inference time: 15-20 s per image

5.2 SECOND CASE STUDY: SUBURBAN RESIDENTIAL AREA

The suburban neighborhoods of Via Piave and Via Rindi are characterized by wide streets with consistent vehicular traffic. The residential area was initially designed as a public housing project, but its original function has diminished.

The municipality has launched a comprehensive redevelopment plan, which includes recent improvements to green areas and streets. In this case, the area's public spaces, parks, and streets require renovation to improve their livability and introduce urban furniture and services to enhance the quality of life for residents through high-quality urban design (Fig. 9).

Figure 9: *Via Piave/Via Rindi suburban area, showcasing the existing public spaces and residential buildings. The image highlights the current state of urban furniture and green areas targeted for redevelopment.*

The examined research tool is designed as a platform for citizens to evaluate redevelopment proposals, exploring reuse and reconfiguration scenarios that reflect their personal preferences and lived experiences.

The input data used in the generation process processed in ComfyUI are described below:

- Raw prompt: Urban design introducing new forms of ephemeral architecture in the [residential area park]. Street furniture and a public green environment offer innovative spaces for the neighborhood and the citizens
- DM: flux1-dev-fp8.safetensors
- LoRA dataset: 18 images
- Inference step: 20
- Ratio: 1.1 it/s
- Inference time: 15-20 s per image

6. ANALYSIS, INTERPRETATION AND RESULTS COMPARISON

The systematic analysis of the results obtained by implementing inference conditioning techniques revealed significant patterns in the effectiveness of the different applied methodologies. The most relevant aspect emerged from merging the three analyzed conditioning techniques: LLM for prompt engineering, LoRA for contextual adaptation, and ControlNet for structural control. This integration produced superior qualitative results regarding architectural coherence and contextual fidelity, significantly surpassing the performance of individual methods used separately. Using Canny Edge and HED maps through ControlNet proved particularly effective in preserving the morphological characteristics of historic buildings and urban spaces in structural control. Depth maps revealed significant limitations in handling complex architectural images, suggesting the need for further optimizations for this specific mode of control.

The comparative analysis of individual implementations revealed distinct specificity and limitations: while the exclusive use of LLM enhanced descriptive accuracy without guaranteeing sufficient architectural coherence, LoRA implementation alone increased stylistic fidelity but occasionally exhibited compositional inconsistencies. ControlNet, used in isolation, preserved spatial relationships but produced sometimes unconvincing results. We observed a significant amplification of generative capabilities by combining these three techniques. The evaluation of contextual fidelity in the two case studies revealed distinct yet equally significant results.

In the historic center (Fig. 10), the conditioned inference process excelled in preserving the architectural historical characteristics of Palazzo Nissim. In the suburban context of Via Piave (Fig. 11), the greater project flexibility allowed for more innovative explorations while maintaining a convincing contextual coherence.

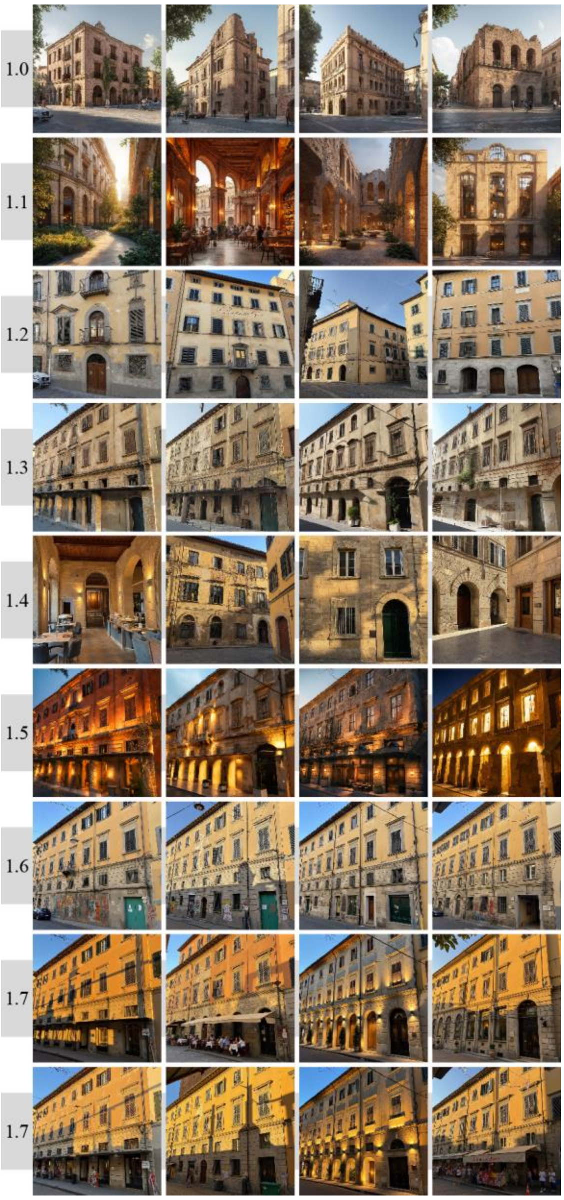

Figure 10: *Comparative analysis of generated visualizations for Palazzo Nissim, showing the progression from the base image through various conditioning stages to the final output (1.0 – Raw prompt; 1.1 – LLM; 1.2 – LoRA; 1.3 – ControlNet; 1.4 – LLM + LoRA; 1.5 – LLM + ControlNet; 1.6 – LoRA + ControlNet; 1.7 – LLM + LoRA + ControlNet).*

A particular aspect emerges from analyzing semantic pertinence in generated visualizations. The prompt engineering through LLM demonstrated notable efficacy in translating abstract concepts into concrete architectural and urban elements, with further enhancement provided by the integration with ControlNet's structural control. This behavior allowed for an optimal balance between conservation and contemporary design in the first case study while facilitating the interpretation of social requalification needs through diverse spatial solutions in the second.

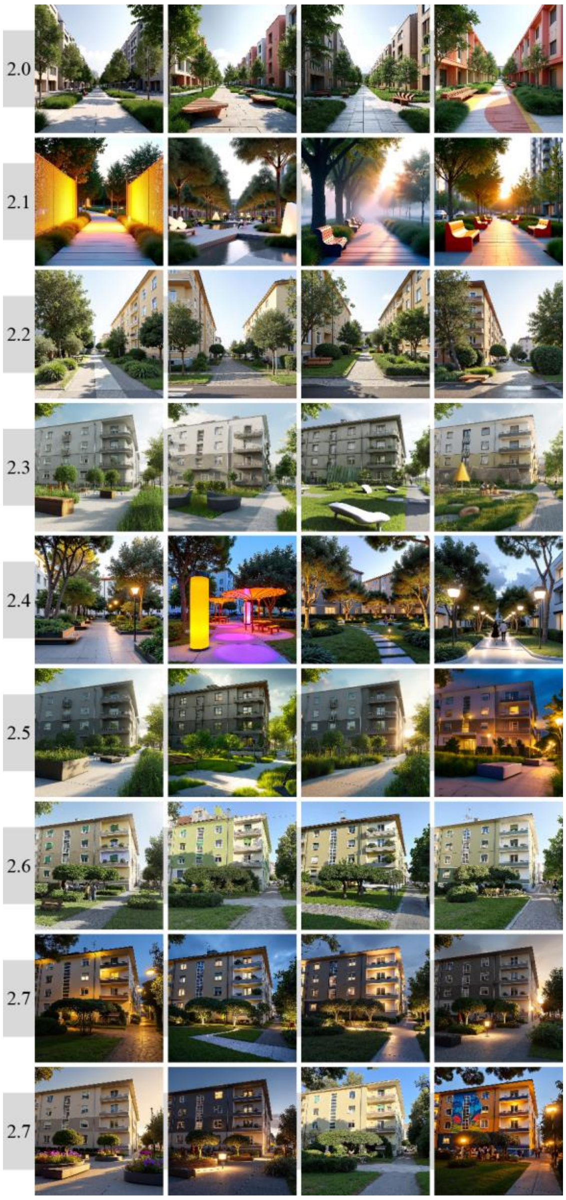

Figure 11: *Comparative analysis of generated visualizations for the Via Piave/Via Rindi suburban area, showing the progression from the base image through various conditioning stages to the final output (2.0 – Raw prompt; 2.1 – LLM; 2.2 – LoRA; 2.3 – ControlNet; 2.4 – LLM + LoRA; 2.5 – LLM + ControlNet; 2.6 – LoRA + ControlNet; 2.7 – LLM + LoRA + ControlNet).*

The generated images through the complete framework (LLM + LoRA + ControlNet) exhibited superior communicative efficacy, distinguishing themselves in their ability to represent complex project scenarios in an accessible manner while maintaining a convincing balance between realism and transformative potential. This characteristic is particularly valuable in participatory design, where communication between technical and non-technical stakeholders is key.

The overall analysis suggests that the integrated approach developed constitutes a fertile ground for further investigation in generating conditioned architectural visualizations [18], offering a suitable balance between technical accuracy and communicative accessibility.

7. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

This research has explored the optimization of inference conditioning techniques for image generation in the context of participatory urban transformation, revealing promising results and outlining future development directions.

The primary limitations encountered are primarily related to the computational capabilities of the hardware used (NVIDIA GeForce RTX 4090 with 24GB GDDR6), despite this configuration enabling high-quality results. Access to greater computational capacity could enable the implementation of more advanced fine-tuning techniques, such as DreamBooth, or more complex base models.

It is essential to emphasize that, within these hardware limitations, the quality of images generated through the combined approach LLM + LoRA + ControlNet has reached notable accuracy and contextual coherence.

A primary direction for further development involves extending the methodology to a broader range of urban contexts, including rural areas, contemporary dense urban environments, and diverse public spaces. Applying the framework to these scenarios may reveal specific effectiveness trends and suggest contextual optimization of conditioning techniques. Developing sets of parameter-specific conditioning strategies for different urban contexts appears particularly promising.

The analysis has highlighted that success in applying these technologies is intrinsically linked to conditioning quality. While dataset availability constitutes a necessary foundation, the sophistication of conditioning techniques determines most of the resulting quality. Experience has demonstrated that approaches limiting control through textual prompts produce significantly inferior results compared to implementing multi-level conditioning strategies. This contributes significantly to architectural representation, suggesting a methodology-based paradigm focused on meticulous control of the generative process.

The potential demonstrated by these experimental tools suggests concrete possibilities for implementation through simplified and accessible interfaces. Translating these technologies into accessible tools could democratize architecture visualization, maintaining high-quality standards while leveraging advanced conditioning techniques.

The developed framework fits emerging AI regulations, including the EU AI Act [19]. In the specific context of participatory urban visualization, current regulations do not present significant obstacles to implementation, requiring primarily transparency in the process and clear communication of tool limitations.

The results obtained open up multiple directions for future research development. Quantitatively, extending to a broader range of case studies will enable the validation and refinement of conditioning techniques in diverse contexts. Qualitatively, integrating complementary strategies like inpainting and outpainting promises to increase control over the generative process further. Following the quick evolution of DMs, which continue to show significant progress in quality and control, will be fundamental.

Future research should focus not only on technical optimization but also on developing framework methodologies that facilitate the integration of these tools into professional practice. The emphasis on accessibility and user-centric design reflects a broader shift in architectural practice toward democratizing technological tools [20]. Particular attention must be paid to developing simplified interfaces to ensure advanced conditioning techniques are accessible without compromising efficacy, balancing accessibility, and comprehensive control over the generative process.

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ELIO: Innovations in Object Digitization and Business Models in the Cultural Sector

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ABSTRACT: Scalable and sustainable digitization is a challenge for modern Galleries, Libraries, Archives, and Museums (GLAM) due to the rapid development of technology, high financial demands, strict legal requirements, and the technological challenges associated with the diversity of collection objects. The ELIO project is a pioneering initiative of the Museum für Naturkunde Berlin that addresses these challenges. ELIO is developing innovative prototypes for digitizing cultural assets in collaboration with leading technology companies to drive digital transformation in GLAM. The project focuses on tailored imaging technologies and business models for collection digitization.

1. INTRODUCTION

The ELIO project (Entwicklungslabor für Innovation in der Objektdigitalisierung) offers an innovative approach to the digitization of collection objects in museums, galleries, archives and libraries (GLAM). The digitization of cultural assets is crucial in modern museum work to enable both long-term preservation and access to these collections. The project aims to develop solutions that meet the technological requirements and needs of museum practice. It is particularly important that the project offers scalable and customized technologies for a wide range of objects of different sizes and materials.

The ELIO project will develop prototypes that enable museums to digitize their collections efficiently. This is of central importance as the variety of objects to be digitized ranges from small artifacts to large-format exhibits. The development of innovative imaging and data curation processes is therefore a key element in meeting the requirements of the various museums and providing a long-term, sustainable solution. [1]

Figure 1: *ELIO Logo*

2. BACKGROUND AND MOTIVATION

Museums and other GLAM institutions face the challenge of making their collections accessible to a wide audience while working with limited financial resources. Digitization offers a solution to expand access to cultural assets worldwide while preserving collections for the future. Digitization is not only a technical necessity, but also a means to reach new audiences and promote interactivity with the public.

The technology behind digitization needs to be flexible,scalable and user-friendly to accommodate a variety of objects of different sizes and materials. While some museums digitize smaller artifacts, the digitization of large exhibits requires specialized solutions. The ELIO project addresses precisely this challenge by developing customized technologies such as 3D scanning and

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photogrammetry that offer high precision and flexibility. These technologies enable detailed object recording, which is essential for conservation and long-term archiving. Flexibility refers to the ability of these technologies to adapt to various object types, from small, delicate items to large, complex structures, ensuring high-quality digitization across different scales. Scalability, on the other hand, ensures that the systems developed can be applied to a wide range of objects, from individual pieces to entire collections. This scalability allows museums to expand their digitization efforts as needed, accommodating growing collections or increasing demand for digital content without compromising on quality or efficiency. Usability, as an additional goal, ensures that these technologies are easy to operate for museum staff, enabling them to efficiently digitize collections without requiring extensive technical expertise. This focus on usability enhances the overall effectiveness and sustainability of the digitization processes. [2]

3. PROJECT DESCRIPTION

The ELIO project was launched by the Museum für Naturkunde Berlin and aims to develop innovative solutions for the digitization of collection objects. By working closely with leading technology companies, we aim to create customized systems that meet the specific requirements of museums, archives and libraries. The solutions include user-friendly, advanced imaging technologies such as high-resolution photogrammetry and 3D scanning, which make it possible to digitize objects with high precision and detail.

A key element of the project is the development of sustainable business models that enable museums to generate revenue from their digitization activities and expertise. These business models will help to ensure the long-term financial sustainability of the project while promoting access to cultural heritage worldwide. The close collaboration between public institutions and private technology companies is an interdisciplinary approach that addresses both the scientific and economic needs of museums. The development of these technologies offers a promising perspective for digital transformation in the cultural sector.

Figure 2: *3D digitization of a beetle using high-precision scanning - an example of the application of innovative imaging technologies in the ELIO project.*

4. TECHNOLOGICAL INNOVATIONS AND METHODS

The ELIO project relies on a variety of technological innovations as well as longterm expertise by Museum staff enabling collections to be digitized with the highest precision and the collected data to be managed efficiently. The project focuses on developing imaging technologies, the use of artificial intelligence, automation, and standardization and interoperability of digital collection data. In the following subsections, each of these points is discussed in more detail.

4.1 IMAGING TECHNOLOGIES

The digitization of objects requires the use of advanced imaging technologies that can capture 2D and 3D data. The key technologies used in the ELIO project include established 2D macro and Micro imaging with stacking as well as high-resolution photogrammetry and 3D scanning. These technologies allow to create precise digital representations of collection objects that can be used freely and without restrictions for all kind of purposes, whereas research and education continue to be the main target groups.

An innovative approach within the project is the development of a modular system for 3D object digitization. This system will allow a wide range of objects — from micrometeorites to large-scale exhibits — to be digitized efficiently. This is particularly important as many museums face the challenge of providing solutions for an increasing amount of requests for 3D imaging.

4.2 PROCESS AUTOMATION AND ARTIFICIAL INTELLIGENCE IN THE DIGITALIZATION PROCESS

Another key area of innovation in the ELIO project is process automation, which makes the digitization workflow more efficient and less error-prone. The use of automation technologies not only optimizes the digitization process, but also enables the development of workflows that accelerate the entire process. Automation includes, in particular, the processing and analysis of image data, which significantly reduces the effort required for data preparation. This automation not only accelerates the digitization process but also improves the consistency and accuracy of the data. [3]

Automation is also used in other areas of the digitization process, such as the standardization of data formats. Previously, manual intervention was required as different camera systems generated different file formats, which could lead to inconsistencies. With the introduction of automated systems for data standardization, these problems are now solved efficiently and error-free. This not only saves time, but also ensures consistent and scalable data processing across the entire collection.

A new aspect of the project involves the integration of machine learning for the automated recognition and classification of objects within digital collections. This would enable museums to digitize and categorize their collections more quickly and efficiently. Unlike the previous uses of AI for process optimization, this application of machine learning focuses specifically on data classification, improving the accuracy and speed with which objects can be identified, cataloged, and indexed. By automating these tasks, museums can enhance the consistency and quality of their digital collections while significantly reducing the time and effort required for curatorial and conservation work.

4.3 STANDARDIZATION AND INTEROPERABILITY

An important goal of the ELIO project is to develop a system that ensures that digital collection data from different sources is interoperable. To achieve this, the project will develop a pipeline or framework that converts non-standardized data from different systems into standardized formats. This standardization takes into account international standards and best practices to ensure that the data can be transformed to the needs of a large variety of systems, such as collection management systems or data aggregation systems.

By creating this framework, museums and other GLAM institutions will be able to manage their collections in a more efficient manner and make them accessible to a global audience. Standardization is crucial to enable seamless integration of the collected data into diverse platforms and to ensure the long-term sustainability and usability of the digital collections. In addition, this process promotes collaboration and data sharing between institutions, enriching the global cultural heritage ecosystem and facilitating the international exchange of collection data.

5. BUSINESS MODELS AND SUSTAINABLE FINANCING

A central component of the ELIO project is the development of business models that enable museums and other GLAM institutions to finance the digitization of collections in the long term. These models are based on the provision of object digitization services and the development of innovative products based on the digital content. Crucially, the business models should envision a sustainable source of income for museums, which often must work with limited financial resources.

Close cooperation between public institutions such as the Museum für Naturkunde Berlin and private technology companies ensures that the developed business models are both technologically innovative and economically viable. The project shows how museums can not only preserve their collections and make them available to the public but also use them commercially to drive the digital transformation in the cultural sector.

Another aim of the ELIO project is to provide digital infrastructures enabling smaller museums and other GLAM institutions to use innovative digitization services without having to make high initial investments. These service models are particularly important for smaller museums that do not have the necessary resources to develop or acquire their own digitization technologies.

6. SOCIAL AND CULTURAL IMPACT

The ELIO project seeks to achieve technological and economic impact while fostering meaningful social significance. The digitization of collections enables museums to make their holdings accessible to a global audience, democratizing access to culture and history. Especially in the context of the growing importance of open access and the demand for greater inclusion and participation in the cultural sector, the project promotes cultural participation and the public understanding of cultural assets. Besser et al. (2015) underscore that digital collections are revolutionizing traditional museum work and represent a radical change in the way museums present, archive, and make accessible their collections. Through this digital transformation, museums can expand their cultural offerings in new, innovative ways and increase public engagement. [4]

7. EFFECTS ON THE MARKET LANDSCAPE OF MUSEUMS

Digitizing museum collections has far-reaching implications for the market landscape of museums and other GLAM institutions. In today's digital era, museums are increasingly faced with the need to diversify their offerings in order to fulfill their cultural mission while surviving in a competitive marketplace with growing market demands and financial uncertainties. By implementing innovative digitization processes and developing new business models, museums can present their collections in a way that is accessible and appealing to a wider audience, resulting in a greater international reach, as Brown (2020) suggests. [5]

7.1 CHANGES IN THE MUSEUM INDUSTRY

By implementing innovative digitization processes, museums can engagea wider audience. The introduction of digital collections changes both the way museums curate their exhibitions and how collections con be accessed. Digital collections allow for broader, geographically unbound accessibility, resulting in a wider international reach. In this context, the notion of the 'museum without borders' is becoming increasingly relevant as the physical presence of the museum is complemented by digital platforms. [6]

At the same time, digitization is changing the competitive landscape. Museums that do not invest in modern digitization risk falling behind in the competition for visitors, research resources and funding. ELIO helps to ensure that museums are able to digitize their collections efficiently and can use digital content commercially. The development of business models enabling museums to generate revenue through the sale of digital data and services is a forward-looking strategy that helps to improve the economic sustainability of museums. [7]

7.2 NEW COOPERATION MODELS BETWEEN THE PUBLIC AND PRIVATE SECTORS

An important aspect of the market changes being driven by the ELIO project is the establishment of new cooperation models between public museums and private technology companies. These partnerships offer museums access to advanced technologies without having to invest heavily in research and development themselves. At the same time, technology companies benefit from the opportunity to establish their products and services in the museum and heritage sector, a market that has traditionally been conservative and slower to adopt new technologies.

The promotion of such public-private partnerships through the ELIO project represents a strategic step towards fostering innovation in the museum sector and could, in the long term, lead to a transformation in which museums are perceived as players in the digital economic cycle.

8. FUTURE PROSPECTS AND LONG-TERM GOALS

The ELIO project aims to create sustainable solutions for the digitization of collections that not only meet the current needs of museums but are also scalable in the long term. A central goal of the project is to extend the developed systems and business models to other GLAM institutions and markets worldwide. The results of ELIO could help to accelerate the digital transformation in museums worldwide and promote the use of cultural heritage objects in the digital space on a global scale.

8.1 SCALABILITY AND INTERNATIONAL APPLICATION

The scalability of the technologies developed as part of ELIO is a decisive factor for the long-term success of the project. The systems developed are designed in such a way that they can be applied to different types of museums, collection sizes and digital requirements. Especially smaller and medium-sized museums that do not have the necessary resources to digitize their collections on their own could benefit from these solutions, as ELIO gives them the opportunity to enter the digitization process in a cost-effective and efficient way.

In addition, the project also aims to establish an (inter)national network of museums and technology companies fostering the exchange of best practices and the joint development of digital solutions. In the long term, this global/national exchange could lead to museums worldwide using similar digital infrastructures and thus enable better networking and collaboration within the cultural sector.

8.2 FURTHER DEVELOPMENT AND LONG-TERM RESEARCH GOALS

ELIO's long-term research goals go beyond the development of prototypes and business models. In the future, the project will continue to develop innovative solutions that involve not only the digital capture of objects, but also new technologies such as machine learning, blockchain for collection authentication, and advanced forms of virtual reality. These technologies could enable museums to revolutionize the way they present their collections and create even deeper interactive experiences.

9. CONCLUSION

The ELIO project offers a complex solution for the digitization of collections in museums and other GLAM institutions. By developing innovative technologies and business models, ELIO supports the digital transformation in the cultural sector while promoting a sustainable economic foundation for museums worldwide. Collaboration between public and private stakeholders ensures that the solutions developed are both technically and financially viable.

By creating scalable and sustainable digitization models, ELIO contributes to preserving cultural heritage for the future and making it accessible to a wider public. The project represents an important step towards a globally connected, digital museum sector that promotes cultural participation while strengthening the competitiveness of museums in an increasingly digitized world.
The goal of the ELIO project is to impact not only the cultural sector in the long term, but also the way we think about collections, culture and knowledge in the digital age. ELIO shows how technology and innovation can be used to improve access and to increase the benefit of cultural heritage preserved in collection holding institutions worldwide.

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Grimm4Geeks: Art Meets Digital Humanities or an Exploratory Approach to Artistic Data Visualization Using the Example of the Children's and Household Tales of the Brothers Grimm

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ABSTRACT: Texts can be understood and illustrated as stories – then we speak of art. However, texts can also be understood as data and visualised regarding certain characteristics - then one speaks of science. However, data can also be understood as material and transferred into a visually appealing form – then we speak of data art. We have come full circle: In the project 'Grimm4Geeks' the Children's and Household Tales of the Brothers Grimm, which represent an important cultural asset, are employed to investigate how data processing methods can be used to generate images that meet both artistic and scientific criteria. This means that the generated images should look 'beautiful' as well as 'say' something about the text. To use the images as an instrument of knowledge they must be comparable. If the generated images are similar, so are the texts. Under this assumption, it can be examined, for example, which fairy tales are stylistically similar or have been adapted to each other over the various editions. However, the aim of the project is not to answer such questions in detail but to develop an exploratory approach to artistic data visualization that allows such comparisons.

1. INTRODUCTION

The 'Grimm4Geeks' project operates in a field of tension between scientific demand and artistic research. It presupposes that there is hidden knowledge in data which can be made visible. Information visualisations in this sense often have a special appearance and are described as *beautiful* [1 and 2]. The boundary to data art, in which data is understood as artistic material, is fluid.

Inspired by the renowned Italian sculptor Michelangelo Buonarroti (1475–1564), who famously remarked that every sculpture already lies within the block of marble, one might envision this dynamic interplay in a similar way. Here, the data serves as the marble block, holding within it hidden forms waiting to be revealed. Through diligent work, what lies concealed within the data is brought to light. The Brothers Grimm's Children's and Household Tales are – to stay with the metaphor – the block of marble that will be chiselled.

Specifically, this means that the fairy tale texts are analysed regarding certain characteristics and these characteristics are then visualised. The texts are thus transformed into images that show certain characteristics based on rules and are therefore comparable.

2. IMAGE CREATION

To create images from the fairy tale texts, which could broadly be described as data art, the individual steps are outlined below.

2.1. DATA COLLECTION

The Children's and Household Tales (KHM) from the German Text Archive (DTA) are used as the database. All volumes of the total of seven editions are available here in fully digitised form so that various comparisons are possible. In this essay, the texts of the first volume of the first edition from 1812 [3] are examined more closely with those of the first volume of the second edition from 1819 [4]. They are further refined for analysis and visualization and then compared with one another.

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2.2. DATA PROCESSING

As an image is to be created for each fairy tale text, the texts must be available individually. They were therefore stored chapter by chapter in individual text files. Chapters consisting of several numbered sections, such as ‘Von einem tapferen Schneider’ (engl. ‘The Brave Little Tailor’), ‘Von den Wichtelmännern’ (engl. ‘The Elves and the Shoemaker’) or ‘Von dem Dummling’ (engl. ‘The Simpleton’), were saved as separate texts. For the first edition’s volume 1, published in 1812, this amounts to a total of 99 texts. For volume 1 of the second edition from 1819, there are 89 texts. This results in a difference of 10 texts, although both volumes have the same number of chapters: Both volumes list 86 chapters in the table of contents. The difference is since fewer chapters are divided into parts in the second edition. The fairy tale ‘Von dem Dummling’ (chapter 64), for example, has four parts in the first edition, whereas in the second edition, parts II, III and IIII, namely ‘Die Bienenkönigin’ (engl. ‘The Queen Bee’), ‘Die drei Federn’ (engl. ‘The Three Feathers’) and ‘Die goldene Gans’ (engl. ‘The Golden Goose’), have each become a separate chapter (chapters 62, 63 and 64).

Furthermore, the individual texts were further prepared for analysis and visualisation to create a comparable starting point. For example, line breaks and hyphens were removed, or characters were transliterated (e.g. ſ → s, aͤ → ä).

2.3. DATA ANALYSIS

The next step is about analysing the data, focusing on counting the following elements:

a) number of words and their respective length (= number of letters)
b) number of sentences and their respective length (= number of words)

Words and sentences are basic textual structural elements that are very easy to recognise. Words can be regarded as the units that are separated from each other by spaces; sentences, on the other hand, as the units that are separated from each other by punctuation marks. In the analysis, the punctuation marks *full stop* (.), *colon* (:), *semicolon* (;), *exclamation mark* (!) and *question mark* (?) were used as separators.

The well-known fairy tale ‘Rothkäppchen’ (engl. ‘Little Red Riding Hood’), used here as an example, has 1140 words and 64 sentences in the 1812 version, based on these parameters, whereas the 1819 version features 1197 words and 70 sentences. The fairy tale has thus become slightly longer and must have been revised. What exactly has been changed cannot, of course, be determined based solely on these figures. However, that is not the purpose here.

In terms of text analysis, this approach is very basic. However, it has the advantage that the focus can be shifted to the data representation, i.e. the artistic-visual aspect.

2.4. DATA REPRESENTATION

The data representation I will present below is inspired by the algorithmic principles of generative art. The origins of generative art can be briefly categorised as follows: they stem in the computer art of the 1960s, in which mathematical models and algorithms formed the foundation for arranging visual elements on a surface. Repetition and chance played an important role here. Original drawings were created using drawing machines, such as those used by Frieder Nake in his ‘Polygonal Drawings’ (1965) [5].

Today, *Processing* is often used for creative coding, a programming language that was developed especially for art and design [6]. A typical example of generative art that can be easily realised with processing is the so-called ‘Wave Clock’ [7]: Here, a line moves clockwise, varying in length, brightness and centre of rotation. The result is a wave-like structure (see Fig. 1).

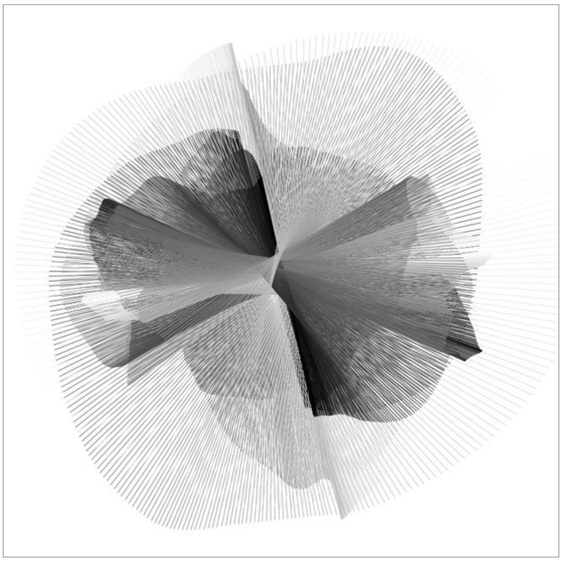

Figure 1: *Wave Clock*

Three random parameters are used in a ‘Wave Clock’. They are therefore not suitable for an adaptation for the described use case because, as described, there are two parameters each that need to be mapped. A different approach is thus required. In the search for a suitable algorithm, it was finally focussed on the use of noise when drawing lines and circles.

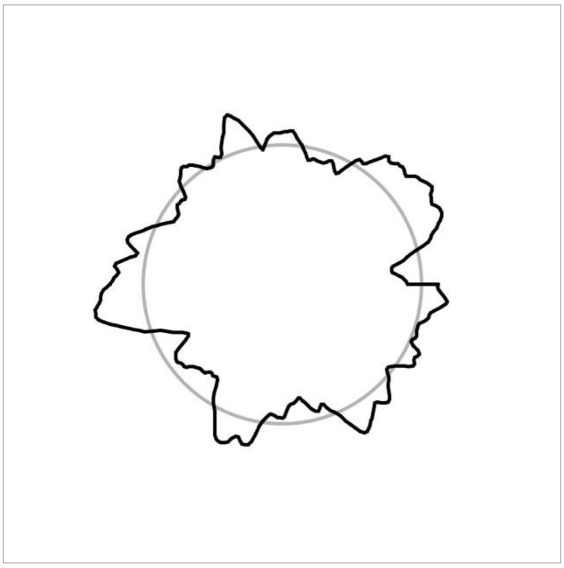

Figure 2: *Noisy Circle*

The term ‘Noisy Circle’ is used when the radius of a circle varies randomly so that the result is not a circle, but a polygonal shape due to the variance in circumference (see Fig. 2). This idea is to be pursued further by placing such randomly constructed circular shapes on top of each other (see Fig. 3) and colouring their surfaces *red* and *blue* (see Fig. 4). These two colours have high contrast and should subsequently increase ‘readability’.
Additionally, a slight transparency was applied to the layers, as they overlap, ensuring that the entire shapes remain visible. Where the two polygons overlap, a purple intersection is created. A neutral grey was chosen as the background colour.

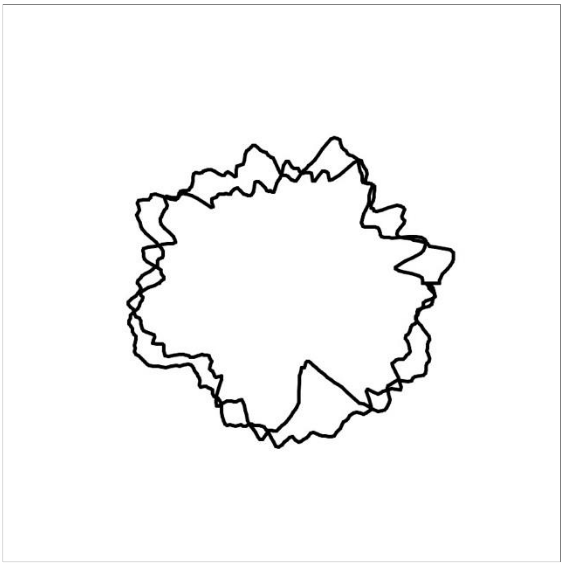

Figure 3: *Noisy Circle (2x)*

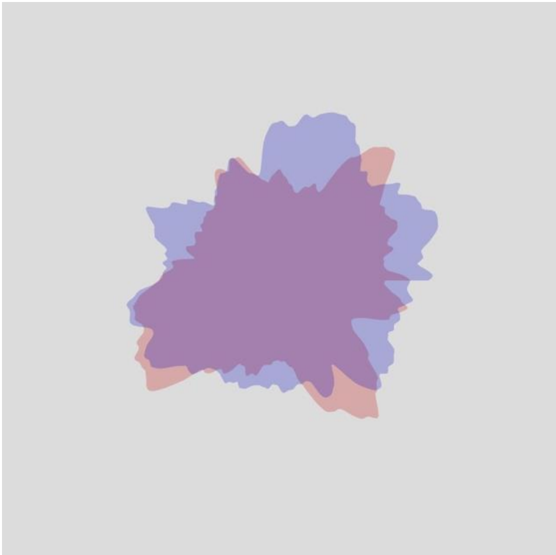

Figure 4: *Colour Layers*

If we now eliminate the randomness by passing corresponding values from the data analysis to the two variables *number of vertices* and *length of radius*, then the two polygon levels represent *words* (red) and *sentences* (blue). The number of vertices represents the number of words or sentences; the length of the radius represents their corresponding length. The fairy tale ‘Rothkäppchen’ (engl. ‘Little Red Riding Hood’) then appears as follows (see Fig. 5 and Fig. 6):

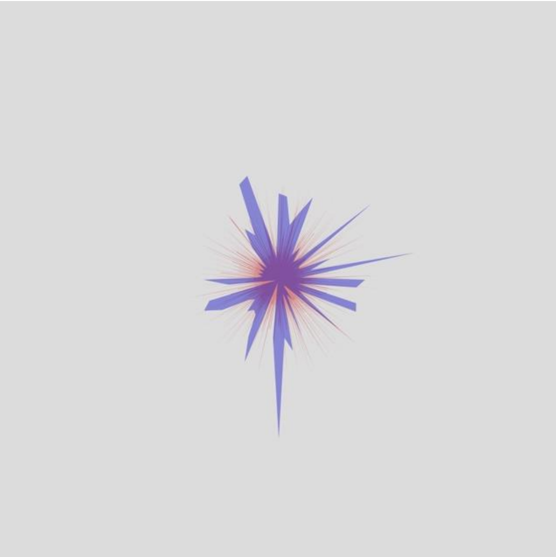

Figure 5: *'Rothkäppchen', First Edition, Vol. 1*

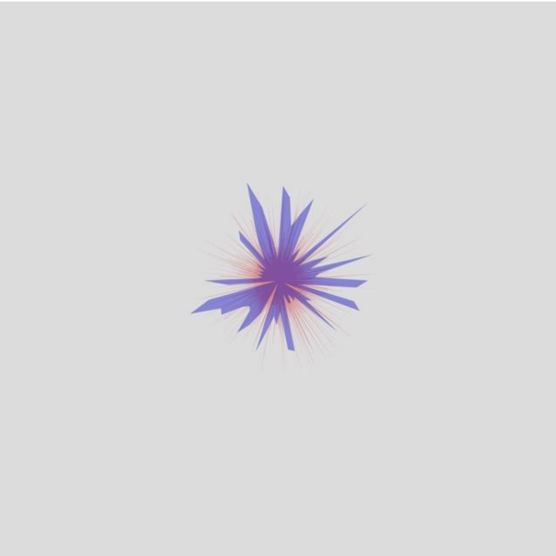

Figure 6: *'Rothkäppchen', Second Edition, Vol. 1*

As already established in section 2.3 based on the figures, a change from the first to the second edition can also be seen in the visualisations. It is noticeable that the deflections of the blue layer are less pronounced in the second edition, which means that the longest sentences were made shorter. However, the earlier observed difference of six sentences is too small to be meaningfully read from the visualisation.

In principle, however, the length of a text correlates with the number of vertices, so the following applies: if the form has few vertices, it is a short text; if it has many, it is a longer text. The fragment 'Schneeblume' (engl. 'Snow Flower'), for example, is much shorter than 'Rothkäppchen'. The blue triangle indicates that the fragment contains only three sentences (see Fig. 7).

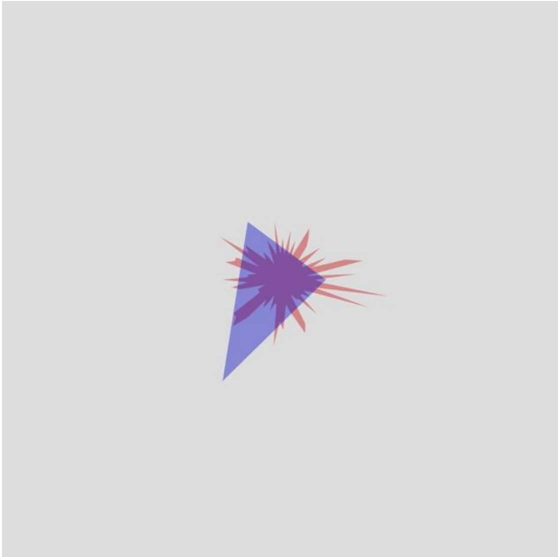

Figure 7: *'Schneeblume', First Edition, Vol. 1*

3. COMPARATIVE VIEW

The developed processing script can be applied to any text so that comparisons can be made easily. For this essay, all fairy tale texts in the first volume of the first and second edition were visualised. If we now look at the around 50 fairy tales that have remained the same in the table of contents of the two editions, i.e. have the same chapter number and the same or a very similar title, the following three observations can be made:

Firstly, some visualisations are congruent, from which it can be concluded that these fairy tales were adopted unedited in the second edition. This applies, for example, to the fairy tale 'Von dem Mäuschen, dem Vögelchen und der Bratwurst' (engl. 'The Mouse, the Bird, and the Sausage') (see Fig. 8.).

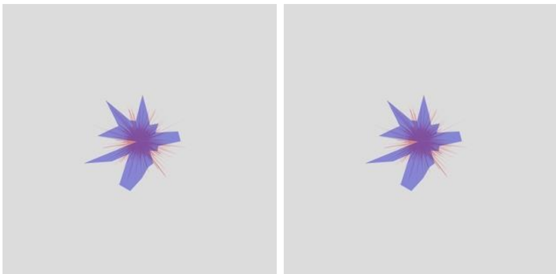

Figure 8: *'Von dem Mäuschen, dem Vögelchen und der Bratwurst', no differences between the first edition (left) and second edition (right)*

Secondly, some fairy tales with several parts were reduced to one chapter in the second edition. 'Von einem tapferen Schneider' (engl. 'The Brave Little Tailor') (see Fig. 9), for example, became 'Das tapfere Schneiderlein' (see Fig. 10). The number of vertices is visibly larger in the second edition so that it can be assumed that both parts were combined into one longer fairy tale text. An examination of the texts confirms this hypothesis.

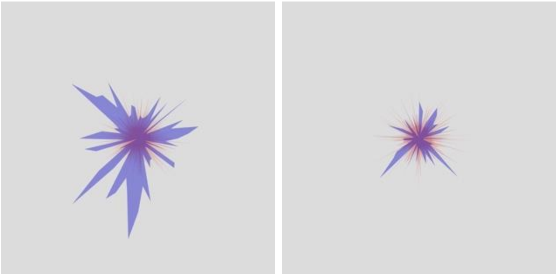

Figure 9: *'Von einem tapferen Schneider', Part I (left), Part II (right), First Edition, Vol. 1*

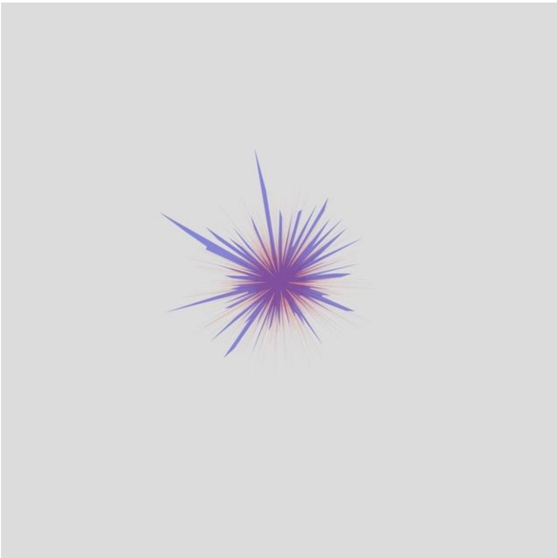

Figure 10: *'Das tapfere Schneiderlein', Second Edition, Vol. 1*

It was also noticed during the review that the fairy tale 'Der gescheidte Hans' (engl. 'Clever Hans') also has two parts in the first edition (see Fig. 11), but only one part in the second. However, a comparison of the visualisations clearly shows that there was no merging, but that the first part was carried over unedited into the second edition (see Fig. 12).

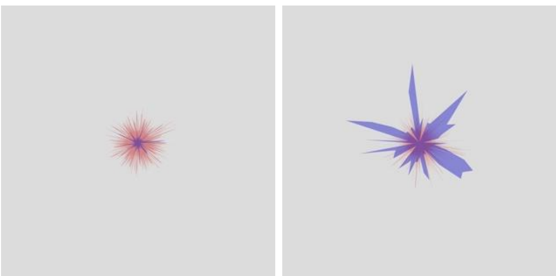

Figure 11: *'Der gescheidte Hans', Part I (left), Part II (right), First Edition, Vol. 1*

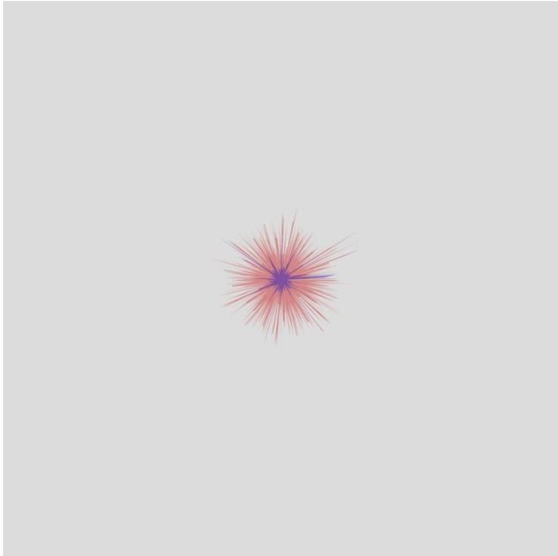

Figure 12: *'Der gescheidte Hans', Second Editon, Vol. 1*

Thirdly, most of the visualisations differ slightly from each other, as is the case with the two versions of the fairy tale 'Little Red Riding Hood' already shown (see Fig. 5 and Fig. 6 again). Overall, a comparative view reveals that the visualisations of the fairy tale texts in the second edition have more vertices throughout, i.e. the fairy tale texts have become longer. This can be characterised as a trend.

4. CONCLUSION

As the explanations have shown, the generated images can be understood as a kind of fingerprint of the respective text. It has been shown that even very basic structural features such as the number and length of words and sentences can act as distinguishing features, insofar as some interesting observations could already be made on this basis and the visualisations provide reliable results that stand up to examination on the text. The set goal was thus achieved.

However, the images are still a very rough fingerprint. In terms of perspective, there are therefore two possible approaches:

On the one hand, further textual features (word types, mean values, variances, proportions of direct speech etc.), but also semantic aspects (emotions etc.) could be included in the analysis to answer more complex research questions.

On the other hand, one could also think even more artistically and generate forms that reflect the content more strongly than the previous polygons. Insofar as design features such as shape and colour are closely linked to feelings, one could, for example, work with rounded or angular shapes and choose colour values that not only pragmatically serve to better distinguish between two feature levels.

The two paths described are by no means mutually exclusive. The present work can therefore be seen as a first attempt and as a starting point for further experiments in the field of tension between art and science.

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Reproducing a Masterpiece. Laocoon: Molds, Plaster Casts, 3D Models

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ABSTRACT: Since the 18th century at the latest, ancient sculptures and reliefs have been spread throughout the world in the form of plaster casts. To this day, casts are valuable tools, particularly in Classical Archaeology. However, casts also bear witness to a centuries-long tradition, to complex networks of artists, collectors and researchers, and also to the object biography of ancient originals. With the help of comprehensive 3D scanning campaigns of a total of 6 casts of the Laocoon group from 1750 to the present day, we are pursuing a variety of questions. Specifically, the 3D scans are analysed through shape comparison in various combinations. This paper is a first report to present our questions, problems, methodology, first results and next steps.

1. INTRODUCTION

Among highlights of ancient sculpture, the Laocoon group holds a special position. Found in 1506, the statue was soon put on public display in the Vatican. Here, it was visited by travelers, artists and scholars and became world famous. It was repeatedly reworked, restored and transported over long distances. The group was also reproduced and molded in order to create casts. These molding campaigns always represent a unique snapshot of a very specific state of the statue group, but have remained largely unstudied until now. The respective moment is lost in the original, but has been preserved in the surviving plaster casts. The technique of 3D scanning is used in this complex network of reproductions as a central tool for documentation, study and precise comparison.

The main fields of research of the projet are: 1) New investigation into the original thanks to snapshots of the work at different times in its object biography; 2) History of the reception of the work in the form of casts while viewing their production and dissemination: when and how was a mold commissioned and how was it made? The precise study of the casts is facilitated considerably by the 3D scans as a means of documentation. Most importantly, the digital comparison is expected to provide a clear statement regarding similarities, matches and deviations - more than the human eye can.

2. LAOCOON. ORIGINAL, PLASTER COPIES AND DIGITAL COPIES

2.1. LAOCOON: THE ORIGINAL MASTERPIECE

Figure 1: Original Laocoon group as seen in the Vatican today

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The ancient original famous Laocoon group is now in the Vatican Museums. Discovered in 1506 near the ruins of the Domus Aurea in Rome, the marble group was in exquisite condition but fragmented into several piecees. The group was immediately recognized as the Laocoon group described by Pliny the Younger, which he had seen in the “domus Titi imperatori”. The statue was acquired by Pope Julius II and thus became part of the Vatican art collections that were being created at the time. Almost every scholar of the following centuries and several artists dedicated themselves to the group: from Goethe, Winckelmann and Lessing, to El Greco and Roy Liechtenstein. Not only are there countless written and pictorial receptions and adaptations, but the original itself has not remained unchanged. In particular, the right arms of each of the three human figures and parts of the upper snake were missing and were repeatedly added, altered and re-added. It was only under Napoleon that the group was moved to Paris in 1798, supplemented and returned to Italy in 1815. Finally, in 1903, a further component was added to the group: the art dealer Ludwig Pollak discovered the original, bent right arm of Laocoon at the Roman art market. Finally, in 1960, large parts of the group were de-restored: In particular, the right arm of Laocoon was replaced with the “new addition” and the added right arms of the two sons were removed.

2.1. THE DISTRIBUTION OF THE LAOCOON IN CASTS AND THEIR DEPENDENCIES

As part of the Vatican collections and undoubtedly as a unique, complex as well as sensorially captivating group, the Laocoon soon became an absolute celebrity and a canonical work. The first copies in various materials were produced soon after the discovery and installation, initially treated as exclusive items, but they were gradually distributed more widely. The Laocoon soon became part of the canon and no plaster cast collection was complete without it - from residences and museums north of the Alps to academies in Italy Spain, and even Mexico. In two-dimensional pictorial sources, the reproduction of the group is almost unmanageable. The reception of the work has already been the subject of numerous studies.

Despite their likely status as primary sources directly linked to the original work, the many faithful plaster casts have not yet been systematically examined.

This study focuses on the plaster casts still preserved today. They can provide further insight into the history of restoration and additions to the piece. For example, research has, against better knowledge, reduced the view to only two versions of the right Laocoon arm - the Montorsoli arm and the Pollak arm - but there are even more variants of the group, which are also firmly documented in casts.

As part of this project, six plaster casts of the group were scanned in 2023 and 2024 to create 3D models as a foundation for the next steps: two in Munich, and one each in Venice, Bologna, Erlangen, and Leipzig. The casts and their molds date from the 18th to 20th centuries.

Plaster Cast today in:	Production of the plaster cast	from the mold:
Venezia, Gall. dell’Accademia	1755-57	from the mold of Filippo Farsetti around the 1750s, taken from the original in Rome
Bologna, Acc. delle Belle Arti	1755-57	from the mold of Filippo Farsetti around the 1750s, taken from the original in Rome
Leipzig, Antikenmuseum	Acquired 1840-1859	from the mold taken before 1815 in Paris
Erlangen, Antiken-sammlung	1883	from the mold in Berlin, Gipsformerei SMB, no. 263
Munich, MfA 1051	1993	from the mold in Berlin, Gipsformerei SMB, no. 263
Munich, MfA 1318	2008	from a mold taken from the original after the de-restauration in the 1960s

Table 1: *Casts of the Laocoon group scanned in 2023 and 2024*

The distribution of the Laocoon in casts is boundless. For this reason, many general questions concerning the general value of casts as sources can be dealt in this project. Our main questions pertain specifically to the molds and how the respective casts differ:

- Comparing two casts that are believed to originate from the same negative mold (Venice/Bologna): Can the digital comparison of 3D scans provide proof of origin from the same mold?
- Comparing casts from different molds (Venice/Leipzig/Erlangen): To what extent do the molds from different periods differ and what does this tell us about changes to the original?

- Comparing casts from the same mold but from different periods (Munich/Erlangen/Berlin): Do the 3D scans shed light on the transformation of the original throughout the centuries?

In the following we would like to present first comparisons and results of this method.

2.2. 3D MODELS AS AN INDISPENSABLE WORKING TOOL

The Laocoon group is so complex, with three human figures, two snakes, the altar and the robes, as well as highly intricate movements, that photographic documentation can only ever be inadequate. In addition, casts show a vast amount of detail: joinings, mold seams, damages, inscriptions, etc. It is almost impossible to compare these details with those on other casts using the medium of photography. The 3D scans are therefore indispensable for studying the casts: in addition to the geometry, they also show the texture in a very satisfactory way. Thanks to the interactive possibilities, they can be placed ad hoc in the correct position for comparison.

Figure 2-3: *Detail from the same perspective in the 3D model with texture of the casts in Bologna (top) and Venice (bottom)*

2.3 METHODOLOGY: SCANNING AND PROCESSING

In addition to documenting the complicated objects, the models are also to be measured and compared so that they can be better assessed in detail. Central questions are: how can casts be compared digitally? What is decisive: surface or volume? Which software is most suitable for this task? How should deviations be classified and interpreted?

To ensure comprehensive and accurate details for the 3D scanning of the Laocoon group plaster casts, we utilised an Artec Leo scanner and the workflow shown in Figure 5. The Artec Leo is a structured-light, wireless scanner designed for professional 3D data acquisition for metrological applications. We utilised the Leo scanner's HD mode, together with hybrid tracking technology to record the complex and precise details of the statues in 3D. Thanks to its ease-of-use, scan time efficiency, and accuracy, this scanner has become widely adopted in museum collection digitisation efforts. Furthermore, with almost 500 gigabytes of storage volume, the Artec Leo scanner was able to accommodate the massive size of the Laocoon raw scans.

Figure 4: *Scanning with the Artec Leo in Erlangen, 2024*

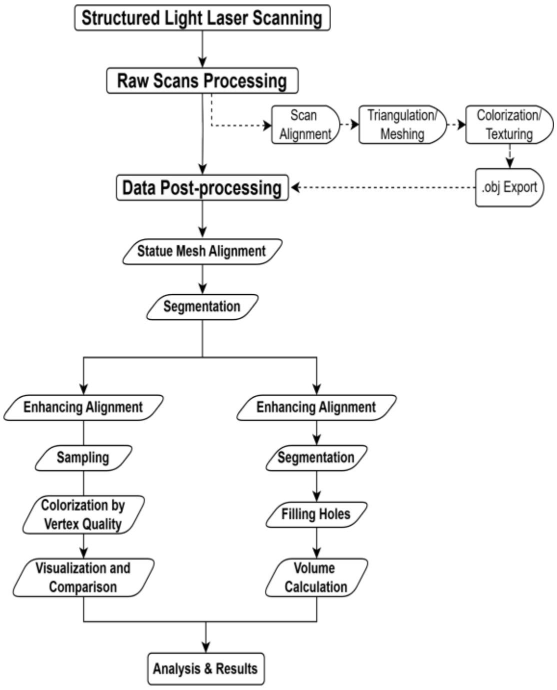

Figure 5: *Workflow from scanning to data processing and analysis*

Data processing was later done in Artec Studio v.18 Professional. We commenced importing the raw scans from the scanner, conducting automatic alignment, and removing any noise. We continued by using the sharp mesh fusion tool to generate detailed triangular mesh 3D models of the different versions of the statue we scanned. Furthermore, we used the Hole Filling tool to close any gaps found in the 3D models, and then we added textures obtained from pictures captured by the Artec Leo to render surface color with realism. All the 3D models were later exported in .obj format to allow import in 3D analysis software apps.

2.4 METHODOLOGY: COMPARISON

To compare the plaster casts of the Laocoon we scanned in Munich, Venice, Bologna, Erlangen, and Leipzig, we performed a three-stage analysis. Each trial used one model for reference to measure the other. This work combined CloudCompare and MeshLab software in a structured manner to evaluate the results.

Figure 6: *3D models of the cast in Venice (right) and Bologna (left)*

For instance, we imported the Bologna 3D model into CloudCompare and prepared it as a reference for the Venice one. These 3D models were manually aligned by selecting common points; afterwards, special parts of interest were segmented and later exported in .obj format for processing. In MeshLab, the three-dimensional differences were computed by using the "Distance from Reference Mesh" tool. Visualisation of these differences was carried out with the "Colorize by Vertex Quality" tool, whereas a graphical form of the vertex quality distribution was obtained with the function "Show Quality Histogram". Quantitative metrics have been generated by the "Per Vertex Quality Histogram" and "Per Vertex Quality Stat" tools, providing detailed statistical insights that we plan to use in future studies.

Other trials were consistently performed by repeating this process, and the Erlangen model was also used as a referential model to the Munich MfA 1051 model and the Venice reference model to the Munich MfA 1051 model.

Moreover, we wanted to find alternative ways to compare each scanned statue beyond surface comparison to aid interpretation of their similarities and differences. Thus, we decided to calculate each statue’s rib cage volume with millimetre precision. To achieve this, we aligned four statues in mesh format within CloudCompare, using the Venice statue as the reference for the other three statues. Following sufficient alignment, we segmented the rib cage of each statue utilising the same software, and the mesh files were later exported into .obj format.

To ensure the alignment enhancement, we imported such mesh files into Meshlab for refinement. Also in this case, we continued to use the

Venice Laocoon as a reference. At this stage, the four statues' transformation matrices were frozen to avoid any further changes, and then their rib cages were meticulously segmented to match one another. As a result, the alignment of the four rib cages became more precise. We subsequently exported them in .obj format.

Filling the holes was crucial in calculating the volume of the rib cages. Therefore, we employed Artec Studio Professional to close any gaps and compute each model's volume. The volume measurement was successful for all the statues' rib cages with exception of the Bologna statue because its back surface was damaged and therefore open, showing the hollow side of the plaster cast, which made it unusable for our volume calculation. Table 2 shows that the rib cages of the Venice and Munich versions are quite similar, while the Erlangen one is about 700.000 mm^3 smaller.

Statue's Rib Cage	Volume Measurement
Erlangen	**31.149.100 mm^3**
Venice	**31.830.100 mm^3**
MfA 1051	**31.842.700 mm^3**
Bologna	**N/A statue damaged and hollow**

Table 2: *Volumetric details of the Laocoon 3D models analysed in this study*

2.5. ANALYSIS AND EVALUATION OF THE MEASUREMENTS

One of our main questions is: Which casts come from the same negative mold and how do the casts differ from each other?

When comparing two models, it is extremely important where the alignment points are placed. Initially, the results were astonishing when the points were distributed over a large area: In some cases, the entire figure tilts strongly out of alignment with the other. With an alignment in the lower area of the statue for example, there are deviations of 5-10 centimetres in the area of Laocoon's head.

The reason for these deviations lies in the way the objects are produced. On the one hand, casts are made from separate parts - torso, lower body, arm, leg, etc. - which are then assembled. These joints can be recognised by a gap that is still present. Sometime such joints were fuzed together, which can be seen despite the seam. These joints are different, depending on the mold.

Figure 7-8*: Joints as seen on the Laocoon group in Erlangen (left) and Leipzig (right)*

Each of these large pieces is in turn created from a mold that is composed of various individual parts in a puzzle-like manner. These can be recognised by an almost web-like arrangement of seams covering the surface of a cast.

Figure 9-10*: Example for a cast in its mold made of individual pieces (left) and visible seams on the surface of a cast (right)*

This molding technique results in a large number of possible deviations in the range of up to 1 centimeter between the large parts and around 1-3 millimeters for the individual molded parts. This can of course add up considerably for large figures.
Analog and digital comparisons and measurements are therefore only possible within the large parts of the body, but not beyond. In principle, this also means that archaeological research should not use larger overall measurements of casts.

On the other hand, the study also shows that discrepancies in the macro range say nothing about the mold, as these questions can only be investigated in the micro range.
For this purpose, individual segments that can be assumed to be stable and less mobile in the mold structure must be identified and determined. For this purpose, we identified (1) the altar, (2) the area of the lower back and

buttocks of the Laocoon, as well as (3) the chest area. These areas were then compared in various combinations.

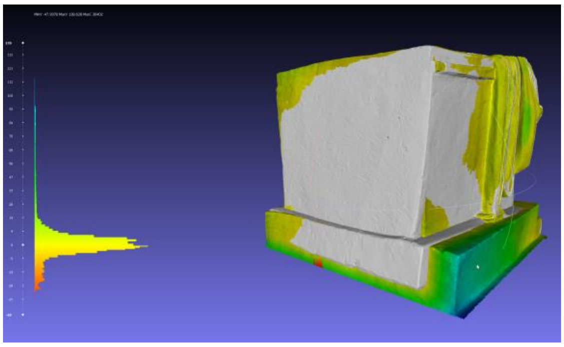

Figure 11: *Comparison of the altar in Venice (in colour) and Bologna with deviations*

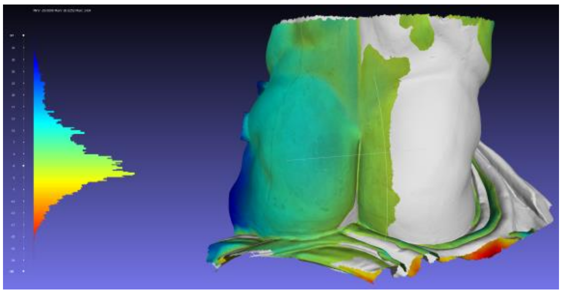

Figure 12: *Comparison of Laocoon's back and buttocks in Venice (in colour) and Bologna*

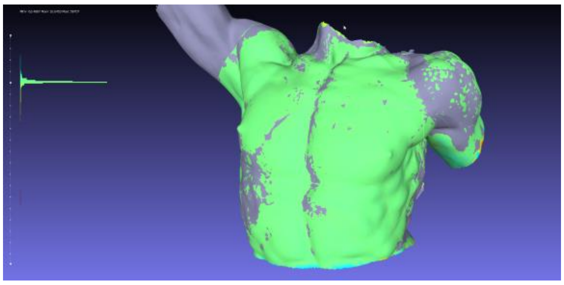

Figure 13: *Comparison of Laocoon's chest in Munich MfA 1051 (in colour) and Erlangen*

Secondly, in addition to dimensional comparisons, small superficial details can also be evaluated as evidence of an origin from the same mold: for example, the inscription LAO on the side of the altar. On the casts the lettering is mirror-inverted and raised, which means that it was carved into the mold.

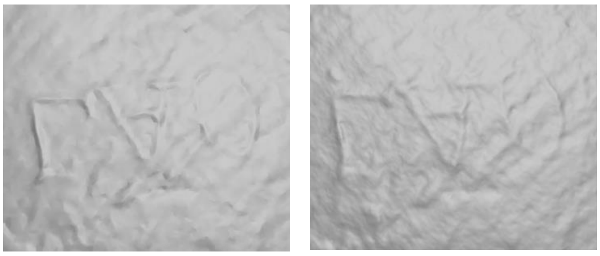

Figure 14-15: *Right side of the altar with the inscription LAO: Bologna (left) and Venice (right) are taken from the same mold*

***Figure** 16: Right side of the altar in Leipzig: no inscription*

3. CONCLUSION

This first report on the project has presented hurdles and initial methods. It is already clear that casts from the same mold can show large deviations of several centimeters, while the surfaces correspond more closely. Therefore, the observation and comparison of segments is the right approach.

Thanks to the successful results from our laser scanning and model comparison process (table 2), we aim to enhance our exploration of the similarities and differences among various versions of the Laocoon group plaster casts using an automated method that incorporates machine learning techniques. This upcoming research will utilise Open3D, an open-source library that facilitates 3D data processing and visualisation, which also supports 3D machine learning with PyTorch and TensorFlow. The significance of improving the workflow presented in this paper to include automatic point cloud alignment is that other researchers who want to evaluate or re-use our 3D scan data cannot easily reproduce our current manual alignments in CloudCompare. Therefore, manually aligned results might be potentially controversial regarding repeatability. Thus, in future work, we plan to use a programmatic approach to match and compare the 3D models of two versions of the Laocoon sculptures we studied. This new development would also allow us to include a numerical evaluation of the registration results while ensuring better repeatability and accuracy.

4. ACKNOWLEDGMENT

We would like to express our sincere thanks for the permission granted to scan and research the casts in the respective collections and for the trust placed in us: dott. Giulio Manieri Elia, Gallerie dell'Accademia di Venezia, Venice, as well as Valeria Finocchi, Museo di Palazzo Grimani, Venice; prof. Alfonso Panzetta, Accademia delle Belle Arti, Bologna; Dr. Jörn Lang, Antikenmuseum, Leipzig; Prof. Andreas Grüner, Antikensammlung, Erlangen.
For the scanning and processing of the casts in Venice and Bologna, our thanks go to Dario Calderone and Ivan Proskurko. Scanning in Erlangen and Leipzig, and processing was done thanks to Yiming Du and Mina Yacoub.

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SESSION III

"What's on in Berlin"

Moderation: Jacopo Spinelli
(BTU Cottbus-Senftenberg)

DomeConnect –
Interactive Live-Streaming Between Immersive Spaces

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ABSTRACT: In recent years, the request for hybrid events has become increasingly prevalent. It is already widespread practice for business meetings, conferences, and workshops to be broadcast live, allowing for remote participation. Even in the entertainment sector, hybrid events are engaging an increasingly interested audience. Such events usually pose a lot more artistic freedom and invite local and remote participants to interact with the exhibition. Combining real and virtual environments and taking full advantage of their inherent properties requires overcoming several technical hurdles. DOMEconnect is a toolbox for event creators and organizers, allowing them to realize hybrid, immersive and interactive experiences that go far beyond sending a single video channel to a streaming service on the internet. Fully immersive media platforms like Planetariums and 3D audio systems are made easily accessible with this toolbox.

1. INTRODUCTION

DOMEconnect aims to create a platform for events that enables organizers and creators easy access to the tools and workflows that are necessary in order to extend the events format beyond the real world and make it fully hybrid. This does not mean that events like concerts, exibitions or artistic installations happen at one specific location, and participants can join a live stream. The goal of DOMEconnect is rather to connect multiple venues with each other, fully taking advantage of the unique and dynamic possibilities that arise between these locations. Connected systems can be as simple as individual VR-Headsets and laptops or as complex as planetariums and immersive media centers with multiple projection systems.

DOMEconnect enables maximum interactivity between each location, inherently facilitating novel event formats. For example, a band can perform a concert live in one location, while musicians from another location join them in real time, all whilst this concert is being shown not only to the audience at both sites, but also to a third remote audience in a planetarium.

For ease of use and accessibility, this tool set must be developed to allow for the utmost compatiblity with existing systems. Four key workflows and their corresponding tools have been developed for DOMEconnect. These cover the areas of video, audio, interaction and streaming.

2.1 VIDEO

In order to account for the various formats of immersive display systems like planetariums, the displayed video material must be prepared accordingly. For pure video recordings, the Fraunhofer HHI can already provide a system called the OmniCam360. This camera allows high resultion video panoramas up to 10k x 5k, which due to the construction of the camera with close to zero parrallax, allows an artefact free live video feed which requires next to no postproduction (like geometric- or colormetric-corrections) and is ready to be streamed in varios formats.

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Our Real Time Stiching Engine (RTSE) then warps, stiches and transforms the video to the destinations required format (e.g. equirectengular, cubemap, dome-master, etc.). The software can either be used on the receiving end, to prepare the video for display, or the transmitting end, preformating the stream. With this workflow, real world video captures can be streamed to varios event locations in an optimal way.

In order to take full advantage of hybrid events, computer generated images (CGI) must also be considered as part of the workflow. The digitization and transmission proccesses allows for the possibility to enhance and alter the material. We have developed various CGI tool chains to either include real world footage in a virtual environment or, vice versa, to include computer generated images in real world footage. In order to implement this, several challenges had to be overcome. For example, real world footage and computer generated environments influence each other visually and artifacts like obstructions, shadows and ghost movements can be countered to increase the immersion of the final result.

Another important factor to be considered is that most rendering engines that enable the display of computer generated images usually do so on a flat screen. Many immersive locations, however, utilize curved and in some cases not even rectangular projection canvases. Therefore, geometry correction has to be applied in order to minimize distortion. To account for these problems, we developed workflows and systems for different rendering engines.

2.2 AUDIO

Immersive locations very often employ proprietary and complex audio setups. These may range from quadrophonic or ambisonics to wave field synthesis setups. These setups often require a specific way of mixing, which is best done on site. To meet this challenge, we developed an audio engine that receives object-based audio signals as input and then converts and processes these signals for every audio system. The audio engine has been developed in such a way that it supports simple expansion with additional audio systems without the need to change the original content. The software also includes various interfaces to allow for external control of the audio scene. These interfaces can be easily accessed from within a variety of frameworks such as rendering engines or digital audio workstations. With this tool, workflows can be adjusted to ensure maximum compatibility for the event itself and the locations where the event is displayed.

2.3 INTERACTION

Another important and interesting aspect of hybrid event formats is the opportunity to implement novel ways of interaction. By leveraging various rendering engines and their real time generated content, opportunities are created for spectators to participate and shape events in completely new ways. DOMEconnect aims to make use of this opportunity and allow organizers and creators of hybrid events to implement all available options in their vision.

However, a crucial factor to be considered is that not all event locations provide the same means of interaction. Interaction must be scaled – a 200-seat planetarium and a single user with a VR Headset should each have a system to meet their needs. To minimize the workload of preparing the presentation for each event location individually, a piece of software was developed that takes care of these additional steps. This interaction server communicates commands between controlling devices and the environment to be controlled. Event locations can utilize their available means of interaction to interface with the interaction server, which then in turn takes care of translating these inputs to commands that can be handled by the presentation.

2.4 STREAMING

The final part of the development of DOMEconnect is focused on the actual streaming of the available media channels. To take the various formats of transmission (video, audio, interaction, synchronization) into account, we developed a framework that allows for individual adjustments of the streaming pipeline during runtime depending on the actual material that is being used. Furthermore, our API can provide an automatically generated Frontend to make the adjustments and fine tuning of the pipeline easily accessible. Inputs and outputs can also be serialized to several formats and protocols.

This tool enables us to set up output streams according to the technical specifications on site. Settings can be changed in real time while the event is in process with no interruption. In addition, we implemented the option for multiple output streams to access the same encoding channel, which decreases resource usage during runtime.

3. CONCLUSION

The DOMEconnect tool suite has already been employed successfully in several events over the course of two years. Real world use has allowed us to further develop and fine tune the various tool chains and workfolws previously mentioned. On every level we found that DOMEconnect was integral to the succsess of each event. From artists using it to express themselves freely without being held up by the technical requirements of complex systems to venues able to fleixbly accomodate a diverse array of formats and presentations which previously would have been unthinkable. We strongly belive that in the future, we can continue to optimize our software and increase it’s accessibility, leading to more creative, engaging and effective immersive and interactive events.

4. ACKNOWLEDGMENT

We would like to thank the "Wissenschaft, Kunst und Design" network for the funding of this project, the Zeiss Planetarium in Berlin for giving us a platform to test some of our new technology and the students of the UdK Berlin for giving us beautiful pieces of art that we were able to make a reality using our toolbox.

SHIFT
MetamorphoSis of cultural Heritage Into augmented hypermedia assets For enhanced accessibiliTy and inclusion

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ABSTRACT: CH institutions face significant challenges in making their vast collections accessible to diverse audiences, including researchers, museum professionals, children, and visually impaired persons. Traditional methods of describing and retrieving CH assets are often static, inconsistent, and not tailored to specific user needs. In response, the EU Horizon SHIFT project develops AI- and ML-based toolkits to support automated, adaptive, and multimodal descriptions of CH objects, supporting inclusive digital storytelling and improving accessibility.

1. INTRODUCTION

Don't touch! Prohibitions on touching walls and exhibits have always regulated the behaviour of visitors to European museums. A popular children's book, 'The Rabbit School', published in 1924 by Albert Sixtus, aptly rhymed: 'Das Berühren der Figüren mit den Pfoten ist verboten' ('Touching the figures with your paws is forbidden'). Thereby an aesthetic of distance, visual devotion and auratic detachment developed out of a conservative concern for the absolute preservation of the collection's exhibits. This was sometimes interrupted by the museum staff's explanations of the items. However, traces of this powerful code of behaviour have left their mark on museum architecture and furnishings, exhibition concepts and visitor guidance systems.

Only in recent decades has it been possible to break the hegemony of the sense of sight in museums through the use of multisensory, interactive and participatory mediation formats. The wider opening to the public and the desire to enable cultural participation regardless of sensory, physical or cognitive limitations have encouraged the implementation of multisensory, inclusive and interactive access modalities. New museum concepts now focus more on multi-perspective storytelling than on the canon of interpretation. Experiential exhibitions and personalised mediation services use a wide range of digital media technologies to actively involve visitors in the museum experience and ensure the participation of all social groups in an accessible dialogue with cultural heritage.

Today, the museum is no longer a place of quiet contemplation, but an orchestra pit for the polyphonic concert of social discourse.

New voices are making themselves heard in the orchestra, preparing the media for the task of mediation. Artificial intelligence has established itself as a permanent member of the chorus, and it requires attunement and training as well as precise guidance in the legal foundations of its use. The voice of the large group of so-called non-visitors to museums can be heard loudly in the background. It calls for the integrative role of culture and the social interaction of museums in and with society. What inhibitions need to be overcome and what media communication strategies can be used to make cultural heritage more attractive to the diverse and heterogeneous audiences that have hitherto kept museums at arm's length? The original object of the collection continues to play first fiddle, to use the image of the orchestra pit. Today, it is no longer silent in the

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contemplative display case, but acts as a digital twin in variable contextualisations and narrative enrichments, challenging dialogue in multi-perspective considerations and interactions with the Citizens. This creates new challenges for museums. The strategic integration of digital formats now affects all areas of museum work and will only be possible through the use of efficient digital tools.

2. SHIFT: MULTI-SENSORY PERCEPTION BASED ON AI AND ML

The SHIFT project 'MetamorphoSis of cultural Heritage Into augmented hypermedia assets For enhanced accessibiliTy and inclusion' (https://shift-europe.eu/) takes these developments into account. It harnesses the potential of generative artificial intelligence (AI) and machine learning (ML) to enhance the attractiveness of cultural offerings and the virtual visitor experience. At the same time, it aims to provide curators and museum staff with the appropriate digital tools to generate attractive new content and to implement these tools efficiently in their work. Particular emphasis will be placed on widening access and participation for visually impaired and blind visitor groups. Multi-sensory interaction with the collections through visual, textual, auditory, haptic and olfactory modalities will also enrich and enhance the general visitor experience.

2.1 SHIFT: OBJECTIVES AND EXPERTISE

The concrete objectives of the Shift project are focused on different areas of work in European cultural heritage communication, in particular the following tasks:
- to enable cultural heritage institutions to successfully adopt digital strategies to promote public engagement,
- to offer unique experiences to the visitors through a hybrid of visual-auditory-haptics sensors for experiencing cultural heritage,
- to enable digital interactions with cultural assets using haptic technology,
- to represent cultural heritage to contemporary times through the development of language models,
- to adopt accessibility by design principles and tools to promote compliance with International standards,
- to implement tools for creating ownership chain for protecting copyrights of digital media.

The project has been funded by the European Commission under the Horizon Europe programme since the year 2022. The consortium includes thirteen partners from seven EU member states and one from an associated country with the full range of expertise required to realize the project objectives.

The expertise in improving appeal of cultural heritage content is provided by Foundation for Research and Technology - Hellas (FORTH), by Queen Mary University of London (QMUL) and by Massive Dynamic Sweden AB (MDS).
The expertise in enriching accessibility to cultural assets is provided by audEERING GmbH (AUD), The Technical University of Munich (TUM) and Software Imagination & Vision (SIMAVI).
The expertise for "Inclusion by design methodologies" is offered by Deutscher Blinden- und Sehbehindertenverband (DBSV) and Eticas Research and Consulting (ERC).
Testing, evaluating and monetising of the shift tools are supported by Semmelweis Medical Museum of the Hungarian National Museum (SOM), The National Association of Public Librarians and Libraries in Romania (ANBPR), Staatliche Museen zu Berlin – Preußischer Kulturbesitz (SMB), The Balkan Museum Network (BMN) and The Heritage Management Organization (HERITΛGE).

2.2 SHIFT: TOOLKITS

A selection of key tools from the project's ongoing development pipeline includes the use of visual, auditory and haptic toolkits. Although it is sometimes still a work in progress, the great potential of the applications becomes obvious.
Text & Video to Affective Speech Synthesis Tool
CH institutions face significant challenges in making their vast collections accessible to diverse audiences, including researchers, museum professionals, children, and visually impaired individuals. Traditional methods of describing and retrieving CH assets are often static, inconsistent, and not tailored to specific user needs. In response, this tool enables automated, adaptive, and multimodal

descriptions of CH objects, supporting inclusive digital storytelling and improving accessibility. The text and audio descriptions of historical photographs, movies, videos, paintings or other cultural artefacts facilitate their immediate understanding by addressing different language levels, from basic to specialist, as well as alternative texts for visually impaired audiences.

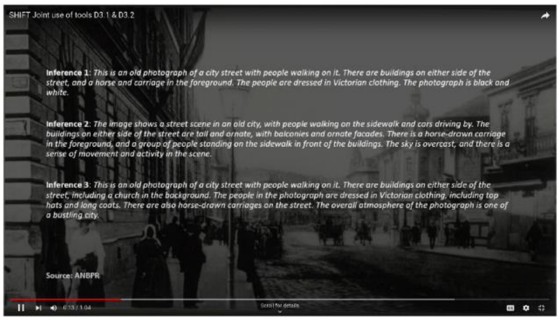
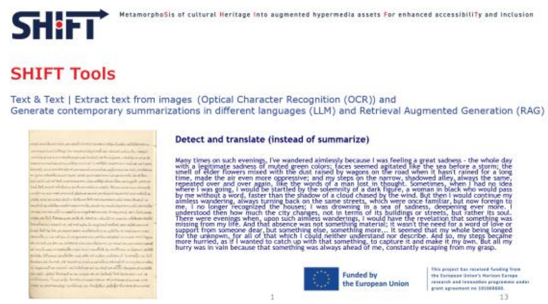


Fig 16. For this ANBPR image we call D3.1 tool to generate text captions (3 different inferences) and call D3.2 tool to synthesise Affective speech and build a video - https://youtu.be/wWC8DpOKVvQ

At the same time, multilingual translation is possible. All texts can be displayed in the selected languages or simultaneously in natural emotional language.

Text to Text Tool

The aim is to extract text from images, books or manuscripts by Optical Character Recognition (OCR). In the case of older texts, such as the historical medical books in the collection of the Semmelweis Museum, contemporary summaries of the content can then be generated in different languages and at different language levels.



The text obtained with the LLM is specified and enriched using RAG (Retrieval Augmented Generation) tools.

Haptic Representation in Virtual Reality Environments Tool

Experiencing haptic feedback by haptic gloves like WEART Haptics enables users to a better understanding of the XR environments. Though it might not precisely replicate the actual size and material of the 3D artefacts the combination of various sensory inputs, such as haptics and background sounds, creates immersive and engaging XR environments. This leads to closer experience and orientation of surface-textures, dimensions, volumes and temperature of CH assets in the XR. With the SHIFT XR accessibility framework, visually impaired users will be able to navigate and explore virtual environments with CH assets.

For each CH asset, users will be able to interact with it, hear personalized information and haptically explore it. For example, a virtual scan of the bust of Nefertiti can be enhanced with an audio description by touching hotspots, while touching a flowing stream in a painting of a river landscape triggers a cold sensation in the fingertips.

Foreground - Background Detection Tool

Detecting and classifying automatically the foreground and background objects in digitized paintings, videos or virtual environments is a method for virtual enhancement of image and video sequence analysis. It enables the generation of short motion clips with considerations on physical limitations in the different zones.

The process is useful for adding various detected or planned patterns of motion to the foreground or background of a static image, updating patterns of motion, or zooming into the foreground for preferred perception by visually impaired people. For example, a seascape can be virtually reanimated by adding moving waves in the foreground and gathering clouds in the background.

3D Extraction Tool

The 3D Extraction Tool uses AI to filter out individual elements, such as figures or heads, from two-dimensional artworks or relief-like coins and medals, and translate them into a three-dimensional format in an algorithmically comprehensible and consistent way.

Content of an image can be segmented, analysed and integrated into other contexts and game scenarios.

Image to Text to Speech Tool

The Image to Text to Speech (TTS) tool is used to generate descriptions of images, which are then transformed and translated for different reception contexts. In a second step, the speech text is presented in natural and emotional language using Speech Emotion Sensitivity (SES) modelling techniques. Emotional nuances of the speech are identified and optimised for the interpretation of a work. In the example of my presentation, you can hear the difference in the way how children, visually impaired people or art professionals are adressed.

Landscape-2-Soundscape Tool

The Landscape to Soundscape tool enriches the visual perception of a painting with its sonic atmosphere. An acoustic event is performed that corresponds to the visual appearance of the painting. In contrast to the musical interpretation of pictorial works, such as Modest Mussorgsky's famous piano cycle 'Pictures at an Exhibition' from 1874, this is more about the synaesthetic transformation of the visible image into an audible one.

Recognising and reproducing the soundscape associated with the visual impression proves difficult in some cases.

As the audio feature on Arnold Böcklin's 'The Isle of the Dead' (3. Version, 1883, National Gallery Berlin) shows, the synthetic generation of the soundscape is misguided by a superficial translation. Although the AI's intonation of rippling water and wind rustling in the poplars is justified by the 1:1 identification of a lake, a boat moored on it and individual, slightly bent poplars, it fails to capture the atmosphere of the painting. The real image, instead, seems to express the perfect, almost frightening stillness of a smooth expanse of water on which a boat glides silently. But how can silence be expressed as an acoustic event?

Scenes in which movement is combined with noise, and where the representation triggers an expected sonic image in the mind of the visitor, are much easier to resolve.

In Schinkel's painting 'Cathedral by the Sea' (1815, National Gallery Berlin), the acoustic image of the clattering hooves of a group of horsemen in the centre of the painting can enhance the overall perception of the painting. The soundscape does not only complement audio description for visually impaired persons, but also provides a multi-sensory experience for sighted visitors in museums, in the creative industries or in a gaming scene.

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3. ACKNOWLEDGMENT

The author is a member of the project consortium. Some passages of this text are based on the jointly published deliverables during the project lifespan.

The New Tactile Model of Pergamon for Berlin

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ABSTRACT: This article is an update on the development process of the haptic model of the ancient metropolis of Pergamon, which the Chair of Architecture and Visualisation is creating in collaboration with the Pergamon Museum Berlin for its reopening. The principles and fundamentals are described in detail in the proceedings of the EVA Berlin Conference 2023 [see Ref. [4]]. In the present article, we will outline the critical points that, with the help of an initial test body, should provide insight into how they will look in milled form, so that they can then be fine-tuned if necessary.

1. INTRODUCTION

After many years of renovation, the Antiquities Collection at the Pergamon Museum in Berlin is expected to reopen in 2027. Although this is still some time away, it will be a significant milestone in the completion of Museum Island. Fortunately, the architecture halls containing the large altar for which the museum is named will then be accessible again. Much will have changed, but the architecture halls will remain preserved in their former appearance as historical witnesses, with only minor alterations. These include the two models in the altar hall. One shows a scaled-down version of the complete altar in its original arrangement to help visitors understand how it was constructed and how the frieze of giants was installed on the outside of the altar in the original. The second model shows a section of the city mountain of Pergamon on an even smaller scale, primarily to demonstrate the context in which the altar stood in ancient Pergamon. The previous model, which was displayed in the hall to the right of the altar until the renovation, has been superseded by new findings, primarily because it did not clearly demonstrate the density of urban development. Instead, the altar was surrounded by spacious grounds and gardens. This earlier model will nevertheless be preserved as a museum artefact, but not in this prominent location. Instead, it will be displayed as part of the museum's history and the history of how the city of Pergamon has been perceived over time. As the main and most accessible source of information about the urban context of the altar, the new model will be tactile and based on the virtual model, which has been continuously updated since 2008 by the authors' chair in collaboration with the Istanbul department of the German Archaeological Institute, in line with ongoing excavations and interpretations.

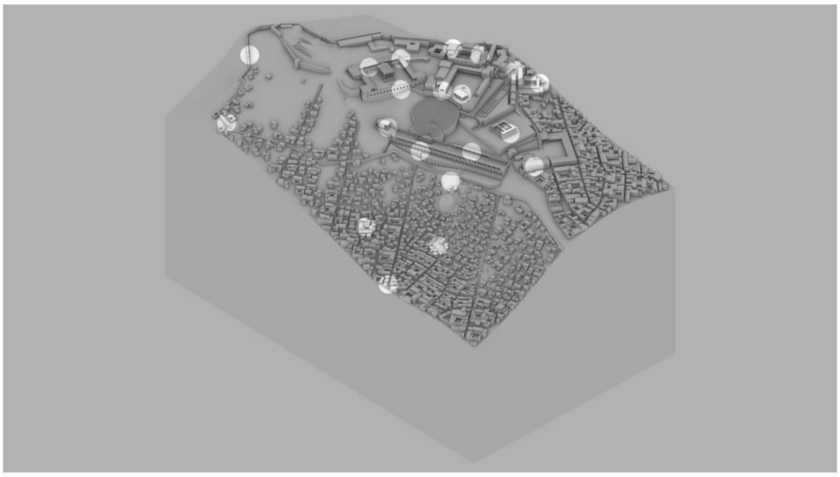

Figure 1: *Section of the city mountain selected by the museum, showing the positions of the components selected for the test body Fig. 2*

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2. THE CHALLANGES

The transition from visual to haptic models presents several challenges. The first of these is all-round visibility: unlike composed perspectives, physical models that viewers can walk around do not allow specific viewpoints to be selected to hide areas outside the scientific hypothesis. Secondly, due to manufacturing constraints, it is not easy to anticipate the visual information, as the material and its contrast properties, as well as the manufacturing process, will result in different contours. For these two reasons, an iterative manufacturing process is required to check how geometry and material interact in sections, in order to achieve the desired visual and haptic quality. The resolution and mobility of the milling head need to be tested. The resolution is determined by the diameter of the milling bit, which causes concave surface transitions to be non-planar. This results in inappropriate differentiation between concave and convex transitions. In masonry, for example, these transitions are geometrically equally sharp-edged in the original. This imbalance also impacts all small-scale structures, from roof tiles to columns and capitals. To ensure the expected visual appearance of the model and to enable adjustment of the geometry if necessary, to anticipate undesirable visual effects, e.g. through greater relief depths to compensate for the weakening of the visual effect of the relief during production, we identified critical points in the designated area (Fig. 1) and compiled them in a test piece to be produced in a single printing process (Fig. 2).

2. THE TEST BODY

This is therefore not an actual model section, but an artificial construction combining different relief structures with varying accessibility for the milling head. These versions include the original model version for visualisations, with different granularity levels to check whether round milling produces relief structures that are less visually distinctive than the visualisation model, and whether a coarser or deeper relief structure that differs from the geometric model for visualisations leads to a more appropriate visual effect.

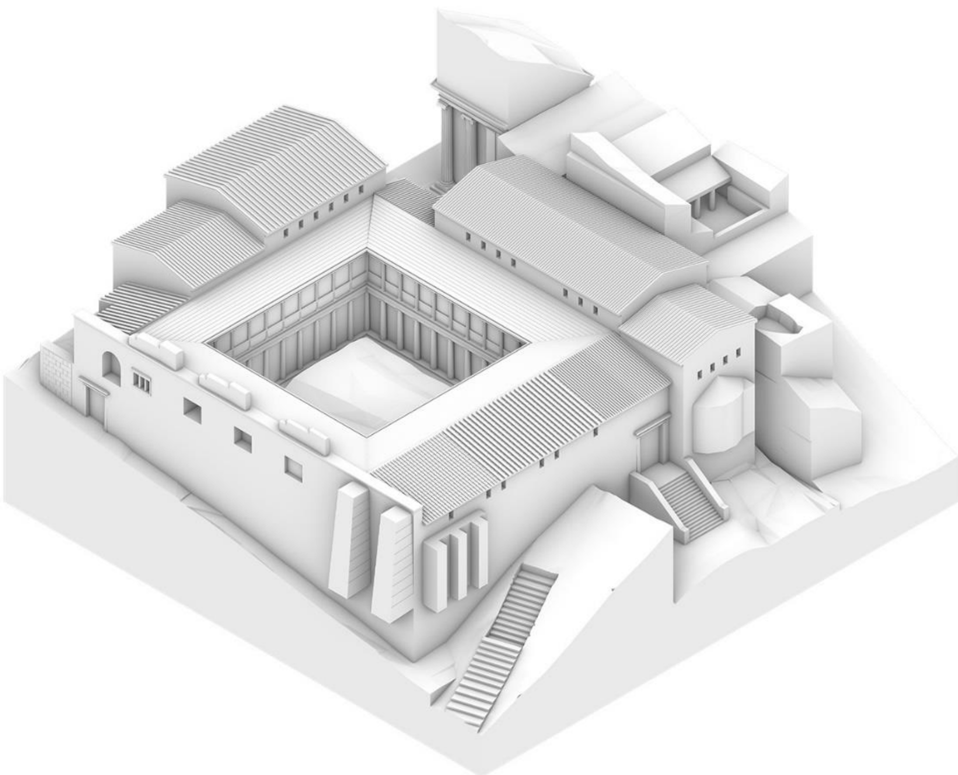

Figure 2: *Test body for milling as a condensed arrangement of the model components selected in Fig. 1*

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The Visual Identity of a Conference between Science, Art, Museums and Technology

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ABSTRACT: The rise of digital tools is resulting in disruptive changes in the fields of culture, media, and visual arts. On this premise, the EVA conference network, including the Berlin edition, was originally established, and provides to this day a significant contribution in the field of digital tools applications in the arts. This study, conducted at the Chair of Architecture and Visualisation at Brandenburg University of Technology (BTU), whose field of expertise is the influence of digital tools on the creative process, builds upon the foundations offered by the EVA conference network and aims to expand its core elements of digitality, art and culture. The goal is to further enhance the EVA conference framework by means of providing a set of practical solutions (digital and physical) based on the teaching activities and the proposals of the Chair's students. The EVA Conference Berlin offers a case study in which the expertise of the Chair – digitalisation and architecture – meets the conference's requirements, offering a portfolio of practical solutions applicable to future editions. We later collected and analysed the students' proposals to structure them into different sub-topics: visual identity, graphics and layout of the conference proceedings and website, design of the conference location, user experience and the organisation of other parallel events to be organised during the conference, such as exhibitions. The Greek and Roman Plaster Cast Collection in Berlin was proposed to the students as potential conference location. The results were later discussed with the conference partners, Fraunhofer Heinrich-Hertz-Institut and Gesellschaft von Freunden des Heinrich-Hertz-Instituts e.V., as well as with the EVA conference network and with the Greek and Roman Plaster Cast Collection, with the aim of implementing the analysis' results in the next conference edition.

1. INTRODUCTION

The EVA conferences are an international network dealing with museology, art and media studies, computer science, curatorial practice, cultural management, archival science and digital humanities. Since the 2023 edition, the Chair of Architecture and Visualisation at Brandenburg University of Technology (BTU) has been the organising institution of the Berlin's edition. For the 2025 edition, the Chair has committed to using its expertise in digitality and creativity to develop a portfolio of proposals for future editions of the conference within a series of teaching seminars. The Chair has also committed to testing digital tools, develop and improve a visual identity and critically discuss the results of the analysis in an academic context, with the aim to provide innovative and creative solutions for cultural engagement. The results are then to be discussed with the international partners in the EVA Conference network to potentially implement them in future editions. These tasks were developed during the winter semester of 2024–25 as part of the teaching activities for Bachelor's and Master's students at the Faculty of Architecture at Brandenburg University of Technology, in preparation for the EVA Conference 2025 in Berlin.

Our work is based on the following theoretical premises. Digitalisation and artificial intelligence (AI) have brought epoch-making breakthroughs in the cultural field. In parallel, creativity and its visual expression have always been linked to technical achievements and critical reflection on them. Taking architecture as an example, this link can be seen from ancient treatises to the present day with connections to art, literature and philosophy, and is also evident in creative programming and AI prompting. Technological improvements that facilitate creative projects have already

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marked several turning points in recent decades, including the advent of photography, film, computers, drawing programmes and digital images. These developments have led to profound reflections on topics such as technological reproducibility [1] on the medium [2] and on many other specific topics such as new media in Art History [3] and Digital Architecture [4].

We contribute to this theoretical framework by means of providing practical solutions for a cultural event, the EVA conference Berlin, traditionally focused on the link between Art and Technogy, developing a portfolio of design solutions which focus on the technical solutions and their creative implications. Our exercise aims at enhancing the EVA Conference message and user experience by means of a coherent and captivating conference setup.

To this end, we invited the Chair's students to reflect upon the interpretation of the digital tool as media that allow the creative expression to occur. The students are prompted to use state-of-the-art digital tools (AI, VR, diverse softwares) to explore and design creative solutions as well as to test their potential and limitations.

As for the EVA conference, we provide a set of proposals for digital solutions for its organisation such as visual identity, user experience and accessibility. The results cover a wide range of solutions for graphics and layout for conference proceedings and the website, as well as design proposals for the location and other events to be organised during the conference. These solutions are ready to be used for the next edition, starting from 2026.

2. METODOLOGY

For our case study, we chose the Greek and Roman Plaster Cast Collection in Berlin. The collection is part of the Freie Universität Berlin and is also used for teaching and research purposes. It contains casts of Greek and Roman sculptures dating from the 3rd millennium BCE to around 500 CE. A permanent exhibition is on display, and a variety of special exhibitions are organised there, ranging from modern art to theatre performances and lectures. The uniqueness of this ancient collection and the peculiarity of the collection's physical space may seem antithetical to a conference dealing with digitality. This, on the contrary, offers a wide range of possible strategies for hosting a conference on new technologies, linking them with the museum institution and using it as a case for studying ancient art.

As a first step we defined the conference identity and the topics to be covered. The conference addresses the ongoing disruptive changes in culture and digitality, such as the rise of artificial intelligence, digital projects in the cultural sector, web-based research and communication collaborations, information technology and multimedia services for libraries, archives, museums and performing arts institutions. Students were asked to form groups and study the location and conference format from the digital and logistical perspective.

As part of the university course, we developed a series of assignments dealing with project proposal for both physical and digital dimensions of the event. The solutions provided by the students took the form of project proposals, which we then analysed to identify some cross-cutting topics that can be applied to future conference's editions. These include a visual identity package, a website, a layout for conference proceedings, brochures and conference poster, communication banners (e.g. for announcements and information or as a social media strategy), a physical layout for the conference in a museum context and a series of activities that could take place during the conference, such as exhibitions, aimed at connecting the digital realm with the conference location. Specifically, these topics were explored through 3D modelling software, renderings, AI tools and digital software for creative projects, as well as mixed techniques of representation and design, such as sketches, collages, layouts and videos.

The challenges posed by the rise of AI softwares push us to experiment with the full potential of digital tools. Our contribution to the assessment of their potential in creative projects involves testing them in the light of well-established design and communication practices. We start from the premise that a critical and comprehensive vision of the cultural field is just as important as mastering any new technology, which ultimately aims to be used professionally and creatively: The three dimensions (technology, applicability in a professional setting, and creativity) are fully represented by the case study offered by the organisation of the EVA conference.

3. RESULTS

This section provides an overview and evaluation of the project proposals. From a practical perspective, a recurring topic in the course's debates was, that the visual identity should be applied in digital format and conveyed through the conference's physical format, for example by creating a visual image within the city with supportive graphics. Therefore, the digital layout (e.g. of the website) and the conference graphics could be designed using the same framework. The results highlight that the website is a key feature and that it should move beyond the actual transitional state until it is truly captivating.
First trials were conducted on variations of the conference logo. Different concepts involved the geometric stylisation of the logo, with the aim of creating a common thread between the various international editions of the conference, as well as exploring colours that characterise the Berlin edition, with possible complementary and contrasting tones.
As for the online digital sections, the design proposals aim to implement various types of content that can be accessed via the website. These would introduce the conference topics and serve as a showcase for the scientific contributions and publications of the conference, as well as providing an interactive digital model of the conference venue with information on the spaces and programme.
Digital animations demonstrating the current capabilities of technological tools would expand the scope of the conference, enabling it to host visual installations by artists whose work may not align with the scientific format of papers. Furthermore, one of the prerequisites for the website section is to integrate archives from past editions.
Further inspiration emerged regarding the potential of VR/AR digital realities to support the conference by combining online digital content with the conference itself in a new physical setting based on the museum's features. This could ultimately break down the divide between the real and virtual worlds, offering a format that can be accessed remotely where digital environments and the host city merge. For example, this could enable historical reconstructions to be accessed digitally (in person and remotely) via VR technology and metaverse-based platforms.
Another focus is establishing a connection between classical art – exemplified by the Cast Collection as a venue – and digital technologies as a tool for reinterpretation. This could involve geometric abstraction or pixel art to recall an early technological repertoire or the digital implementation of exhibited museum artworks.
Regarding the application of artificial intelligence-based software for creating digital images, the idea of generating visuals was investigated during the project. The aim was to test and report on the progress of AI image generators using different techniques and the topics and information of the conference as prompts.
Finally, but equally importantly, the issue of inclusion in relation to digital technology was addressed. From a technical standpoint, digital tools can help to overcome physical barriers. However, the visual aspect of new technologies should not be underestimated, particularly in today's image-driven society. In terms of visual identity, potential additions to consider for future editions were highlighted, such as the selection of colours and text size, and the integration of automatic text-to-speech tools with multilingual translation. In terms of physical realisation, digital installations could incorporate a sensory layer involving touch (through digital fabrication) or hearing (through audio material activated by spatial localisation), enabling users to move between spaces and experience the content.

4. CONCLUSION

This paper presents a comprehensive exploration of how digital tools could be used to enhance the key message of the EVA Conference series, which focuses on the electronic Visualisation and the Arts, considering both organisational and user experience factors. The Greek and Roman Plaster Cast Collection in Berlin was used as a case study to highlight the challenges and opportunities of incorporating digital advancements into traditional cultural environments.
The results demonstrate that combining digital and physical formats, such as creating a cohesive visual identity, an interactive website and VR/AR elements, can significantly improve accessibility, engagement and the conference's impact. The development of a digital contents integrating multimedia and interactive elements provides a compelling example of how new technologies can enhance the presentation and dissemination of academic and artistic contributions.
In addition, we highlight the importance of using digital tools to bridge the gap between physical spaces and virtual environments. The

integration of VR-based elements and AI-generated visuals introduces new ways of experiencing exhibitions, transforming the conference into a dynamic environment that fosters the exchange of diverse expertise.

A key takeaway from this teaching project is the crucial role of inclusivity in designing and implementing digital solutions. Additionally, future editions of the conference could benefit from expanding the sensory experience using digital tools to not only communicate visually, but also engage users through touch and sound.

In conclusion, the solutions proposed for the 2025 edition of the EVA Conference offer an exciting blueprint for future digital-age conferences. They exemplify how interdisciplinary collaboration between academia, design and technology can create innovative solutions that respond to the challenges of the digital era and push the boundaries of cultural engagement and creativity.

The lessons learnt here provide valuable insights for future editions of the EVA Conference and are discussed within the organising partners. The outcomes of this study also contribute to the debate within the EVA conference network about the evolving role of digital tools in cultural and academic spaces. Possible further research developments would be the involvement of students in the practical realisation of the proposals concerning visual identity, proceedings and graphics, websites, exhibitions and other activities, physical layout, digitality and accessibility.

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Courses: „MUSEEN UND K.I.“ – Darstellung Vertiefung; „AUSTELLUNG UND K.I.“ – Visualisierung, Spezialfragen. Winter Semester 2024-2025.

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Progam EVA Berlin 2025

Conference Day I

“AI and the Arts”

Wednesday, March 12: 9:00 am – 7:30 pm

08:45 am – 09:00 am	Reception
09:00 am – 09:45 am	Morning Refreshment
09:45 am – 10:00 am	Conference Opening

10:00 am – 10:30 am
Keynote 1: Matteo Vallerian
(Max Planck Institute for the History of Science (MPIWG) in Berlin)

10:30 am – 12:00 am
Session 1: “Generative Identities”

Matilde Gardini and Cristiana Bartolomei
(Department of Architecture – Alma Mater Studiorum University of Bologna):
From Concept to Reality: Analyzing the Role of AI in Architectural Visualization and Design

Katharina Weinstock
(HfG Karlsruhe / DFG-Schwerpunktprogramm “Das digitale Bild”):
Memory, Ghosts and Trauma. AI-Generated Photorealism Beyond the Deepfake.

Abigail Rekas and Xinpeng Liu
(University of Galway):
Authorship and AI – Considering the Copyright Protection of AI Generated Materials

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12:00 am – 01:00 pm
Lunch Break

01:00 pm – 02:45 pm
Session 2: “CH between Draft and Signature”

Ilan Manouach
(Aalto University/University of Liege):
Generative Palimpsests: The Feature Space of Synthetic Comics

Mar Morosse
(Baruch College, City University of New York):
Artificial Intelligence and Art History: Exploring New Dimensions in Cultural Analysis

Julio Velasco
(Centre Marc Bloch):
AI in Artistic Creation: Tool, Gadget, or Aesthetic (R)evolution – Text/Image Platforms

Sofia Menconero and Leonardo Baglioni
(Sapienza University of Rome – Dept. of History, Representation and Restoration of Architecture):
AI and Landscape Painting: Perspective and Augmented Reality in Perugino’s Annunciazione Ranieri

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02:45 pm – 03:15 pm
Coffee Break

03:15 pm – 05:00 pm
Session 3: "Connected to the Machine"

Isabelle Hamm
(University of Cologne):
Generative AI and Art Mediation: Exploring Personalization, Participation, and Shared Experiences

Sławomir Nikiel
(University of Zielona Góra):
Concept Art Design and Generative Artificial Intelligence

Karam Al-Janabi, Hendrik Appel, Brian Eschrich, Robert Fischer, Maria Matthes and Monika Reich
(Chair for Immersive Media Design, TU Dresden / Interactive Science Lab,
Center of Interdisciplinary Digital Sciences, TU Dresden):
Discussing AI with AI – Interacting with a Chatbot System

Brian Eschrich, Robert Fischer, Maria Matthes, Kelsang Mende and Monika Reich
(Chair for Immersive Media Design, TU Dresden / Interactive Science Lab,
Center of Interdisciplinary Digital Sciences, TU Dresden):
Exploring Virtual Reality in an Exhibition Context/ Virtual Reality Demonstrator

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05:00 pm – 05:30 pm
Coffee Break

05:30 pm – 07:30 pm
Exhibition, Performances

Eva Waldherr	werk5 GmbH
Andrea de Polo Saibanti	Zeutschel GmbH
Gerhard Schnittger	Verus Digital GmbH
Monika Reich	TU Dresden
Robert Fischer	TU Dresden

Conference Day II
"Digitally Formatted"
Thursday, March 13: 9:00 am – 9:30 pm

08:45 am – 09:00 am	Reception
09:00 am – 09:30 am	Morning Refreshment

09:30 am – 11:15 am

Session 1: "Memory Twins I"

Marinos Ioannides, Elena Karittevli, Panayiotis Panayiotou and Drew Baker
(UNESCO Chair on Digital Cultural Heritage, Cyprus University of Technology):
Beyond Digital Twins: Introducing the Memory Twin for Cultural Heritage

Yinhua Chu
(Associate Professor, National Taipei University of Education):
Digital Ghosts: Flusser, Vampyroteuthis, and Li Yi-Fan's Virtual Memories

Zijing Song and Christian Wagner
(City University of Hong Kong):
The Virtual Time Machine: An Artistic Exploration with Generative Artificial Intelligence in Heritage Practices

Andrea de Polo Saibanti, Frank Ulrich Weber and Matthias Ronge
(Zeutschel GmbH / MIK Center, Berlin):
Using Kitodo for Digitizing your Resources

11:15 am – 11:45 am
Coffee Break

11:45 am – 01:00 pm

Session 2: "Memory Twins II"

Benjamin Feder and Daniel Johannes Meyer
(Fraunhofer Heinrich-Hertz-Institut):
ToHyVe: Walkable 360° Videos for Hybrid Formats

Alessandro Basso, Caterina Palestini, Maurizio Perticarini and Giovanni Rasetti
(Università degli Studi di Camerino /Università degli Studi G.d'Annunzio Dip. Architettura):
D(A)nte's (I)nferno Representations Through Integrated A.I. and Parametric Drawing Techniques.

Tina Schneider, Jasper Funk-Smit and Jens Dobberthin
(Museum für Naturkunde Leibniz-Institut für Evolutions- und Biodiversitätsforschung):
Transformation of a Dor Beetle – from a Scientific Collection Object to a Multimedia, Hybrid, Interactive and Barrier-free Experience

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01:00 pm – 02:00 pm
Lunch Break

02:00 pm – 03:30 pm

Session 3: "On Display – Experiencing the New Museum"

Ulf Beyschlag
(tat-team GbR):
Mobile Museum

Francesca Fatta and Paola Raffa
(Mediterranea University of Reggio Calabria):
From Museum to Theater Digital Humanities Tools towards include and Cultural Fruition

Roberta Spallone, Chiara Teolato, Michele Russo, Marco Vitali, Valerio Palma, Enrico Pupi and Martina Rinascimento
(Politecnico di Torino – Department of Architecture and Design /Consorzio Residenze Reali Sabaude / Sapienza Università di Roma – Department of History, Representation and Restoration of Architecture / Shazarch s.r.l.):
Visualising Piffetti's Library in Villa Della Regina Museum:
An Interdisciplinary Digital Project for Knowledge Accessibility

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03:30 pm – 04:00 pm

Coffee Break

04:00 pm – 05:45 pm

Session 4: "CH In Conversation"

Thomas Weibel
(University of Applied Sciences of the Grisons):
The Antikythera Mechanism: Data Visualisation using Web-based Virtual Reality

Riccardo Rapparini
(Università di Parma):
Broadcasting Architecture in the Age of New Media. Innovative Tools for Changing Times

Laura Farroni and Matteo Flavio Mancini
(Department of Architecture – Roma Tre University):
Data Transformation for Narratives Context: From Scientific Research to its Communication

Francesco Stilo and Lorella Pizzonia
('Mediterranea' University of Reggio Calabria, Department of Architecture and Territory (dArTe))
The Famedio by Leone Savoja at the Monumental Cemetery of Messina

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05:45 pm – 06:15 pm

Keynote 2: Joachim Bauer
(Albert Ludwig University of Freiburg, International Psychoanalytic University Berlin, Deutsche Psychologen Akademie (German Psychologists Academy))

06:30 pm – 08:00 pm

Introduction to the HHI
Visit of Forum Digital Technologies (FDT) and of Innovation Center for Immersive Imaging Technologies (3IT) at Science Tech Space @ Fraunhofer Heinrich-Hertz-Institut.

08:00 pm – 08:30 pm

Social Event
Buffet and drinks, followed by an open-ended get together.

Conference Day III
“Hybride Realities”
Friday, March 14: 09:00 am – 05:00 pm

08:45 am – 09:30 am Reception and Morning Refreshment

09:30 am – 11:00 am
Session 1: “Knowledge Architectures”

Domenic Städtler
(Institute for Museum Research):
Authority Files for Search and Filter Options in the German Digital Library

Angela Kailus
(Deutsches Dokumentationszentrum für Kunstgeschichte –
Bildarchiv Foto Marburg, Philipps-Universität Marburg):
Minimum Record Recommendation for Museums and Collections

Frithjof Schwartz and Björn Böhme
(Staatliche Schlösser und Gärten Baden-Württemberg / MicroMovie GmbH):
Virtual Models from the Ego Perspective. A Development for Comparative Perception

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11:00 am – 11:30 am
Coffee Break

11:30 am – 01:00 pm
Session 2: “CH Digitally Reproduced”

Enrico Pupi and Piergiuseppe Rechichi
(Politecnico di Torino / Università di Pisa):
Optimizing Inference Conditioning Techniques In Image Generation For Participatory Urban Transformation.

Lisa Pfeiffer
(Museum für Naturkunde):
ELIO: Innovations in Object Digitalization and Business Models in the Cultural Sector

Benjamin Feder and Daniel Johannes Meyer
(Fraunhofer Heinrich-Hertz-Institut):
DOMEconnect – Interactive Live Streaming Connecting Immersive Venues

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01:00 pm – 02:00 pm
Lunch Break

02:00 pm – 03:30 pm
Session 3: “What’s on in Berlin”

Andreas Bienert
(University of Applied Sciences Potsdam):
SHIFT Metamorpho**S**is of cultural **H**eritage **I**nto augmented hypermedia assets **F**or enhanced accessibili**T**y and inclusion

Lyubov Dimova, Dominik Lengyel
(Brandenburgische Technische Universität Cottbus-Senftenberg):
The New Tactile Model of Pergamon for Berlin

Jacopo Spinelli, Dominik Lengyel
(Brandenburgische Technische Universität Cottbus-Senftenberg):
The Visual Identity of a Conference between Science, Art, Museums and Technology

03:30 pm – 04:00 pm
Coffee Break

04:30 pm – 05:00 pm
Conference Closing Remarks

PROGRAMME ORGANISATION

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Univ.-Prof. Dipl.-Ing. Dominik Lengyel
(Brandenburg University of Technology Cottbus-Senftenberg,
Chair of Architecture and Visualisation)

Prof. Dr. Andreas Bienert
(form. Staatliche Museen zu Berlin – Preußischer Kulturbesitz)

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