Electronic Media & the Visual Arts

EVA 2025 Florence

PROCEEDINGS

Editor: Vito Cappellini

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26 May 2025

Edited by
Vito Cappellini

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Grand Hotel Minerva, Florence

26 May 2025

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  - Society
  - Public Administrations
- **Artificial Intelligence Perspectives and Evolution**
- **European Commission Projects and Plans regarding Innovation Technologies, Artificial Intelligence and Cultural Heritage**
- **Leading Applications in the Cultural Area:**
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  - Museums
  - Libraries
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  - Monuments
  - Historical Palaces
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- **Augmented, Mixed and Virtual Reality**
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- **Digital Art**
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- **NFTs and Digital Product Passport**
- **Cultural Tourism and Travel Applications**
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26 May 2025

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10,00	*Opening:*	*Eugenio Giani,* *President of REGIONE TOSCANA*
		Giorgio Battistelli, *Director of Dipartimento di Ingegneria dell'Informazione - UNIVERSITA' DEGLI STUDI DI FIRENZE*
		Alessandra Poggiani, *General Director of CINECA*
		Paolo Castellacci, *President of GRUPPO SESA*

10,50 **SESSION 1 – STRATEGIC ISSUES**

Chairman: Enrico Del Re, University of Florence, Italy

"Artificial Intelligence Tools in Cultural and Creative Industries"	Antonella Guidazzoli, Maria Chiara Liguori VisitLab - CINECA Bologna, Italy
"Virtual Reconstruction of Frescoes Using Generative AI: The Case Study of Mirabello Castle"	V. Cantoni, L. Goretti, M. Musci, A. Setti Dept. of Electrical, Computer and Biomedical Engineering - University of Pavia Pavia, Italy
"Artificial Intelligence and Digital Innovation in Tuscany Region"	Stefano Ciuoffo[1], Gianluca Vannuccini[2] [1]Deputy Governor for Innovation Tuscany Region Florence, Italy [2]CIO Tuscany Region Florence, Italy
"Data Space Culture: Digital Sovereignty for Culture and the Creative Industries"	Dirk Petrat Chief Digital Officer, Hamburg Ministry of Culture and Media, Co-chair of the steering committee for the Data Space Culture project Hamburg, Germany
"Italian Fashion and Hollywood: Iconic Designers, Stars of the Digital Stage, Museums to the Silver Screen, and Streaming"	Jonathan P. Bowen[1], Tula Giannini[2] [1]School of Engineering London South Bank University London, UK [2]School of Information Pratt Institute New York, USA

“Preliminary Experiment of Genetic Programming in Digital Art and Design”

E. Cappellini[1], L. Dei Cas[2], R. Folgieri[3]
[1]Department of Architecture, Design and Urban Planning
Università degli Studi di Sassari
Sassari, Italy
[2]Ulixe Nova Group
Torino, Italy
[3]Department of Philosophy “Piero Martinetti”,
Università degli Studi di Milano
Milano, Italy

“Smart Monitoring and Actuation Services for the Protection of Cultural Heritage”

Edoardo Calia
CTO-LINKS Foundation
Turin, Italy

“The Universal Gallery: A Laboratory for AI Orchestration in the Multimedia Creative Process”

Bruno Cerboni
SMART-ART Media Consulting,
Digital Media
Rome, Italy

13,10 Lunch Break

14,40 **OPEN SESSION – INTERNATIONAL EVA NETWORK**

Chairman: Vito Cappellini, University of Florence, Florence, Italy

- *Paolo Tedeschi, Direttore Competitività Territoriale della Toscana e Autorità di Gestione – REGIONE TOSCANA, Florence, Italy*
- *Roberto Ferrari, Executive Director– MUSEO GALILEO, Florence, Italy*
- *Edoardo Calia, CTO-LINKS Foundation, Turin, Italy*
- *Riccardo Bruschi, Managing Director T.T.TECNOSISTEMI SB – DIGITAL VALUE, Prato, Italy*

Speakers Presentations

15,40 **SESSION 2 – NEW SCIENCE, TECHNOLOGY AND CULTURE DEVELOPMENTS & APPLICATIONS**

Chairman: Antonella Guidazzoli, CINECA, Bologna, Italy

“Language Models – Perspectives and Limitations”

Riccardo Leonardi
Dept. of Information Engineering
University of Brescia
Brescia, Italy

"How Cyber Skills are Evolving in the Age of AI"	Rita Forsi[1], Clarissa Cecchi[2] [1]Vice President and Director of the Technical-Scientific Committee of Women4Cyber Italy [2]Member of Technical-Scientific Committee of Women4Cyber Italy
"Proposal for Next-Generation FTV Integrating Analytical and AI Approaches"	Masayuki Tanimoto[1], Hirokuni Kurokawa (Aiguo He)[2] [1]Nagoya Industrial Science Research Institute Nagoya, Japan [2] Intelligent Vision & Image Systems Tokyo, Japan
"Critical aspects in bringing artificial intelligence from the laboratory to the clinics: the role of Ethics Committees"	Andrea Barucci[1], Maria Carmela Leo[2], Salvatore De Masi[3] , Roberto Pini[1] [1]Istituto di Fisica Applicata "Nello Carrara" – CNR Firenze, Italy [2]Segreteria Comitato Etico Regione Toscana - Pediatrico, AOU Meyer IRCCS Firenze, Italy [3]Clinical Trial Center, Azienda Ospedaliero Universitaria Careggi Firenze, Italy
"FAMILIE – Scailable Community Assistance with Ethical AI in Smart Cities"	Mika-Petri Laakkonen[1], Ville Pietiläinen[2], Jari Kaivo-oja[3], Minna Vanhanen[1], Hanna-Leena Huttunen[1] [1]Oulu University of Applied Sciences Oulu, Finland [2]University of Lapland Rovaniemi, Finland [3]University of Turku Turku, Finland
"Sound Voiding: Audio Experiences in Cultural Online XR Projects"	Alena Khudnitskaya Dept. of Archives Studies and Museology Comenius University Bratislava, Slovakia
"Human – Centric Digital Innovation: The Integrated Approach of SESA Group"	Francesco Falaschi Innovation SESA S.p.A. Empoli-FI, Italy

17,10 **SESSION 3 – CULTURAL ACTIVITIES – REAL AND VIRTUAL GALLERIES AND ACCESS TO THE RELATED INFORMATION**

Chairman: Dominik Lengyel, BTU University of Technology, Cottbus, Germany

"RE-ART Europe by Smarticon"

Sara Penco
Restauratrice e ideatrice del brevetto per metodo Smarticon
Rome, Italy

"Cultural Innovation through Co-Creation in Smart Cities"

Francesco Bellini, Irina Gorelova, Fabrizio D'Ascenzo
Department of Management
Sapienza University of Rome
Rome, Italy

"The Consistency of a Photomontage in the Transition to Virtual Space"

D. Lengyel[1], C. Toulouse[2]
[1]BTU University of Technology
Cottbus-Senftenberg
Cottbus, Germany
[2]Lengyel Toulouse Architects
Berlin, Germany

"Flying with The Butterfly"

Jean Paul Carradori[1], Hirofumi Yoshida[2], Fabio Pagani[3], Simone "zeta" Saccomandi[4]
[1]Director, light-video-set designer
Mutaforma Project
[2]Music Director of the Modena-Pavarotti Theater Philharmonic Orchestra
[3]Communication manager Sistine Chapel Choir
Screenwriter
[4]Sound Engineer, System Engineer, Sound Designer
ZetaStudioRecording

"Recent Advances in the Applications of Artificial Neural Networks to the Analysis of Ancient Egyptian Hieroglyphs"

Maria Messineo[1], Andrea Barucci[2], Costanza Cucci[2], Vittoria Del Vecchio[2], Fabio Nesi[2], Marcello Picollo[2], Fabrizio Argenti[1]
[1]Dept. Information Engineering
University of Florence
Firenze, Italy
[2]Institute of Applied Physics "Nello Carrara"
National Research Council of Italy
Sesto Fiorentino - Firenze, Italy

"AI ArtCentrica Stories"

M. Cappellini, E. Accorsi, S. Ollani
ArtCentrica S.r.l.
Florence, Italy

PROCEEDINGS

STRATEGIC ISSUES

ARTIFICIAL INTELLIGENCE TOOLS IN CULTURAL AND CREATIVE INDUSTRIES

Antonella Guidazzoli, Maria Chiara Liguori
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Italy
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Abstract - Artificial Intelligence (AI) has now permeated all domains, including culture and the arts. Cineca, rooted in a strongly technical and scientific background, is actively engaged in fostering a collaborative ecosystem that brings together researchers and companies within this context as well. The integration of open science tools and hybrid workflows supports the optimisation of production processes—aiming not only to reduce costs and accelerate innovation, but also to offer support and inspiration for both research and creative endeavors.

INTRODUCTION

Today, artificial intelligence has become pervasive, seamlessly integrated into even the smallest daily actions, such as taking a photograph. At Cineca, AI has been applied across various research domains for years, leveraging the power of supercomputing to process vast amounts of data efficiently.

It is no surprise, then, that Cineca is leading the IT4LIA project—one of Europe's AI Factories [1]—which will feature a supercomputer specifically optimized for AI applications. The AI Factory concept fosters a dynamic ecosystem where researchers, developers, large enterprises, small businesses, and start-ups collaborate. DAMA, Bologna Technopole [2] is already recognized as a central hub for supercomputing, big data, and quantum computing, and will now host the AI Factory infrastructure as well.

The project is the result of a collaboration between prominent Italian institutions, including CINECA, which will coordinate the project, INFN, the Bruno Kessler Foundation (FBK), the ItaliaMeteo Agency, the National Research Center in HPC, Big Data, and Quantum Computing (ICSC), and other institutional and regional partners. The infrastructure will serve as a key resource to foster collaboration between research and industry, accelerating the development of innovative solutions focused particularly on supporting sectors such as agribusiness, cybersecurity, earth sciences, and manufacturing, yet no field is left behind. Even culture—once considered alien to high-performance computing—is now benefiting from AI-driven innovation.

This project represents a crucial step in bolstering Italian and European leadership in technological innovation, delivering tangible benefits for research and the country's economic fabric.

AI APPLICATIONS IN CULTURE AND CREATIVITY

As part of the National Recovery and Resilience Plan investment M1C3 1.1 - Strategies and Digital Platforms for Cultural Heritage - the Central Institute for the Digitization of Cultural Heritage – Digital Library, under the Ministry of Culture, is developing and overseeing the implementation of the National Plan for Cultural Heritage Digitization.

In this initiative, one of Cineca's key roles is to identify and integrate open-science artificial intelligence solutions to analyze, manage, and enrich digitized cultural content [3; 4]. A notable proof of concept currently in development focuses on the automatic transcription of the vast heritage of manuscript texts (Fig. 1). This involves enhancing the quality of existing digitization, applying text recognition technologies, integrating specialized vocabularies, and implementing automatic error correction [5]. Such advancements significantly streamline scholarly research while also opening new opportunities for the cultural and creative industries to leverage these enriched digital resources.

In a recent collaboration, the *AI for Culture* team from Cineca's HPC department supported Daimon Film Srl in producing a documentary about Italian musician Edoardo Bennato [6]. Due to the limited availability of high-quality audiovisual materials from Bennato's early years, the production company sought Cineca's expertise in scouting open-source models to enhance and possibly animate the existing images. However, the results did not meet expectations. As a result, the company turned to commercial solutions, which yielded only low-resolution footage. To overcome this limitation, Cineca leveraged supercomputing and custom scripts to develop an optimized workflow, enabling the rapid upscaling of individual frames. This process ultimately generated hundreds of high-quality 4K sequences, significantly enhancing the documentary's visual quality.

As part of its technology scouting efforts, Cineca identified *Real-ESRGAN* [7] as a promising open-source solution for image upscaling and restoration. Developed by Xinntao et al., *Real-ESRGAN* is an NCNN-based implementation designed to enhance low-resolution images by reconstructing fine details and textures using deep learning techniques. This tool has been widely adopted for various applications, from film restoration to digital content enhancement. Within the *PNRR MIC* project, *Real-ESRGAN* is accessible via API on Leonardo, enabling high-performance image processing for cultural and creative applications.

As in the previous use case, artificial intelligence served as a powerful auxiliary tool—enhancing creative possibilities without replacing the expertise and artistic vision of human operators.

The integration of AI-driven open science tools with the concept of hybrid workflows presents a transformative approach to optimizing production processes and reducing operational costs across disciplines. By combining automated, data-driven intelligence with collaborative, human-in-the-loop methodologies, hybrid workflows enable more agile decision-making, faster iteration cycles, and improved resource management.

Open science tools, grounded in principles of transparency, FAIR data practices (Findable, Accessible, Interoperable, Reusable), and community-driven development, provide a modular and interoperable foundation for collaboration across domains. When coupled with scalable AI components, such workflows facilitate reproducible experimentation, intelligent resource orchestration, and predictive analytics, resulting in accelerated innovation cycles and measurable cost savings. This paradigm supports both exploratory research and industrial deployment, bridging the gap between computational automation and expert-driven insight.

The experience of the EU Digital Deal project [8], with the realisation of the installation *The Models* by the artist duo *dmstfctn*, winners of the call for an artistic residency in Bologna on the theme of debunking, fits well into this context [9]. The artists decided to reflect on the dangers of mystification created by unsupervised artificial intelligence that, left to its own devices, can begin to hallucinate (Fig. 2). In the project, inspired by the theatre of the Commedia dell'Arte, the Puppet Theatre and some of the most famous masks, stable in their unchanging characteristics, two Large Language Models were made to interact with each other on the basis of the specific characters of the masks, a series of stage sets - from the archives of the Puppet Museum in Budrio [10] - and a series of props. This resulted in fourteen thousand theatrical dialogues.

Language models generate text on a probabilistic basis from a set of textual cues (the prompts). Trained on large corpus of data, these models simulate conversations by predicting the probability that one sequence of words will follow another, in a manner not too different from automatic sentence completion systems. The quality and consistency of the text produced depends on the breadth and variety of the training corpus. However, the model has no real understanding of the 'meaning' of the text but operates solely on probabilistic assessments. For this reason, the artists took great care in writing the prompts so that the result reflected their intentions and accurately guided the masks' responses to props and context, while remaining true to the character's identity.

In this case, artistic creativity is expressed not only by the intentionality behind the installation, which is to highlight the hallucinatory limits of AI, but also in the interaction with it, mediated by the prompts developed by the artists to always achieve something going beyond the uniformity of the usual response.

CONCLUSIONS

From the experiences proposed here, we can see how AI can be a useful tool to support creative engagement, and herein lies the point, namely the invitation not to let one's guard down and to make a conscious use of this technology [11]. There is always a risk that, out of laziness, we will delegate real creative activities to an automated being, with the risk of unlearning how to use these skills [12]. This highlights the importance of adopting a Human-AI framework—one that emphasizes *augmentation over substitution*, and *collaboration over automation*. Within such a framework, AI is not seen as a replacement for human ingenuity but rather as a partner that can amplify our creative capacities while respecting human intent, judgment, and cultural values. It calls for a mindful integration of AI into creative processes, where human agency remains central, and the purpose of the technology is to enhance rather than erode our cognitive and imaginative abilities.

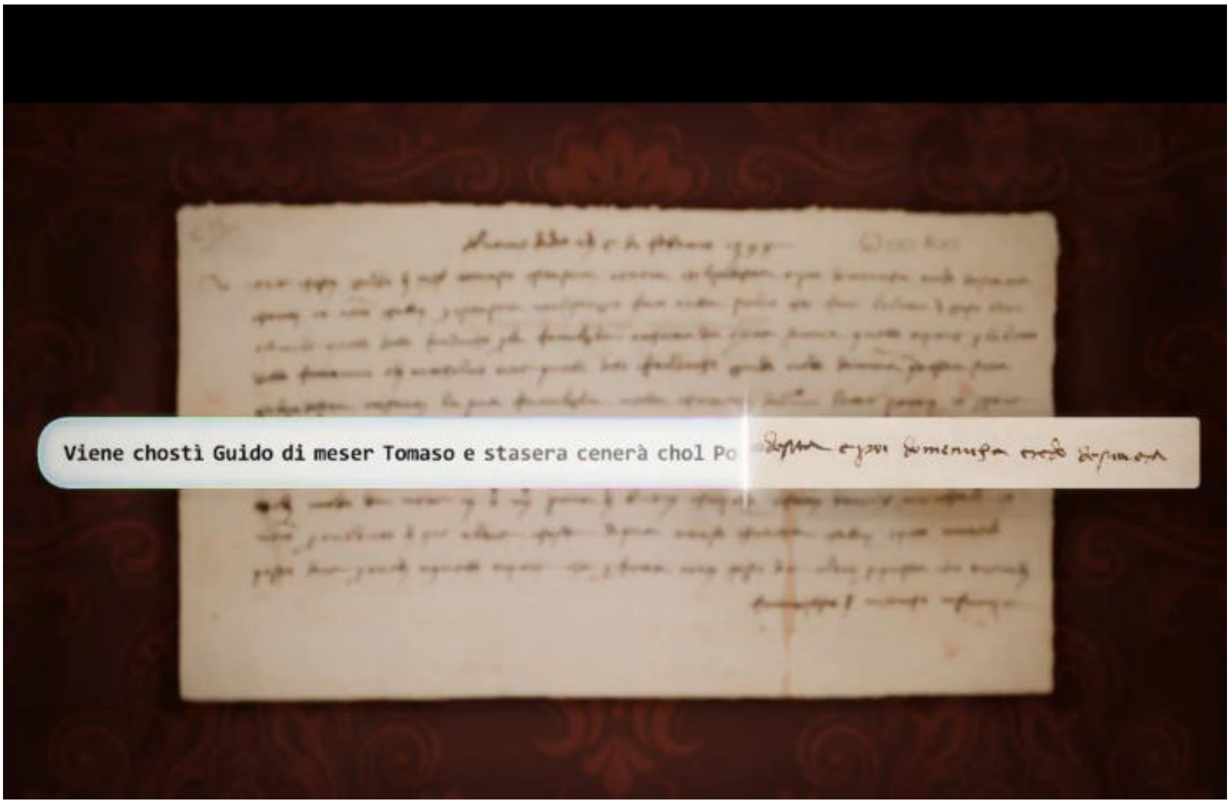

Fig. 1 – AI assisted transcription of an ancient manuscript

Fig. 2 – The Models installation, by dmstfctn

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VIRTUAL RECONSTRUCTION OF FRESCOES USING GENERATIVE AI: THE CASE STUDY OF MIRABELLO CASTLE

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Abstract – This paper explores the application of Artificial Intelligence (AI) in the field of cultural heritage, focusing on the use of generative techniques to produce a plausible virtual reconstruction of the damaged frescoes of Mirabello Castle, located in Italy. The reconstruction process serves as a foundational step toward the creation of immersive and interactive experiences, integrating real and AI-generated content within a digital environment enhanced by a previously developed 3D model of the castle.

ARTIFICIAL INTELLIGENCE FOR CULTURAL HERITAGE

The integration of Artificial Intelligence (AI) into cultural heritage practices is reshaping how artworks are preserved, interpreted, and disseminated. Among the most promising approaches are Generative AI models—such as Generative Adversarial Networks (GANs) [1] and diffusion-based techniques [2]—capable of producing realistic multimedia content from incomplete or fragmentary inputs. These models enable the digital reconstruction of frescoes and other pictorial heritage, offering plausible visualizations based on stylistic, chromatic, and iconographic cues.

In the context of mural painting, AI complements traditional restoration methods—which are often invasive or irreversible—by providing non-destructive and reproducible alternatives. Such reconstructions allow experts to hypothesize the original appearance of artworks, guided by the contextual knowledge embedded in the models' training data [3][4]. Deep learning algorithms are particularly effective for tasks such as *inpainting*, style transfer, and image super-resolution, owing to their ability to replicate complex artistic features [5].

Rather than replacing physical restoration, AI serves as a supplementary tool for documentation, research, and public engagement. High-quality digital reconstructions can inform curatorial strategies and enhance accessibility through Virtual and Augmented Reality (VR/AR) applications, supporting broader cultural dissemination and interactive exploration.

This paper presents a case study focused on the frescoes of Mirabello Castle, a sixteenth-century architectural complex in northern Italy. Our method combines photographic evidence with AI-generated reconstructions, integrated within a previously developed 3D digital model of the castle. The result is an immersive and historically informed virtual experience that offers a glimpse into the site's original visual narrative.

In doing so, the project demonstrates the potential of interdisciplinary collaboration between computer scientists and art historians. It also highlights the importance of carefully curated datasets to ensure stylistic and contextual consistency in the generated reconstructions.

In-painting and out-painting

Generative Adversarial Networks (GANs), introduced by Goodfellow et al. in 2014 [1], and more recently diffusion models [2], have demonstrated high effectiveness in generating high-fidelity images from incomplete or corrupted inputs. In the context of cultural heritage, these models have been successfully applied to virtual restoration, enabling the reconstruction of missing sections in artworks—particularly frescoes—with results that are aesthetically and stylistically coherent [3–6].

This ability stems from the capacity of deep neural networks to analyze and learn intricate visual features such as color, texture, composition, and structure from large-scale image datasets. These models are particularly suited to tasks such as inpainting, style transfer, and image super-resolution, supporting reconstructions that maintain both visual consistency and historical plausibility.

The generation of output images using generative AI models can occur either ex nihilo or be guided by three key inputs: 1) a text prompt, 2) a starting image, and 3) a selection mask.

The text prompt is a free-form textual description, written in semi-natural language, that describes the desired characteristics of the output image. It can include positive elements (what should appear, how it should look) and negative elements (what should be excluded). These prompts may also encode expert knowledge, such as stylistic or historical information gathered by art historians or restorers.

The starting image is used when working with existing artworks; it provides the visual basis for the reconstruction. When the image contains damaged or missing areas, the technique is called *inpainting*—the model generates plausible content to fill the gaps [7]. Conversely, *outpainting* expands the image beyond its original boundaries, synthesizing new content that remains consistent with the existing visual style. In practice, both techniques are often used together in a complementary fashion.

The selection mask defines the specific region of the image where generation will take place. The generative field can be further refined through the use of a virtual canvas, allowing the model to intervene only in designated areas. Moreover, it is possible to assign different weights to specific regions of the input image, depending on their historical or stylistic relevance, giving experts greater control over the generation process.

Despite the guidance provided by prompt, image, and mask, the generation process remains inherently stochastic. The final result is influenced by various technical parameters—including sampling method, denoising strength, and model checkpoint—all of which must be fine-tuned by the operator. Each model has its own internal representations, and even minor changes in its training can significantly affect its behavior.

While many pre-trained models are publicly available, scientifically valid and philologically consistent, reconstructions often require retraining on custom datasets. In the digital humanities, this typically involves curating focused image collections that reflect the same author, historical period, geographic context, or artistic style as the artwork under study. This process demands strong domain expertise and close collaboration between AI developers and art historians to ensure the coherence, reliability, and interpretative integrity of the generated content.

THE FRESCOES OF MIRABELLO CASTLE

The frescoes that once decorated the interior spaces of Mirabello Castle are still largely hidden beneath multiple layers of plaster, both on the ground and first floors of the structure. On the ground floor, an engraved and painted coat of arms remains visible, representing one of the few elements currently accessible for direct observation.

On the upper floor, stratigraphic investigations have revealed the presence of a painted ornamental band, executed in chiaroscuro and measuring approximately one meter in height. This band runs continuously beneath the shutter of the wooden ceilings across four rooms and displays a recurring decorative motif: a procession of wreaths and winged putti supporting cornucopiae, which conclude in spiral decorations. These are interspersed with pottery, candelabra, and floral elements, composing a coherent and stylistically unified frieze consistent across the surveyed sections [8–13].

THE VIRTUAL RECONSTRUCTION STEP BY STEP

The virtual reconstruction of the frescoes of Mirabello Castle was conducted using Stable Diffusion, a deep learning model for text-to-image generation based on diffusion techniques. Developed by Stability AI and released in 2022, Stable Diffusion has proven effective in producing detailed visual content guided by textual prompts.

To assist in the generation of specific decorative details, ChatGPT was used to produce customized prompts based on user-defined requirements. These prompts were then employed to guide the image synthesis process, ensuring stylistic and thematic coherence. Among various pre-trained models tested—sourced from open platforms such as Civitai, a repository and marketplace for generative AI models, and Hugging Face, a collaborative platform for AI deployment—the most effective was identified as “sd-v1-5-inpainting.ckpt [c6bbc15e32]”.

The reconstruction process began with the outpainting technique: each fresco fragment was digitally extended as much as possible to achieve a plausible and stylistically coherent reconstruction. Particular care was taken to preserve consistency with the central portion of the original fragment, as the generative quality tends to decline with increased extrapolation due to the model’s expanded degrees of freedom.

Both image-to-image (Img2Img) and text-to-image (Txt2Img) modes of Stable Diffusion were used (see Table 1). Although functionally similar, these modes offer different levels of control based on parameter configurations. Multiple batch iterations were executed, with varied settings, to identify the optimal outcome for each fragment.

The images obtained through outpainting were subsequently refined and composed using PicsArt, an AI-powered design tool that enabled the precise positioning and alignment of fragments within their original architectural layout.

The next phase involved the inpainting of residual gaps—those portions of the wall surface left incomplete after the initial reconstruction. These areas were manually selected using a brush tool, and the corresponding visual content was generated through text prompts submitted via the command-line interface.

To enhance structural accuracy and stylistic continuity, final refinements were performed using ControlNet, specifically leveraging two auxiliary control modes: openpose and canny. The openpose module preserved the spatial arrangement and definition of figures and objects, while the canny mode was used to correct color inconsistencies caused by uneven lighting conditions in the source photographs.

In cases where the original frescoes were largely intact, only the inpainting technique was applied, without the need for preliminary outpainting or image compositing.

	Img2Img	Txt2Img
Sampling Method	euler a	euler a
Sampling Steps	50	20
Resize Mode	resize and fill	resize and fill
Resize To	enlargement of width and height	enlargement of width and height
CFG Scale	7	7
Denoising Strength	from 0.8 to 1	-
ControlNet - Pixel Perfect	yes	yes
ControlNet - Control Image	independent upload	independent upload
ControlNet - Type	inpaint	inpaint
ControlNet - Preprocessor	only + lama	only / only + lama
ControlNet - Control Mode	controlNet is more important	balanced
ControlNet - Resize Mode	resize and fill	resize and fill
ControlNet - Control Weight	1	from 0.2 to 0.4
ControlNet - Start Control Step	0	0
ControlNet - End Control Step	1	from 0.4 to 0.6

Table 1. Parameter settings for Stable Diffusion reconstruction workflows: comparison between image-to-image (Img2Img) and text-to-image (Txt2Img) modes.

As a final step, the extension “old-photo-restoration” was used to upscale the reconstructed images. This enhancement restored fine visual detail and improved overall image quality, compensating for the initial resolution reduction imposed by the input constraints of Stable Diffusion. Examples of the digitally reconstructed frescoes are presented in Figure 1 and Figure 2.

CONCLUSION

The application of AI-based techniques has enabled the virtual reconstruction of entire frescoed walls dating back to the sixteenth century. Beyond their relevance for historical research, documentation, and restoration planning, such reconstructions hold considerable potential for educational, cultural, and touristic dissemination. Integrated into interactive systems, they offer a dynamic and accessible visual narrative of the castle’s artistic and architectural evolution.

The approach described in this study demonstrates how high-quality digital representations of cultural heritage can be created and experienced in immersive environments. These reconstructions support academic analysis, foster public engagement, and help preserve the visual memory of artworks in cases where physical restoration is impractical or impossible.

However, it is crucial to acknowledge the ethical and methodological challenges associated with AI in this domain. The accuracy of generative outputs depends heavily on the quality and representativeness of the training data; biased or incomplete datasets can lead to distorted reconstructions. Furthermore, AI-driven restoration inherently involves interpretative decisions that must be informed by human expertise. To safeguard the authenticity and integrity of the original artworks, AI should be employed in close collaboration with art historians and cultural heritage professionals, and always with critical awareness of its epistemological limitations.

Figure 1. Application of generative AI techniques for the virtual reconstruction of frescoes featuring floral motifs, spiral decorations, and winged putti supporting cornucopiae. Shown on the left are the original fragments; on the right, the corresponding digital reconstruction.

Figure 2. AI-based virtual reconstruction of frescoes depicting vases with floral motifs and spiral decorations. The original fragment is shown in the top left corner; the final reconstructed version is displayed on the right.

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ARTIFICIAL INTELLIGENCE AND DIGITAL INNOVATION IN TUSCANY REGION

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Tuscany Region has a long experience in the area of digital innovation. Indeed, starting since the first years of 2000 has introduced a series of platforms, both regarding the regional processes and the activation-allocation of Digital Services in the territories, which have been precursors of many initiatives, today consolidated also at national level. The Regional Law 1/2004 and the Regional Law 54/2009 had indeed introduced from one side a strong Governance of Digital Innovation for all the Region and from the other side had defined a Network constituted by Local Institutions and Digital Infrastructures, made synergic through the Tuscany Region.

The regional Platforms developed since those years are today consolidated assets, through which hundred of thousands of citizens and enterprises are any day using advanced digital services by Public Administration and also by Health Organizations.

In the last twenty years - we can outline - the global context is completely changed: from one side - due to the Pandemic situation - the digital services became always more fundamental and - through the Next Gen EU Recovery Fund - wide scale Innovations were introduced for the entire Italian Public Administration. The Cyber Attacks have been always more and more critical and, in parallel, the European and National Authorities have introduced an increasing number of security requirements to can continue to operate in the context of public and private digital services. Finally the most recent Innovation, introducing a completely new discontinuity, is represented by Artificial Intelligence.

In all this context the importance of assuring to all the People suitable basic and specialistic Digital Skills is becoming more and more fundamental to be able to compete in a professional and working context, which is becoming always more wide and competitive.

Further it is of central importance, in the context of a Toscana Diffusa (Diffused Tuscany), the concept of inclusion of all the territory defined in the connected Regional Law 11/2025, to be able to guarantee an adequate fixed and mobile connectivity to any citizen in the own home or working environment. The Tuscany Region has decided to readapt all these challenges into the Regional Law 57/2024, which has defined strategic paths of Regional Action for the overview and control of digital tTransformation in Tuscany, by defining - for the same Region - a government role and supervision of the most critical digital infrastructures, together with an innovation propulsion role though innovative instruments like a Regional CSIRT, and the Regulatory Sandbox directly adopted by the European AI ACT.

Tuscany Region is sharing this evolution phase with all the Stakeholders on multiple fronts:

- with citizens, through more than 180 digital facilitation points and many stimulating initiatives for specialistic digital skills in particular oriented to the young womens in the framework of the stem disciplines;

- with the Local Organizations through the Telematic Network of Tuscany Region and with an Inhouse Agency such as the METIS Consortium, which can assure to all the Tuscan Municipalities, included those more distant from the Urban Centers, to address together and through “in house” modalities the most Strategic Elements defined by the Law 57/24 to be managed in a more structural form, with the goal to obtain economical scaling with reference to the market and to permit to all the Local Tuscany Administrations to reach a homogeneous level of Innovation, improving procurement levels on the market and by efficiently using already defined solutions or platforms or services already defined at regional level;

- with the Universities, which through three Interuniversitary Competence Centers on “Artificial Intelligence”, on “Cybersecurity” and on “5G” find a common background of cooperation with the Public Administration and the Enterprises to transfer on the public and private sectors of Tuscany the Excellences of University and Scientific Research;

- with the Categories of Professionals and of the Associations, which are along the time involved in the Codesign processes (such as that in due course on the new Digital One Shop Stop) and of continuous improvement of Regional Platforms;

- with the Third Sector, the Area of Association and of Workers Unions, included the Retired Persons Unions, that are actively involved in the management and promotion of the more than 180 Digital Facilitation Points in Tuscany and play a fundamental role in the promotion among the citizenship of public digital services implemented in our Region;

- with the Enterprises, through an already consolidated role since many years of regional procurement platform, a role of aggregated procurement body at regional level, which permits to all the Tuscany Public Administrations of procuring software and IT services provided by the Regional public bids, with high quality and innovation levels, with economic scaling effects. The enterprises sector is also involved by the Region in dissemination initiatives on the territory, which result more and more strategic, in particular in the framework of Artificial Intelligence, due to the fact that all the public and private bodies are today involved in such new challenges (never before found), and it is highly opportune to set up brainstorming occasions and of collegial discussion initiatives for selecting the more sustainable and efficient forms of implementation of Artificial Intelligence in the public and private sectors.

The Region plans to continue to implement these development paths and to carry out what is foreseen in the LR57/24 and in the Law 11/25 about the Toscana Diffusa, with the goal to ensure to all the Local Tuscany Organizations and to all the citizens equal access and utilization rights of the essential public services, equal working development opportunities, of study and professional growth, or of leisure, no matter if they live or work in the Region main cities or in one of the many very beautiful internal areas of the Tuscany Region.

DATA SPACE CULTURE: DIGITAL SOVEREIGNTY FOR CULTURE AND THE CREATIVE INDUSTRIES

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Abstract

Data spaces are part of EU and Member State data strategies and are based on the principle of data sovereignty. In a federated structure, they create a networked environment for the secure, interoperable and sustainable sharing of content. The Data Space Culture project, initiated by acatech (1), the Fraunhofer Institute for Applied Information Technology FIT (2) and the Hamburg Ministry of Culture and Media and funded by the Federal Government Commissioner for Culture and the Media (3), is currently testing data space technology for the cultural sector and the creative industries in Germany. Over the past two years, a prototype of a data space with basic services has been developed that is suitable for implementation.

Introduction

With the ongoing digitalization of cultural life, the need for comprehensive data usage is growing. Cultural data is available in large quantities, but is often difficult for third parties to use due to technical obstacles. Different file formats, metadata standards and licensing regulations hinder data exchange, meaning that in particular valuable data often remains underutilized for reuse in new digital offerings. It is therefore a need for suitable digital infrastructures to make these data treasures available in new value-added services. Platforms, usually dominated by hyperscalers, often offer user-friendly and market-oriented solutions. However, the use of such platforms repeatedly goes hand in hand with a loss of data sovereignty, as proprietary systems are usually implemented and the reuse of data is difficult to control.

The concept of data spaces is a counter-model and is based on the principle of data sovereignty. Data owners retain complete control over their data, especially regarding who can access this data and under what technical and legal conditions. Data spaces are part of EU and Member State data strategies that aim to change the new dependencies on large platforms (4). They aim to ensure the secure, interoperable and sustainable sharing of content and create a networked environment in a federated structure in which participants can access, expand and make meaningful use of shared databases. There is no need for central data storage. EU regulations on data protection and the protection of intellectual property are valid. Barriers of isolated technological stand-alone solutions are avoided and revenue opportunities for data providers are made possible.

The Data Space Culture project, initiated by acatech (5) , the Fraunhofer Institute for Applied Information Technology FIT (6) and the Hamburg Ministry of Culture and Media and funded by the Federal Government Commissioner for Culture and the Media (7), is currently testing data space technology for the cultural sector and the creative industries in Germany. The technical feasibility and added value of data space technology for the cultural and creative sector are being worked out through use cases. As one of the 18 lighthouse projects from the previous German government's digital strategy (8), it has achieved particular visibility at national level (9). At European level, this technological alternative approach to platforms is accompanied by a comprehensive legal framework. The Data Governance Act (10) regulates the secure and trustworthy exchange of data within the EU and the organizational framework for the design of data spaces.

Technological foundations

Data spaces use standardized connector technology based on open source components, as developed by the International Data Spaces Association (IDSA), for networking and data exchange (11). In the Data Space Culture project, the basic technologies EDC (Eclipse Dataspace Components) and XFSC (Eclipse Cross Federation Services Components) were successfully tested, and it has been demonstrated that they are suitable as a sustainable technological base for a future carrier organization.

Data space technology improves the findability of cultural data through standardized description formats and enables them to be linked. Standardized metadata models allow interoperability between different platforms. The digital provenance of content can be made traceable, so that creators have transparent control over their data and rights holders can better protect their works. Decentralized storage services enable sustainable and secure long-term archiving that guarantees through connector technology discoverability and a high standard of data quality. Access to diverse, domain-specific data sets is provided by secure identification and authentication mechanisms, which enables trustworthy data exchange. With their focus on machine-readable implementation of usage specifications, data spaces offer the necessary infrastructure for interoperable data transactions based on common governance principles, standards and agreements on services. Overall, data spaces are also suitable for the use of innovative AI services in the future. These support the automatic indexing, classification and contextualization of data, which enables more efficient searchability of collections that can be found in data spaces. Data space technology also opens up opportunities to support personalized recommendation services.

Benefits of data spaces for culture

The testing of data space technology for the cultural sector is based on use cases that depict practice-oriented scenarios in four cultural segments: Networked cultural platforms (12), smart theatre services (13), smart museum services (14) and smart music services (15). The focus is on assessing whether, against the background of data sovereignty, the use of data space technology in practice actually increases the digital sphere of influence and whether efficiency gains can be expected.

The results achieved so far can be summarized as follows:

- Broker and catalogue services have shown that datasets from a wide range of cultural and creative sectors are easy to find and are available for reuse.

- Standard-based recommendations for the generation of metadata, among other things, can contribute to participants' planning and investment security.

- The combination of data sets from different sources can be supported by automated processes so that efficiency gains can be expected. The use of AI solutions can be helpful. There are also innovative design options for new digital offerings, which opens up prospects for new value chains and promotes the networking of cultural stakeholders.

- The interoperability of standardized connectors facilitates the seamless integration of different systems.

- The automation of data flows ensures clear access control.

- The connector technology enables the networking of heterogeneous data with different indexing quality.

- The data is processed in the course of specific reuse, thus reducing the effort required for generic processing and resulting in an increase in data quality with direct added value.

- In the cultural sector, adaptations to the existing connector technology are necessary in order to enable low-threshold access for the cultural sector in its often very small-scale structure. This process is not yet complete and needs to be further optimized, particularly with regards to interoperability and user-friendliness.

- The specific requirements of the cultural and creative sector demand additional services in order to benefit from the advantages of a data space. These include, for example, a sample contract service for securing copyrights, payment services and AI solutions that process different types of data in a user-friendly way.

- There is a need to be able to access and combine both open and protected data from a digital environment for new applications, which requires a powerful broker service with good search functions.

European dimension of the cultural data space

Against the backdrop of European data and data space strategies, data spaces open up far-reaching opportunities for cooperation within the EU. The EU Commission has launched various sector-specific data space initiatives, including the Common European Data Space for Cultural Heritage under the leadership of Europeana.

Such a data space is intended to promote standardized metadata and common technical frameworks so that digital cultural assets can be shared and combined across borders for further use in education, research, tourism or the creative industries. The focus is also on new usage scenarios (e.g. for AI training and immersive exhibitions) and the promotion of cooperation with the creative industries and research. Europeana acts as a coordinator for a digital ecosystem in culture (16).

Through transnational cooperation, Europe-wide decentralized cultural databases can be created that will facilitate access to all areas of European culture in the future. The German

Data Space Culture project can play a key role by networking with other European initiatives and facilitating the exchange of cultural data across national borders.

There are also useful links with the EU's AI strategy. The European Union aims to strengthen Europe's competitiveness in the global AI sector through an AI initiative. Among other things, so-called AI factories are to help strengthen the EU's strategic autonomy in this field and establish a European AI ecosystem. The aim is to drive forward the development of new technologies and applications and to promote cooperation and development in the field of artificial intelligence (AI). In this context, data spaces are seen as an important point of reference for AI applications, as they can provide the data required for the development of artificial intelligence without being dependent on non-European digital infrastructures (17).

Outlook

With start-up funding from the federal government, a prototype of a data space for culture and the creative industries with basic services has been created in Germany over the last two years. The data space technology has been adapted for the cultural sector in such a way that it is now suitable for use in practice, so that a data space carrier organization can be established. As a result, the various data platforms within the cultural sector can be interlinked into one data space, which in the long term can be expected to lead to efficiency gains in data management and data use with revenue opportunities for the cultural sector. Due to similar interests at European level, the establishment of a European Digital Infrastructure Consortium (EDIC) for the cultural and creative sector in Europe should therefore be explored on the basis of a data space technology that has been tested for the cultural sector.

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ITALIAN FASHION AND HOLLYWOOD: ICONIC DESIGNERS, STARS OF THE DIGITAL STAGE, MUSEUMS TO THE SILVER SCREEN, AND STREAMING

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Abstract – We begin in the 1960s with a defining moment for Italian film and fashion as art where Italy meets New York and Hollywood in the film, *La Dolce Vita* (see Fig. 1), directed by Federico Fellini and considered one the greatest films of all time. Produced by Astor Pictures of New York and filmed on location in Rome and at Cinecittà Studios. It is especially memorable for its passionate scenes with film stars Marcello Mastroianni and Anita Eckberg at the Trevi Fountain, dressed in stunning black and white costumes by Danilo Donati, who was awarded an Oscar for best costume design, while the film's composer Nino Rota (1911–1979) wrote the film score, and later won an Oscar for the score of *Godfather Part II*, 1974. *La Dolce Vita* became a lynchpin of a new cinematic art defining the angst and free spirit of the 1960s, that captured the imagination of a rising mass audience of a new popular culture movement enabled by the international distribution of films on the silver screen in theatres and television that broke the code of the old sociopolitical status of the arts as elitist.

INTRODUCTION

From the 1960s to the present, the arts have experienced a continual state of transformation, capturing a global audience while becoming the central influencer of human identity and expression in tandem with mobile phones in the hands of billions of users and social media operating 24/7 [1][5][9]. At the heart of these developments, the art of Italian fashion, from Florence to Milan and Rome, starring designers of Italy's great fashion houses, Gucci, Ferragamo, Pucci, Versace, and Armani, hold sway in the technosphere as global symbols of high fashion. Their art, past to present finds inspiration working in close physical proximity to *The Last Supper* of the Santa Maria delle Grazie, Milan, by Leonardo da Vinci, Michelangelo's Sistine Chapel, Rome, and the Uffizi Gallery Museum of Costume at the Pitti Palace, Florence, while Cinecittà studios outside Rome continue to advance Italy's film industry providing the latest technologies on a grand scale seen in their 360° rotating 25-meter diameter platform that moves between real and virtual production including sound stages, backlot area, production offices, permanent sets and support services [3].

ARTISTIC INFLUENCERS OF ITALIAN FASHION

Seen prominently in Italian fashion are the geometric shapes and vivid colours used by major abstract artists such as Piet Mondrian (1872–1944), Wassily Kandinsky (1866–1944), Sonia Delaunay (1885–1979), and Kazimir Malevich (1879–1935), Andy Warhol (1928–1987) was especially influential with the Marilyn Diptych, made of two silver canvases on which the artist silkscreened a photograph of Marilyn Monroe fifty times. Patterns in haute couture, as seen in Fig. 2, exemplify the fashion houses founded in Florence by Guccio Gucci (1881–

1953), Salvatore Ferragamo (1898–1960), Emilio Pucci (1914–1992), and Roberto Cavalli (1940–2024). whose contemporary designers continue to feature them, demonstrating the real connections between abstract painting and Florentine haute couture. In particular, Fig. 2b shows an exquisite silk dress by Pucci, who lived and worked primarily at the Palazzo Pucci in Florence, which served as his atelier, boutique, and Sala Bianca hosting fashion shows for over 40 years. Palazzo Pucci is in the heart of Florence, near the Duomo. Designs by Pucci were a favourite of Marilyn Monroe, who was interred in a Pucci dress.

With the Artificial Intelligence (AI) revolution and the marriage between the realm of fashion and Hollywood, a new film industrywide relationship, the fashion industry rose to a new level of recognition as an art form with the power to influence human identity and existence – from the 21st century forward with digital technology, the Internet, global platforms, social media, and streaming, the iconic Italian designers, from Florence to Milan and Rome, became designers to the stars as Marilyn Monroe, Elizabeth Taylor, and Judy Garland.

Throughout the 1960s, the city of Florence was recognized as the fashion capital of Italy. In the 1970s designers Versace and Armani each established their fashion house in Milan, which became the world's fashion capital with the success of its fashion week over the years beginning in 1958 – although Gucci, Ferragamo and Pucci, have retained their headquarters to this day in Florence, even though these Florentine designers also have establishments in Milan. Gucci developed a major presence in New York City (NYC) when Maurizio Gucci, grandson of Gucci's founder Guccio Gucci (1881–1953), married Patrizia Reggiani in 1972, the year they took up residence in NYC at the luxury penthouse, Olympic Tower, which Maurizio inherited from his father, valued at around $35 million, while he continued to maintain his palatial residences in Italy. It is notable that Gucci, the oldest Italian fashion house, founded in Florence in 1921, retains its leading position in the global market. In 2024, the Gucci brand, owned by the Kering Group, had a global revenue of about €7.65 billion, while in 2022, Gucci's revenue was €10.5 billion.

As of 2023, the film industry in Italy generated around €531 million in revenue, up from about €333 million a year earlier. The revenue of the Italian film industry was forecast to grow by around 84% between 2021 and 2026. Gucci's holding company Guccio Gucci S.p.A. is based in Florence, Italy, and is a subsidiary of the French luxury group Kering. In 2023, Gucci operated 538 stores for 20,711 employees and generated €9.9 billion in revenue.

In 2010, Gucci launched a partnership with Christie's to develop a wider repository of the brand's archives and provide an authenticity certification service. In 2011, the company opened the Gucci Museum (Gucci Museo) in Florence to celebrate its 90th anniversary.

SOCIAL MEDIA INFLUENCE AND GENERATIVE AI

The impact of social media on media awards such as the Oscars is increasingly having an impact on awards' outcomes; for example, TikTokers around the world are part of the conversation and real-time narrative. Seeing the world and ourselves on a digital screen, be it a smartphone, computer, television, or iPad, is a 24/7 activity. Day and night, users feel their phone must be in hand or within reach, or panic could take hold. We are in service to the overriding need to receive and interact with humans and information, to see those we love, or fantasize about, to see art and the array of things of interest that stimulate our imagination and creativity. Hollywood and the fashion industry, the image makers, play a huge role in creating a synthetic world, while our smartphones capture real experiences that we incorporate into our "real" virtual world, where imagination and creativity increasingly dominate, with humans taking their cues from Hollywood, makers of dreams.

Gucci Art Space has partnered with Christie's 3.0, an auctioneer's platform dedicated to digital art – 'Parallel Universes: From Future Frequencies to Gucci Cosmos'. They are exploring the intersection between fashion, art, and technology, in an exhibition of nine artworks using generative AI [2][8], that shows Gucci's interest in bringing together fashion and the latest technology for advanced AI methods of production, which might empower their means of communication and interaction with virtual customers.

With the AI revolution and the marriage between the realm of fashion and Hollywood, fashion rose to a new level of recognition as an art form with the power to influence human identity and existence – from the 21st century forward with digital technology and the Internet developing to global platforms, social media and streaming the iconic Italian designers, Florence to Milan, Gucci, Ferragamo, Pucci, and Versace became designers to the stars, included Marilyn Monroe, Elizabeth Taylor, and Judy Garland.

ITALIAN FASHION DESIGNERS

The 2021 film *House of Gucci*, produced in Italy, is being streamed across the globe, giving access to millions of people to get an up-close and personal experience of Italy's fashion world. Hollywood stars Adam Driver and Lady Gaga convincingly play the lead roles in this full-length film, which focuses on the story of Maurizio Gucci (1948–1995), grandson of the founder, Guccio Gucci. Driver's portrayal of Maurizio, the last Gucci to occupy a majority stake in the business, is exceptionally captivating. His scenes with Lady Gaga bring to life with remarkable realism his romantic relationship with Patrizia Reggiani, played by Lady Gaga. The film's opening section climaxes with their electrifying lovemaking, defined by raw male dominance (X-rated) is immediately followed by their extravagant marriage ceremony. In stark contrast, the film culminates with the brutal assassination by gunshot of Maurizio, ordered by Patrizia. Quite a Hollywood drama – although also real.

In November 1997, Princess Diana, wearing an Atelier Versace jewelled silk gown designed especially for her, was on the cover of Harper's Bazaar's November 1997 issue [10]. The photograph for the magazine cover was taken from a 1991 photoshoot by Patrick Demarchelier with the heading, "Diana, A Tribute to a Princess", reminding us of the enduring links between the British Royals and Hollywood.

2023 marked 100 years since Salvatore Ferragamo opened his first store in Hollywood across from the Grauman's Egyptian Theatre, a lavish movie theatre on Hollywood Boulevard in Los Angeles, where he lived until returning to Florence in 1927. In May 2020, the theatre was purchased by Netflix. Ferragamo's colourful life and work are celebrated in a new exhibition. 'Salvatore Ferragamo 1898–1960' at the fashion house's museum in Florence. It explores the Italian shoe designer's wide-ranging career, which began in the golden age of Hollywood. See Fig. 2a for Ferragamo's platform shoe made for Judy Garland in homage to *The Wizard of Oz*.

In Spring 2019, Gucci sponsored an exhibition at the Costume Institute, Metropolitan Museum of Art, titled *Camp* (see Fig. 2c), based on Susan Sontag's *Notes on 'Camp'* [13] that provides the framework for the exhibition, which examines the aesthetic of camp in fashion as "irony, humor, parody, pastiche, artifice, theatricality, and exaggeration are expressed in fashion."

Giorgio Armani (born 1934) continues to contribute across the many facets of his work. In 1975, he founded Giorgio Armani S.p.A. in Milan, with his friend Galeotti, and presented his first collection of men's ready-to-wear for Spring and Summer of 1976 under his name.

The Armani Hotel was opened in Burj Khalifa on 27 April 2010, comprising the bottom 39 floors of the supertall skyscraper in Dubai, United Arab Emirates; it has 160 guest rooms and suites, and 144 residences. Giorgio Armani is also designing the interiors of the Armani Residences, also within the skyscraper, and its specially designed line of products from the Armani/Casa home furnishings collection. Armani is one of the richest men in fashion, his worth estimated at $6.24 billion according to the Bloomberg Billionaires Index. In the 1990 short documentary film *Made in Milan* directed by Martin Scorsese, Armani discusses his ideas focusing on preparing for a show, and his views on fashion, family, and the city of Milan. Amani and Valentino from the 1970s Italian fashion revolution continue to enrich and inspire fashion's future and the Italian-Hollywood connection.

THE RED CARPET – FASHION'S GLOBAL STAGE

Wearing a form-fitting cut-out white Gucci bridal gown, "Jessica Chastain was a vision last night as she attended the 2025 Breakthrough Prize Ceremony, which celebrates the latest achievements in the scientific and mathematical fields" [4]. Yes, even the 11th Science and Math Breakthrough Prize Ceremony, on 5 April 2025 in Santa Monica, California, looked to the red carpet of Hollywood stars including Gwyneth Paltrow, Zoe Saldana, Lauren Sánchez, Katy Perry, Paris Hilton and Christina Aguilera, all flaunting seductive designer clothing, to attract the public lens to the main event. The red carpet, now the magic carpet for an increasing number of award ceremonies, seems to transform serious gatherings into party-like events. At this one, often called the Oscars of Science, Hollywood stars embraced the latest fashion trend for sparkly sheer see-through dresses, bringing attention to nude female bodies. The 2025 Academy Awards, also known as the Oscars, featured a festive red-carpet event shown live on television and streamed around the world. Hollywood stars paraded their alluring looks in silver, gold, and black [11]. Whether elegant or nude [12], Hollywood and Italian fashion rule.

CONCLUSION

Italian Fashion and Hollywood threads through many facets of contemporary life reflected in the rich and colourful lives of Italian designers, and the Hollywood creatives and moguls working at the forefront of the arts and technology revolution that took hold in the 1960s, and now reaching its pinnacle with digital screens and animated images on global platforms. Streaming and interacting across social media, we see a concentration of star power in the minds of the public that seems to be recasting the arts and human identity [6][7] at the intersection of human and artificial intelligence – humans just cannot seem to let go of their digital devices, body and mind, outer and inner space, all connected.

Fig. 1. Marcello Mastroianni and Anita Ekberg at Trevi Fountain, Rome, in the film *La Dolce Vita* (1960), directed by Federico Fellini.

Fig. 2a. Top: Ferragamo, Rainbow platform shoe made for Judy Garland and "Somewhere, over the rainbow." **Below**: Bamboo Handbag by Gucci, 1960, Archivo Storico, Florence.

Fig. 2b. Silk dress with geometric pattern design by Emilio Pucci, 1981, Florence. Galleria del Costume.

Fig. 2c. Female Coat and male suit by Alessandro Michele for Gucci on show at the 2019 *Camp* exhibition at the Metropolitan Museum, Costume Institute.

Fig. 2. Geometric pattern designs by the Florence designers Ferragamo, Gucci, and Pucci, making connections with digital computer art.

Images of the Mind's Eye – by Tula Giannini

Images of the mind's eye
Seeing out an inside
24/7 screens capture
Conscious and subconscious
States of being
Seeing real and virtual collide
Multiply and divide

Imagination or hallucination
Physical integration
of body and mind
Neural networks rewind
Seeing through a clouded lens
Can we be friends

Gazing at a digital screen
an unrelenting theme
I see your face
In subconscious space
Feeling intense emotion
Deep devotion
Drives our senses
No fences

Touching your face
We kiss
Is this real love
or the digital abyss
In either case
Don't erase
This moment in imaginary space.

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PRELIMINARY EXPERIMENT OF GENETIC PROGRAMMING IN DIGITAL ART AND DESIGN

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Abstract – This paper explores the application of genetic programming (GP) in the realm of algorithm-generated art and design, presenting a possible application of the fusion of computational methods and human creativity. By leveraging evolutionary algorithms, our approach aims at autonomously generating novel aesthetic forms while allowing for dynamic interaction with human designers, fostering a symbiotic relationship between machine intelligence and artistic intuition.

Through a simple example, we demonstrate how GP enables the exploration of uncharted design spaces, producing outputs that are both unexpected and aesthetically compelling. This work stands out for its hybrid methodology, merging principles from IT and genetic programming with traditional artistic practice, resulting in a digital artifact that challenges conventional creative paradigms.

The significance of this approach lies in its capacity, intrinsic to natural systems, to expand the boundaries of digital art, offering new tools for artistic expression and design thinking. By integrating evolutionary computation with human-guided selection, we provide a framework that enhances—rather than replaces—human creativity, positioning our method as a pioneering example of subject hybridization in computational art. This research contributes to ongoing discussions on the role of IT in cretivity, illustrating how algorithmic systems can serve as collaborative partners in the artistic process.

INTRODUCTION

The intersection of computational methods and artistic creativity has given rise to new paradigms in digital art and design [11]. Pioneering application of algorithmic generation of artworks [4] represent evidence of how the hybridization of technology and human creativity can rise new form of art. In this context, genetic programming (GP)[2], a subset of evolutionary algorithms [3], emerges as a powerful tool for generating novel aesthetic forms by simulating processes akin to natural evolution [9].

This paper investigates the application of GP in algorithm-generated art and design, emphasizing its potential to expand creative boundaries through human-machine collaboration.

Traditional artistic processes are often constrained by the limitations of human imagination and manual execution [15]. In contrast, GP enables the exploration of vast design spaces autonomously, producing outcomes that may elude human designers [6]. By integrating human intuition with machine-generated variability, our approach fosters a symbiotic relationship where each complements the other's strengths.

The significance of this research lies in its contribution to the evolving discourse on the role of Artificial Intelligence (AI) and Information Technology (IT) in creative industries. We present a framework where GP serves not as a replacement for human creativity but as an enhancer, offering new tools for artistic expression and design thinking.

In the following paragraphs we introduce the background of the presented model and related work, the adopted methodology, a case study related to the production of an artifact created following the approach, discussion and conclusion illustrating further possible developments.

BACKGROUND AND RELATED WORK

"Generative art refers to any art practice where the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, which is set into motion with some degree of autonomy contributing to or resulting in a completed work of art." — *Philip Galanter* [14]

This idea of a rule-based system capable of producing autonomous outcomes is foundational to many forms of computational art, and provides conceptual grounding for the application of Genetic Programming (GP) in creative domains.

A notable early example is the work of Vera Molnár, who began using computers in the 1960s to explore geometric abstraction through repetition and controlled variation [12, 13]. Her artworks often relied on algorithmic rules and introduced randomness to deviate from strict symmetry. While Molnár did not employ evolutionary algorithms, her iterative approach, where subtle modifications to parameters yield new visual configurations, mirrors the core dynamics of GP: inheritance, mutation, and transformation of structural patterns.

Similarly, the compositional methods of John Cage anticipated algorithmic and generative thinking in art. Cage famously used chance operations, such as coin tosses and the I Ching, to determine musical elements [16]. His embrace of indeterminacy served as a critique of artistic control, framing randomness not as error but as method. This philosophy aligns with GP's evolutionary processes, where variation and selection lead to unexpected yet coherent results over time.

In more interactive and technologically mediated contexts, Rafael Lozano-Hemmer exemplifies a shift toward dynamic, real-time systems. His installations integrate light, sound, sensors, and audience data to generate responsive environments [10]. Though not evolutionary in structure, these works embody a form of generativity where outputs are co-produced by machine logic and human presence, an idea central to the human-machine collaboration we pursue in this paper.

The work of Erick Calderon, known as *Snowfro*, offers an even closer connection to the evolutionary paradigm[17]. His *Chromie Squiggles*, created on the Art Blocks platform, are generated through an algorithm that interprets a unique 64-character string, essentially a digital "genetic code", into distinct visual outputs. Each Squiggle is both programmatically deterministic and aesthetically unique, reflecting principles of inheritance, encoded identity, and variation. While these works do not evolve over time, their structural design draws a clear parallel to GP's use of encoded traits to generate novel forms.

Together, these examples establish a lineage of artists who have leveraged procedural systems, whether deterministic, random, interactive, or encoded, to expand the boundaries of creative production. Our research builds on this tradition by introducing Genetic Programming as a structured method for evolving design outputs through controlled randomness, recombination, and aesthetic evaluation. Starting from the previous concept, the paper presents an evolution of the algorithmic art generation adopting a new hybrid approach integreting a specific sub-field of IT into the process and focusing on the creative interaction between humans and machines. Specifically, Genetic Programming (GP) [2] has been used to enhance the human-machine collaboration in the creative process. Inspired by biological evolution, GP involves the use of algorithms to iteratively refine solutions based on fitness criteria. As seen, in art and design, generative art has been employed to generate visual compositions [6], music [16], and even architectural forms [8], whilst GP has fewer examples of application, focusing mainly on eveolutionalry algorithms. For example, early work by Sims (1991) [18], demonstrated the potential of evolutionary algorithms to create complex visual art, while later advancements expanded these techniques to interactive design systems [1, 21, 22].

The concept of human-machine collaboration in creative processes has gained traction in recent years [16]. Projects like Google's DeepDream [19] and OpenAI's DALL-E [5] showcase the potential of AI to augment human creativity. However, these systems often operate as black boxes, limiting user control [20]. Our approach distinguishes itself by emphasizing dynamic interaction, allowing designers to guide the evolutionary process in real-time.

Our work builds on all the previous considerations and focuses on the unique aesthetic possibilities unlocked by GP, particularly in producing unexpected, evolved and novel forms.

METHODOLOGY

Our framework relies on the concept of algorithmic generated art, focusing on GP as a methodology to generate unique outputs through an iterative process of mutation, crossover, and selection [7]. The system begins with an initial population of designs, each represented as a set of parameters. These designs evolve over generations based on fitness functions that evaluate aesthetic and functional criteria. Mutation introduces random modifications to individuals in the original population, such as altering node values in a program tree, ensuring genetic diversity and preventing premature convergence to suboptimal solutions as an output. Crossover (recombination) exchanges genetic strings between parent solutions, combining promising traits to generate offspring with potentially improved characteristics. Selection mechanisms, such as tournament or fitness-proportionate selection, determine which individuals are retained for reproduction (in our case for new generation of artefacts) based on their original characteristics. Central to this process is the fitness function, which quantitatively evaluates each solution against predefined criteria (e.g., aesthetic quality or functionality), guiding the evolutionary search toward novel outcomes. Together, these operations enable GP to explore vast design spaces, balancing exploration (via mutation and crossover) and exploitation (via selection) to evolve increasingly refined and innovative artefact.

An important phase in our approach is the initial definition of the string characterizing the two "parent" objects that is the definition of the "DNA" traits defining each of them subsequently recombined to obtain new generations of objects on he basis of fitness rules. In simple words, the human artist defines the characteristics of the original two objects at the beginning of the process and the rules to combine them (crossover, mutation and fitness). In the following phase, the machine combine these elements to create new generations of artifacts, without any further control on the creative process behind the original idea. The contribution of the artist in this innovative creative process lies in the initial concept, the definition of the characteristic DNA strings, and the establishment of the rules for artistic generation, while the technology executes what human artistic intuition has conceived—without undermining the creative and aesthetic essence of the work.

CASE STUDY: A DIGITAL ARTIFACT

We present a case study of a first digital artifact created using our framework starting from the digital signature (DNA). In this first experiment we didn't introduce the fitness concept to test the power of the crossover and mutation mechanisms in producing a new artistic "individual". The artifact represent a first exemplified example of the hybrid nature of our methodology, combining algorithmic generation with manual refinement. The process involved:

- Initialization: defining a set of base strings (DNA) defining the characteristics of two initial designs.
- evolution: running the GP algorithm for multiple generations, with periodic human intervention.
- refinement: selecting the final output to achieve the desired aesthetic.

The initial two "individuals" comprised two lines connecting points within a two-dimensional space, each distinguished by differing attractor points (governing curvature).

The DNA was accordingly defined as a string incorporating:

⟨starting point coordinates; end point coordinates; attractor point coordinates⟩

The two original individuals ("parents") shared identical start and end x-coordinates, but, by necessity, possessed distinct attractor point coordinates, thereby producing divergent geometries.

- The objective entailed generating a lineage of "offspring" through recombination of the parental traits via genetic programming algorithms. Here, the artist controlled both the mutation rate and the crossover segment (in this instance, the terminal portion of the string).
- The outcome was a singular artefact that interrogates conventional creative paradigms, synthesising machine-derived intricacy with human aesthetic judgment.

Figures 1and 2, below, illustrates the progeny derived from the initial parent strings (vector of features):

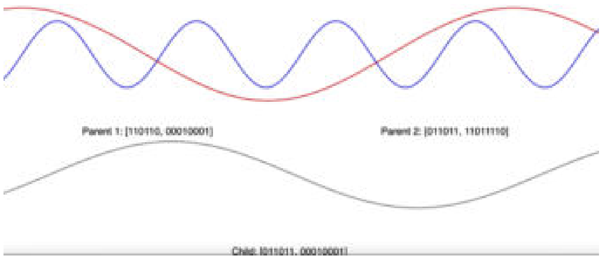

Figure 1: parent 1 and parent 2 with their combined DNA result shown as child, mutation rate 0.05, attempt Num. 36, deviation from parent1: 4 bits out of 14 = 28.6%, deviation from parent2: 5 bits out of 14 = 35.7%

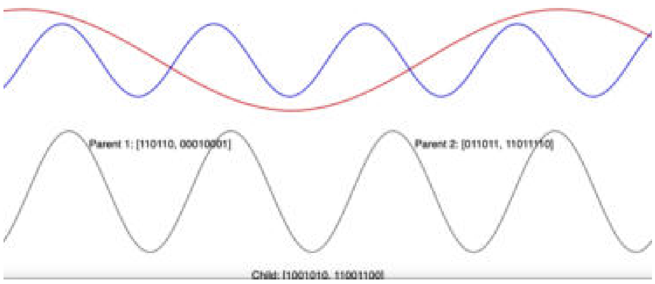

Figure 2: parent 1 and parent 2 with their combined DNA result shown as child, mutation rate 0.08, attempt Num. 74, deviation from parent1: 10 bits out of 15 = 66.7%, deviation from parent2: 7 bits out of 15 = 46.7%

RESULTS AND DISCUSSION

Despite preliminary, our experiment demonstrated GP's ability to explore design spaces beyond human preconceptions. The algorithm produced forms that were both unexpected and aesthetically coherent, highlighting its potential as a tool for creative discovery and the possible estention to more complex designs.

The case study illustrated the effectiveness of human-guided evolution. Designer interventions ensured that the outputs remained aligned with artistic goals, while the GP introduced elements of novelty and serendipity. This synergy underscores the value of collaborative creativity.

Our findings suggest that GP can provide accessible tools for artistic exploration and creativity, preserving human control, balancing automation with creative control and addressing ethical concerns around authorship in AI-generated art.

CONCLUSION

This paper has presented a novel approach to algorithm-generated art and design using genetic programming. By combining the exploratory power of GP with human creative guidance, our framework produces outputs that are both innovative and aesthetically compelling. The case study showcased the potential of this hybrid methodology to redefine creative processes, offering a glimpse into the future of human-machine collaboration in art. As digital art continues to evolve, tools like GP will play an increasingly vital role in expanding the boundaries of digital innovation.

Subsequent investigations will focus on refining fitness metrics to better align with the artist's desired aesthetic outcomes—a dimension intentionally excluded from this preliminary experiment.

Further studies will also explore more complex applications, including:

- Enhancing interactivity in GP systems to facilitate more intuitive human input.
- Extending the application of GP to broader creative domains (e.g., generative music, dynamic sculpture).
- Examining the ethical and philosophical implications of machine-generated art, particularly regarding authorship and creative agency.

These efforts aim to deepen the synergy between computational generativity and human artistic intent while addressing emerging challenges in AI-driven creativity.

These efforts will further bridge the gap between computational methods and human creativity, paving the way for new forms of artistic expression.

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SMART MONITORING AND ACTUATION SERVICES FOR THE PROTECTION OF CULTURAL HERITAGE

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The preservation of cultural heritage, particularly paintings and handcrafted artifacts, is increasingly reliant on innovative digital technologies. **As environmental factors** such as humidity, temperature, light exposure, and air pollutants **critically affect the degradation process** of artworks, continuous monitoring and predictive analysis have emerged as essential strategies for preventive conservation. This paper presents a comprehensive overview of the current scenario in monitoring and actuation services for cultural heritage protection, emphasizing the integration of advanced digital technologies to safeguard artifacts from environmental damage.

The proposed system leverages a **modern, modular architecture** that integrates state-of-the-art Internet of Things **(IoT)** technologies with **AI-driven analytics**. At the hardware level, the solution employs miniature electronics and low-power environmental sensors capable of capturing key metrics in real time from both storage and exhibition environments. These devices can be connected to the Internet through different technologies depending on the requirements in terms of computational resources, power consumption and cost. Among these technologies **we will focus on LoRa** (Long Range) communication protocols and the related LoRaWAN architecture, which offer energy-efficient, long-distance data transmission ideally suited for heritage sites that may lack dense connectivity infrastructure. LoRa also features decentralized governance and technical management model that make it suitable for low cost projects and setups.

Sensor data is collected via a messaging protocol based on MQTT (originally *Message Queueing Telemetry Transport*), ensuring lightweight and reliable communication between devices and the backend. This choice supports scalability, interoperability, and secure transmission of large volumes of environmental data, facilitating centralized monitoring without imposing significant operational overhead. We will cover the MQTT general architecture and its light and simple **publisher/subscriber paradigm**.

At the core of the system lies a **cloud-based AI engine** that performs data aggregation, anomaly detection, and predictive forecasting. By training on historical and real-time data, the AI engine is capable of assessing the health status of artifacts and identifying early warning signs of material degradation, such as erosion, discoloration, or canvas tension loss. Forecasting models provide insights into future risks, allowing for timely interventions and adaptive environmental control strategies.

In addition to monitoring, the system includes **actuation capabilities** that respond dynamically to emerging threats. This may involve adjusting lighting conditions, activating climate control systems, or notifying conservation staff to take preventive measures. Such a closed-loop architecture ensures not only the detection of risks but also their mitigation through automated or semi-automated responses.

This report further discusses challenges and opportunities in deploying these technologies across diverse heritage contexts, including museums, archives, and archaeological sites. Key considerations include sensor calibration, data privacy, energy efficiency, and the integration of legacy infrastructure.

These principles have been put into practice in a small pilot project that LINKS Foundation carried out in the period January-April 2025, having as a target a small church located in a small city close to Turin. In order to demonstrate the joint power of monitoring and actuation - as well as the benefits for visitors who gained better access both to the overall building and the frescos on the inside walls -, a small energy generation (PV) system has been setup in the church, extended with actuators to provide remotely controlled lighting and other services. Thanks to this simple but smart solution users and technical managers were offered higher flexibility of access without the need of having on site personnel.

In conclusion, the confluence of IoT, low-power communication protocols like LoRa, MQTT messaging, and AI-driven cloud analytics presents a transformative opportunity for cultural heritage conservation. By enabling proactive and predictive care of artworks based on precise environmental monitoring, this digital approach contributes significantly to the longevity and accessibility of humanity’s cultural legacy.

THE UNIVERSAL GALLERY: A LABORATORY FOR AI ORCHESTRATION IN THE MULTIMEDIA CREATIVE PROCESS

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Abstract -- This paper analyzes the "Universal Gallery" project as a case study of systemic integration of Artificial Intelligence in the creative process. Through the orchestration of multiple AI tools, the author has developed a creative ecosystem that transcends traditional boundaries between literature, visual art, and technology. The project has represented an experimental laboratory where the artist evolves into a "conductor" of complex creative processes, amplifying expressive and distributive possibilities.

INTRODUCTION

The "Universal Gallery" emerges as a multidimensional project that transcends traditional boundaries between literature, visual art, and technology. It is not simply a series of illustrated books, but a complex narrative ecosystem that utilizes Artificial Intelligence in every phase of the creative process - from conception to realization, from distribution to promotion.

The founding idea is that of an impossible building, a gallery that defies the laws of physics, explored through three trilogies and a monographic volume. Each book is enriched with dozens of original illustrations that are not mere decorations, but structural elements of the narrative. These visual elements, generated through a complex orchestration of AI tools, become bridges between the textual dimension and the imaginative one.

What makes this project particularly significant in the context of EVA Florence 2025 is its value as an experimental laboratory for the systemic integration of AI in cultural production. The "Universal Gallery" represents a case study of how a contemporary artist can orchestrate multiple technological tools in a coherent creative process, maintaining their artistic vision as a unifying element.

METHODOLOGY: THE ARTIST AS CONDUCTOR OF AI PROCESSES

The creative process of the "Universal Gallery" has been articulated through a methodological approach that I have defined as "layered orchestration," where different AI tools are coordinated in an integrated workflow, each with a specific but interdependent role.

The Conceptual Map as a Score

The starting point was the creation of a detailed conceptual map (see Figure 1) that functioned as a true score for the entire project. This map, developed iteratively through mind mapping software integrated with AI prompting for conceptual expansion, allowed visualization of the entire Universal Gallery ecosystem in its multiple dimensions:

- Narrative (the three trilogies and the monographic volume)
- Visual (illustrations, covers, maps)
- Technological (AR/VR, NFT, multilingual e-book)
- Distributive (channels, formats, markets)
- Promotional (social media, events, virtual tours)

This map was not a static element but an evolving organism, continuously updated through feedback cycles between human ideation and algorithmic suggestions.

Integrated Production Workflow

The production process followed a non-linear but cyclical workflow, where each phase was fed by the results of the others:

1. **Narrative conception**: Use of LLMs for expanding narrative premises, developing alternative narrative arcs, and creating coherent symbolic systems.
2. **Visual prototyping**: Use of text-to-image models for rapid visualization of concepts, characters, and environments, with subsequent iterations based on human feedback.
3. **Integrated literary production**: Creation of narrative texts with AI support for stylistic coherence, development of specific terminologies, and maintenance of continuity.
4. **Advanced illustration**: Generation of visual works through complex pipelines that combine multiple generative AIs, with strategic manual interventions.
5. **Multimedia integration**: Development of complementary content (audio, video, augmented reality) through specialized AI tools.

This workflow was not simply sequential but recursive, with continuous cycles of feedback and refinement. The human element remained central as a curatorial and decision-making force.

AI TOOLS ORCHESTRATED IN THE CREATION OF THE UNIVERSAL GALLERY

The realization of the project required the integration of numerous AI tools, each selected for its specific capabilities and orchestrated within a coherent technological ecosystem.

Textual and Narrative Generation

The narrative structure of the Universal Gallery, with its complex interconnections and symbolic stratifications, has benefited from the use of:

- **Advanced Large Language Models**: Used not only for generating textual drafts, but especially for expanding narrative premises, creating coherent symbolic systems, and identifying thematic connections.
- **Specialized worldbuilding systems**: Tools dedicated to the creation of coherent narrative universes, with particular attention to the internal consistency of elements such as toponyms, specific terminologies, and rule systems.
- **Narrative continuity assistants**: Software that monitors and maintains the coherence of narrative details across different volumes, identifying potential inconsistencies.

Visual and Illustrative Creation

The visual component of the project, with its hundreds of original illustrations, required a particularly sophisticated orchestration:

- **Generative text-to-image models**: Used for the initial creation of works, with particular attention to the selection and refinement of prompts to maintain stylistic coherence.
- **Upscaling and refinement systems**: Tools dedicated to improving resolution and details, crucial for maintaining the visual quality necessary for printing.
- **AI post-processing pipelines**: Customized workflows for stylistic refinement, artifact correction, and aesthetic harmonization between different illustrations.

The main challenge in this area was maintaining a balance between creative novelty and stylistic coherence. "Prompt engineering" techniques were fundamental, with the development of a true "prompting language" specific to the project.

CRITICAL ANALYSIS: CHALLENGES, LIMITATIONS, AND SOLUTIONS

The systemic integration of AI in the creative process presented significant challenges, the overcoming of which required innovative approaches and constant critical reflection.

The Paradox of Aesthetic Homogeneity

One of the most relevant challenges was countering the tendency of generative AI systems to produce aesthetically homogeneous results, a phenomenon I have defined as "algorithmic stylistic convergence."

To overcome this limitation, I developed several strategies:

- **Adversarial prompting**: Construction of prompts that deliberately challenge the dominant stylistic tendencies of the models.
- **Technical hybridization**: Combination of outputs from different AI systems, creating pipelines that mix the characteristics of different models.
- **Strategic disruption interventions**: Introduction of random or counterintuitive elements in the generative process to force the system out of its stylistic "comfort zones."

These techniques have allowed for obtaining visual results with a distinctive identity, avoiding the generic aesthetic that often characterizes AI-generated works.

Narrative and Symbolic Coherence

Maintaining coherence in a complex narrative universe, with multiple timelines and symbolic stratifications, required specific solutions:

- **Dynamic knowledge graphs**: Creation of evolved relational databases that map entities, relationships, and attributes of the narrative universe, constantly updated during the creative process.
- **Continuity verification systems**: AI tools specialized in detecting narrative inconsistencies across different volumes and timelines.
- **Prompts with contextual memory**: Development of prompting techniques that explicitly incorporate the "memory" of the narrative universe, ensuring that each new generation is informed by the complete context.

The most innovative aspect was the use of AI systems not only to generate content but also to verify and maintain the internal coherence of the narrative universe, acting as "guardians of continuity."

CONCLUSIONS AND FUTURE PERSPECTIVES

The experience of the "Universal Gallery" demonstrates that the systemic integration of AI in creative processes can open unexplored territories of artistic expression, provided that the artist maintains the role of "conductor" of the process, guiding it with a clear vision.

The project suggests the emergence of a new creative paradigm, which we could define as "orchestrated creativity," where the artist evolves from direct producer to process director, AI tools function as extensions of the artistic vision, and the creative process becomes explicitly iterative and non-linear.

In conclusion, the "Universal Gallery" project suggests an evolution of the artist's role towards that of a "meta-creator" - a figure who operates simultaneously at the level of vision, process, and tool, orchestrating complex systems to realize works that transcend the capabilities of the single human creator or the single machine.

This evolution does not diminish the value of the artist, but transforms and potentially amplifies it, opening new territories of expression and connection that can enrich the contemporary cultural landscape.

Figure 1 - Conceptual Map of the Universal Gallery System

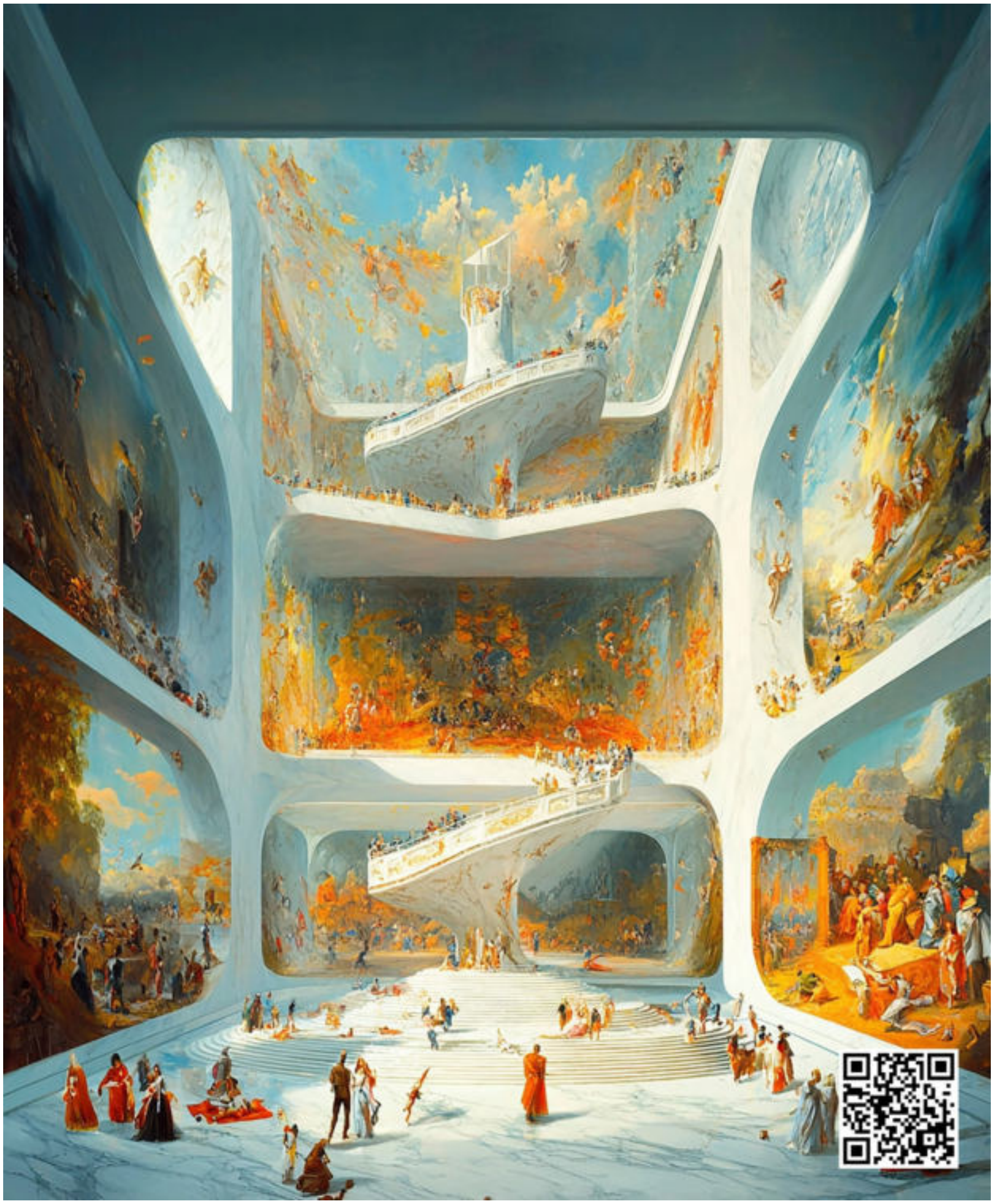

Figure 2 - The Dreamlike Atrium of the Universal Gallery

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NEW SCIENCE, TECHNOLOGY AND CULTURE DEVELOPMENTS & APPLICATIONS

Language Models – Perspectives and Limitations

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"In principio erat Verbum, et Verbum erat apud Deum, et Deus erat Verbum" or in English *"In the beginning was the Word, and the Word was with God, and the Word was God"*. This is one of the most debated passages in the Gospel of John.

"Verbum" in Latin or as expressed in Greek language "Logos" carries in this unique statement the essence of creativity at the root of all languages, as the representation of cultural diversities, as the evidence of rational thinking, as the tangible mean to express art and emotions. Apostle John makes it indissociable from God (or let me allow his "Love"). "Verbum" in this statement establishes the bridge between Human and Divine.

Thanks to the power of AI, the power of Words can be "partially" broadened with the advent of Large Language Models (LLM's). LLM's are providing us with the ability to replicate natural expressions or thoughts with respect to all contextual diversities, as they have been expressed so far by the most sophisticated writers, educators, philosophers, scientists, ... They allow to organize Words in meaningful sentence, clear statements that we all or most of us like to consider "right", consistently in all forms, everywhere, in time, and across times. LLM's represent a condensed mediator that can replicate past rational, beauty and depth of thoughts.

However, it remains my personal belief that they will never provide the one sparkle that comes in Humanity (when getting closer to its divine dimension) with the intangible value brought by Love. Only with Love, Humanity surpasses itself and aspires at creating new forms of language and find the full essence of "Verbum", the bridge with the Divine. We should recall it every day, to place it at the foundation of all "human" interaction. To create unprecedent forms of language, we need to recall that respect of what we do not believe in or what is fundamentally different from what we see is at the base of creativity which we just need to unveil.

LLM's provide a fascinating mean to condense already expressed human thinking. But they will not provide for human creativity. True innovation would come only thanks to feeling and interaction, understanding diversity. Learning to give up what is known, what we consider right, what is believed "true". LLM's magically convey in often crystal clear statements the spirit of previous thoughts and acts. They represent a fantastic thread to replicate and express concepts, to generate statements that have been understood, that most of us agree upon.

Concurrently the recent surge of research on MLLM's (Multimedia Large Language Models) [1-3] extend LLM's abilities to modalities beyond languages, particularly images, opening up more extended opportunities. MLLM's are being designed to extract generic media tokens which when combined with LLM's provide us with even richer means to describe content in all its diversity whether in visual, phonetic, tactile forms. MLLM's share the ability to condense the description of Nature as visually captured by cameras or as phonetically acquired with microphones or potentially as perceived from any form of media. They condense in "Words" we do not necessarily model the same way, identified as "tokens", that support for a richer description of information, when combined with Natural Language.

How to use LLM's and MLLM's jointly falls outside the scope of this contribution. It is a matter of continuous on-going research in AI. What we can state is that MLLM's again will expand our means to understand our surrounding, describe or help generate realistic artificial scenarios, recognize and retrieve what is of interest, enhancing our ability to process and interact with media as much as we can do it between ourselves.

As much as text can be better modelled, learnt and processed thanks to LLM's, MLLM's tokens need to be extracted from real media. In general, MLLM's tokens have been originally designed to process digital representation of media not in compressed form but as reproduced for the recipients of the multimedia message, be it a video, or an audio recording since these are the forms we deal with as humans.

Technology has provided us with standard means to share multimedia information through standardized condensed representation formats. These are necessary to ensure reduced energy consumption and optimal use of existing communication infrastructure. Numerous studies have explored the idea of performing "intelligent" processing tasks such as detection or recognition directly from these condensed representation formats, bypassing full audio or video reconstruction to reduce computational overhead. Since the reconstruction is feasible and since any mediating human will always be able to process as expected a sufficient quality reconstructed media, compressed multimedia latent may be directly fed into a recognition model that can be jointly trained with the reconstruction network. Alternatively, a single bridge module may directly connect the latent to a task specific recognition network avoiding unnecessary stages of full reconstruction. The latent representation can thus only be used to directly extract the needed features for a downstream recognition task.

The concept of bridging the latent space produced by neural image compression has been also proposed for generating any downstream MLLM's representation format [4] (see Fig. 1). Image latent codes from compressed media can thus be mapped into the token space compatible for MLLM's, allowing for any MLLM's compatible processing. Ultimately this will lead to richer interaction that may handle large amounts of media, enabling in many cases front-end processing directly by machines to convert latents into the required representation tokens. Whether we consider conjunction of LLM's and MLLM's, these model will help us understand faster or explain more straightforwardly what we already have agreed upon as Humanity.

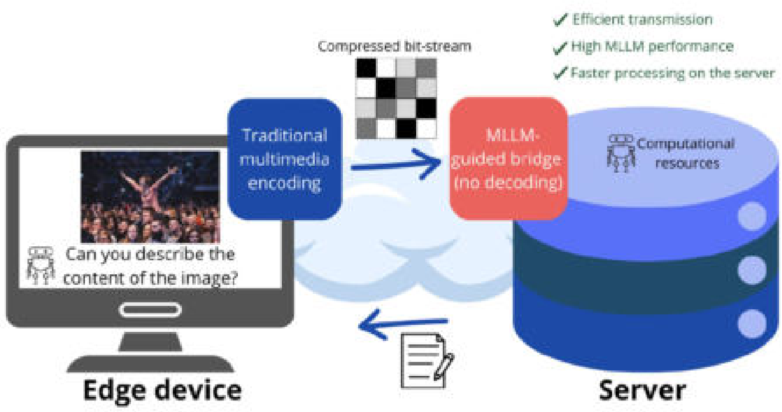

Fig. 1: Bridging Visual Data Latent Representation for Multimodal Large Language Model

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How Cyber Skills Are Evolving in the Age of AI

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As artificial intelligence (AI) becomes ever more central to cybersecurity, it is no longer sufficient to rely solely on algorithms, data and technical controls. A growing body of research demonstrates that human "soft" skills like empathy, ethical reasoning, critical thinking, creativity and clear communication, are essential to identify hidden biases, anticipate adversarial manipulations, and build stakeholder trust in AI-driven defences [1]. This article aims at presenting a scientifically grounded argument - drawing on industry reports, academic studies and EU and U.S. policy frameworks - that embedding soft skills across the AI lifecycle can produce fairer, more transparent and more resilient cybersecurity defensive systems.

In a recent study, published by the Journal of Computer Information Systems, it is analysed how despite decades of progress, gender inequality and a lack of diversity remain pressing issues across many professions, with no exception for cybersecurity. Although the gender gap in employment has narrowed in Europe, women still experience lower employment rates than men in certain sectors, possibly also due to national and cultural trends, starting from early education.

The cybersecurity sector reflects this disparity. Even amid a global shortage of skilled professionals, as of April 2025, women made up only 22% [2] of the cybersecurity workforce worldwide; while keep sustaining that this underrepresented group represents a strategic asset for the filed. The web platform Dark Reading, also reports that women constitute only 20–25% of cybersecurity professionals; a diversity gap that is now linking with blind spots in AI-driven threat detection. For instance, in a pilot study, a security vendor diversified its model-development team and instituted bias-awareness workshops; false-negative rates for attack detection on under-represented traffic patterns dropped by 30% compared to a control group [ibid, 12]. This underscores how interpersonal skills like open communication, perspective-taking and inclusive leadership can translate into measurable technical gains.

In the perspective of the current years, it is evident that the surge of AI usage and an ever more blended mix of AI-Cybersecurity competencies will require an industry-wide shift towards more holistic and inclusive competences. In the United States, NIST's AI Risk Management Framework (AI RMF) defines four core functions to guide trustworthy AI development [3]:

1. Govern,
2. Map,
3. Measure
4. Manage

NIST emphasizes that "Governance is designed to be a cross-cutting function … to be infused throughout the other three functions" and that "diverse and multidisciplinary perspectives" are essential to surface assumptions and emergent risks. Implementing AI RMF thus becomes an exercise in organizational culture change: setting up cross-functional teams, clarifying roles and fostering continuous dialogue, encourage activities that rely on leadership, collaboration and ethical judgment.

Cultivating Soft Skills Across the AI Lifecycle

Phase	Key Soft Skills	Technical Complement	Research Basis
Problem Framing & Design	Empathy, active listening/tactical empathy	Threat modelling, requirements	WEF skills demand
Data Collection & Labelling	Cultural competence, bias awareness	Data governance, feature engineering	ENISA multilayer framework
Model Development	Creativity, critical thinking	Algorithm selection, adversarial testing	Raghavan et al.
Testing & Validation	Collaboration, communication	Explainability tools, red teaming	NIST AI RMF Core
Deployment & Monitoring	Adaptability, ethical reasoning	Continuous integration, MLOps	JRC resilience analysis

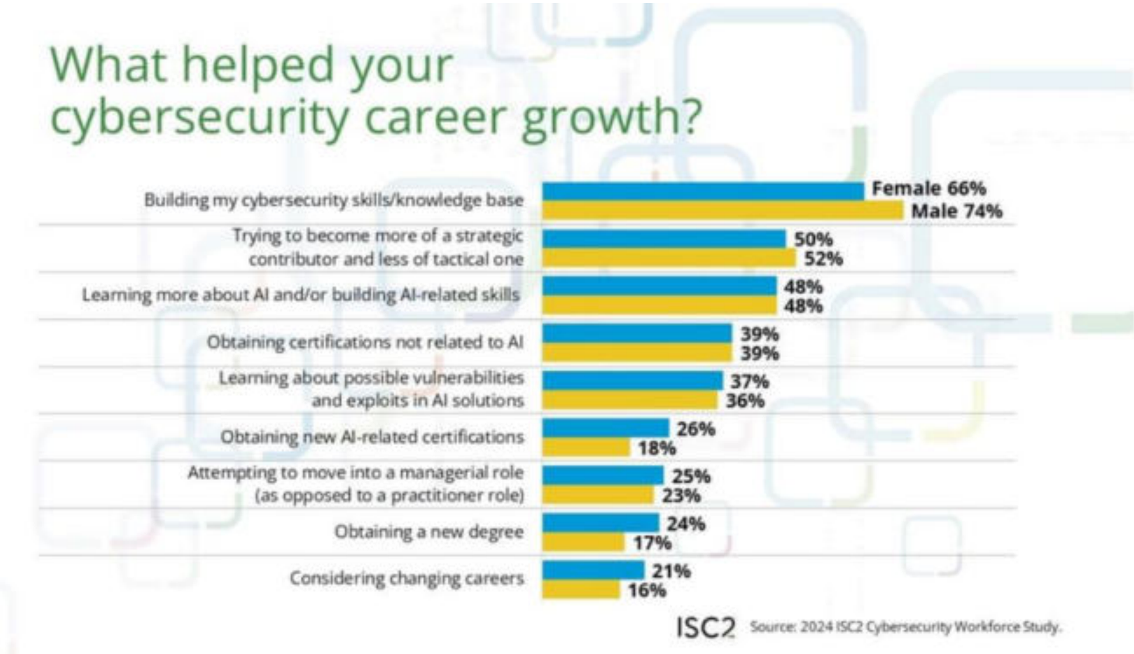
Embedding soft-skill training through scenario-based red teaming, role-playing exercises and cross-disciplinary workshops, has shown to improve team performance and model robustness [4]. For example, Google's "Search Inside Yourself" program, which blends mindfulness and emotional-intelligence training, correlates with higher project success rates in AI initiatives.

In this perspective, it does not come as a surprise that the human judgment is at the core of correct evaluation, data correlation, assessment and risk prediction of IT systems. Bias in AI-based cybersecurity tools can emerge at multiple stages: dataset curation, feature selection, model training and evaluation. For instance, using network-traffic data sourced predominantly from one region can lead an intrusion-detection model to under-detect anomalies in traffic patterns from other geographies. ENISA's multilayer framework warns that "the first step in the security of AI systems … is to operate in a secure environment, i.e. to secure the ICT infrastructure that hosts the AI systems" [5], but equally vital is securing the human processes that generate and label data.

An **AI system**, as defined by NIST, is "an engineered or machine-based system that can…generate outputs such as predictions, recommendations, or decisions influencing real or virtual environments," [3] often operating with various levels of autonomy. The AI lifecycle typically extents from stages like planning, data collection, model training, testing, deployment, to continuous monitoring. Crucially, industry guidelines insist that risk management be integrated *throughout* this lifecycle. For instance, the NIST AI Risk Management Framework (AI RMF) stresses that risk assessment and *Test, Evaluation, Verification, and Validation* (TEVV) processes should begin in the design phase and continue through deployment [ibid]. In Europe, the AI Act (Regulation 2024/1689) similarly mandates a risk-management system for high-risk AI that "should span the entire life cycle of the AI system" and be iterative and updated as the system evolves [6, 7]. In both cases, the goal is to anticipate technical and ethical issues like data poisoning or model evasion *before* AI tools become operational. These human-led assessments require both technical understanding (of model vulnerabilities) and judgment calls on acceptable risk: underscoring why critical thinking and ethical reasoning are as important as coding skills.

One illustrative example comes from a 2021 study conducted by the European Commission's Joint Research Centre (JRC), in collaboration with ENISA on AI security in self-driving vehicles [8]. JRC found that AI components in autonomous cars (vision systems, path planners, etc.) must be continuously validated to ensure safety. Simple real-world manipulations—like altered road paint or misleading signs—can trick AI perception and lead to dangerous outcomes. To address this, the report recommends security assessments of AI components throughout their lifecycle and towards the model continuous improvement. In practice, this means using threat intelligence and red-teaming to identify new attack modes, adopting the "security by design" principle and regular scanning for redundancies, errors, vulnerabilities, etc… so that cybersecurity is baked-in from the start. While this use case is in automotive, the principle applies broadly: whether defending a power grid or a data centre, organizations must iteratively test AI defences and update controls as threats evolve. The JRC example exemplifies how AI in cyber-physical domains demands both rigorous technical evaluation and imaginative scenario planning – roles that require technical acumen and creative soft skills.

AI's integration appears to open new avenues that play to diverse strengths. Studies show that women in cybersecurity are rapidly acquiring AI knowledge and credentials: for instance, 26% of women respondents in a recent survey conducted by the International Information System Security Certification Consortium (ISC2) were pursuing AI-specific certifications (versus 18% of men) [9]. This suggests women see AI as an opportunity to specialize and advance. Importantly, the unique soft skills women often bring—empathy, collaboration, mentoring—are highly valuable in emerging AI-centric roles. As Benson *et al.* note, women's increasing presence would "bring unique competencies to cybersecurity," including innovative thinking and flexible communication, which can "help overcome biases" in this traditionally male-dominated fields.



Empathy and cultural competence are critical during data annotation. Teams with diverse perspectives are more likely to spot labelling guidelines that disadvantage minority behaviours, reducing false positives and negatives. It is being reiterated that ethical awareness and critical thinking can help individuals to analyze claims and practices more accurately particularly when encountering biases. Embedding ethicists and social scientists alongside data engineers creates the dialogue needed to challenge proxy features—such as zip code or user-agent strings that may act as stand-ins for protected attributes [11].

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Proposal for Next-Generation FTV Integrating Analytical and AI Approaches

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Abstract –Next-generation FTV requires sparse camera setup, real-time processing and photorealistic synthesized views. Although there are many scene representations for FTV, none of them meets all these requirements. FTV needs all rays in 3D space. One ray in 3D space is expressed by one point in ray-space. Ray-space itself has no explicit information about object geometry. If geometry is available, the entire ray-space can be reconstructed from a portion of ray-space captured with sparse camera setup. There are two approaches to geometry detection: analytical and AI (learning) approaches. We propose to integrate these two approaches to realize the next generation FTV.

1 INTRODUCTION

Free-viewpoint television (FTV) [1]-[8] enables users to view a 3D scene by freely changing the viewpoint as we do naturally in the real world. Since FTV has an infinite number of views, it has very high capability of sensing and representation of 3D space. For example, FTV is an immersive medium that enables VR/AR/MR experiences. It is a natural interface between humans and the environment. It is also a tool to create innovative contents. Furthermore, it is an information infrastructure for secure society. Thus, FTV makes a great contribution to many fields such as industry, life, society, science, education, culture, tourism, sports, amusement and so on.

FTV requires all rays in 3D space. Ray-space theory [9] was developed to describe all rays in the 3D space. In the ray-space theory, one ray in the 3D space is expressed by one point in the ray-space. The ray-space itself has no explicit information of object geometry. If the information of object geometry is added to the ray-space, various types of scene representations are created.

Geometry can be detected from the ray-space. There are two approaches to geometry detection: analytical and AI (learning) approaches. Analytical approach is a traditional approach. Typical examples of this approach are MVD (Multiview + Depth) [5],[10] and MVS (Multiview + Surface) [11],[12]. More recently, AI (learning) approach has been emerging. Typical examples of this approach are NeRF (Neural Radiance Field) [13] and 3D GS (Gaussian Splatting) [14]. The purpose of this paper is to clarify major scene representations and to provide direction for the next-generation FTV.

2 RAY-SPACE SCENE REPRESENTATION FOR FTV

Fig. 1 shows relation among major FTV scene representations. 5D (5-dimensional) ray-space is the most simple and fundamental scene representation. Ray-space is defined to represent all rays in the 3D space. In the ray-space theory, one ray in the 3D space is mapped to one point in a parameter space. This parameter space is ray-space. When position and direction of a ray in the 3D space are expressed by (x, y, z) and (θ, φ), respectively, one ray is expressed by 5 parameters $(x, y, z, \theta, \varphi)$. This parameter space is 5D ray-space. The 5D ray-space has information of all rays in the 3D space. If the 5D ray-space is captured by cameras, FTV can be easily realized. However, it is not possible to install cameras at all positions in the 3D space.

In the 3D space where rays travel straight without attenuation, all rays on the same straight line have the same value. Therefore, the 5D ray-space is very redundant. When we set up a reference plane surrounding the 3D space, all rays in the 3D space are represented by rays crossing the reference plane. These rays are expressed by position (ξ, η) on the reference plane and direction (θ, φ). This is 4D ray-space ($\xi, \eta, \theta, \varphi$).

We use spherical representation for 4D ray-space. This spherical 4D ray-space has many planar reference planes each of which has different direction. One reference plane collects only parallel rays normal to this reference plane. Therefore, one ray in the 3D space is expressed by normal direction (θ, φ) of the reference plane and position (ξ, η) on the reference plane. This ray is expressed by one point in the spherical 4D ray-space ($\xi, \eta, \theta, \varphi$). When each point in the ray-space has an intensity f of the ray, it is expressed as $f(\xi, \eta, \theta, \varphi)$.

The meaning of the 4D ray-space is as follows. $f(\xi, \eta, \theta, \varphi)$ of the parallel rays forms an orthogonal projection view (ξ, η) on the reference plane. Therefore, the 4D ray-space corresponds to collecting the orthogonal projection views of the 3D space from all directions.

A directional sphere is defined to visualize the geometric structure of the 4D ray-space. In the directional sphere, (θ, φ) denotes direction from the origin, a point on the sphere, and a tangent plane at that point. By placing the orthogonal projection view (ξ, η) on the tangent plane (θ, φ), the directional sphere can visualize the entire 4D ray-space.

Views captured by real cameras are not orthogonal projection views but perspective projection views. However, orthogonal projection views and perspective projection views can be converted each other. Furthermore, perspective projection views are very similar to orthogonal projection views if objects are located far from the camera.

Data amount of 4D ray-space is much smaller than that of 5D ray-space. However, capturing 4D ray-space requires very dense camera setup surrounding the 3D space.

3 SAMPLED 4D RAY-SPACE

Practical ray-space is sampled 4D ray-space. Sampled 4D ray-space is captured by cameras at discrete positions surrounding the 3D space. Sampled 4D ray-space is equivalent to MV (Multiview). FTV can't be realized only by sampled 4D ray-space since many rays required for FTV are missing. These missing rays can be reconstructed if object geometry is available. This scene representation is "Sampled 4D Ray-Space + Geometry". The 4D ray-space has specific geometric structure, which can be used to detect object geometry.

There are many ways to detect and use geometry. Therefore, many scene representations fall into the category of "Sampled 4D Ray-Space + Geometry". They are divided into two approaches: analytical and AI (learning) approaches.

3.1 Analytical Approach

In the analytical approach, geometry is derived analytically. Typical scene representations of this approach are MVD and MVS. Geometry of MVD is depth. If each pixel of sampled 4D ray-space is traced back into the 3D space by a depth in the ray direction, many points are placed in the 3D space. Therefore, MVD is equivalent to Point Cloud. View synthesis of MVD is sensitive to depth error.

On the other hand, geometry of MVS is surface. Surface information of objects is detected analytically by using the geometric structure of the 4D ray-space and vector expansion by dual basis.

If 3 orthogonal projection views of a surface are given, surface direction is uniquely determined. A surface $\mathbf{S}_0$ with a normal vector $\boldsymbol{u}_0$ is seen as 3 orthogonal projection views $\mathbf{S}_1$, $\mathbf{S}_2$, $\mathbf{S}_3$ in 3 different directions $\boldsymbol{u}_1$, $\boldsymbol{u}_2$, $\boldsymbol{u}_3$. Here, $\boldsymbol{u}_0$, $\boldsymbol{u}_1$, $\boldsymbol{u}_2$, $\boldsymbol{u}_3$ are normal unit vectors of $\mathbf{S}_0$, $\mathbf{S}_1$, $\mathbf{S}_2$, $\mathbf{S}_3$, respectively, and $\boldsymbol{u}_1$, $\boldsymbol{u}_2$, $\boldsymbol{u}_3$ are linearly independent. In this case, the normal vector $\boldsymbol{u}_0$ of $\mathbf{S}_0$ is expanded as

$$\boldsymbol{u}_0=(\boldsymbol{u}_1,\boldsymbol{u}_0)\boldsymbol{u}^1+(\boldsymbol{u}_2,\boldsymbol{u}_0)\boldsymbol{u}^2+(\boldsymbol{u}_3,\boldsymbol{u}_0)\boldsymbol{u}^3 \qquad (1)$$

Here, $\boldsymbol{u}^1, \boldsymbol{u}^2, \boldsymbol{u}^3$ are dual basis of $\boldsymbol{u}_1, \boldsymbol{u}_2, \boldsymbol{u}_3$ and given by

$$\begin{aligned}\boldsymbol{u}^1&=\frac{\boldsymbol{u}_2\times\boldsymbol{u}_3}{\det(\boldsymbol{u}_1\boldsymbol{u}_2\boldsymbol{u}_3)}\\ \boldsymbol{u}^2&=\frac{\boldsymbol{u}_3\times\boldsymbol{u}_1}{\det(\boldsymbol{u}_1\boldsymbol{u}_2\boldsymbol{u}_3)}\\ \boldsymbol{u}^3&=\frac{\boldsymbol{u}_1\times\boldsymbol{u}_2}{\det(\boldsymbol{u}_1\boldsymbol{u}_2\boldsymbol{u}_3)}\end{aligned} \qquad (2)$$

Substituting (2) into (1),

$$\boldsymbol{u}_0=\frac{(\boldsymbol{u}_0,\boldsymbol{u}_1)(\boldsymbol{u}_2\times\boldsymbol{u}_3)+(\boldsymbol{u}_0,\boldsymbol{u}_2)(\boldsymbol{u}_3\times\boldsymbol{u}_1)+(\boldsymbol{u}_0,\boldsymbol{u}_3)(\boldsymbol{u}_1\times\boldsymbol{u}_2)}{\det(\boldsymbol{u}_1\boldsymbol{u}_2\boldsymbol{u}_3)} \qquad (3)$$

is derived. When S_0, S_1, S_2, S_3 are areas of $\mathbf{S}_0$, $\mathbf{S}_1$, $\mathbf{S}_2$, $\mathbf{S}_3$,

$$\begin{aligned}(\boldsymbol{u}_0,\boldsymbol{u}_1)&= S_1/S_0\\ (\boldsymbol{u}_0,\boldsymbol{u}_2)&= S_2/S_0\\ (\boldsymbol{u}_0,\boldsymbol{u}_3)&= S_3/S_0\end{aligned} \qquad (4)$$

hold.

Substituting (4) into (3),

$$\boldsymbol{u}_0=\frac{S_1(\boldsymbol{u}_2\times\boldsymbol{u}_3)+S_2(\boldsymbol{u}_3\times\boldsymbol{u}_1)+S_3(\boldsymbol{u}_1\times\boldsymbol{u}_2)}{\det(\boldsymbol{u}_1\boldsymbol{u}_2\boldsymbol{u}_3)S_0} \qquad (5)$$

is derived. Since $\boldsymbol{u}_0$ is a directional vector, the magnitude of $\boldsymbol{u}_0$ is not important. Therefore, we can omit the denominator of (5) and

$$\boldsymbol{u}_0=S_1(\boldsymbol{u}_2\times\boldsymbol{u}_3)+S_2(\boldsymbol{u}_3\times\boldsymbol{u}_1)+S_3(\boldsymbol{u}_1\times\boldsymbol{u}_2) \qquad (6)$$

is obtained.

(6) means that surface direction is given by the average of 3 dual basis vectors $\boldsymbol{u}_2\times\boldsymbol{u}_3$, $\boldsymbol{u}_3\times\boldsymbol{u}_1$, $\boldsymbol{u}_1\times\boldsymbol{u}_2$ weighted by areas of 3 views. Therefore, the detectable range of $\boldsymbol{u}_0$ is the inside of a spherical triangle with vertices $\boldsymbol{u}_2\times\boldsymbol{u}_3$, $\boldsymbol{u}_3\times\boldsymbol{u}_1$, $\boldsymbol{u}_1\times\boldsymbol{u}_2$. This method can detect a wide range of surface direction.

Influence of depth error on view synthesis in MVS is less than that in MVD. Furthermore, data amount of MVS is much smaller than MVD.

3.2 AI Approach

In the AI approach, learning-based methods such as neural network are used to determine geometry. Typical scene representations of this approach are NeRF and 3D GS.

The input to NeRF is MV. Simply speaking, geometry of NeRF is point. The object area is represented by radiance field. The radiance field is filled with many points. Each point has directional color and opacity. These are the parameters of the radiance field. Opacity gives implicit geometry.

Free-viewpoint images are synthesized by ray tracing in the radiance field. The parameters of the radiance field are optimized to minimize the synthesis error by using MLP (Multi-Layer

Perceptron). Although NeRF can synthesize complex scenes, it requires dense camera setup and long training and rendering times.

The input to 3D GS is also MV. 3D GS uses more explicit geometry. The 3D scene is represented by 3D Gaussians (ellipsoids) in 3D GS. Free-viewpoint images are synthesized by projecting ellipsoids in the 3D space onto 2D image plane.

MV images produce a point cloud. From this point cloud, initial 3D Gaussians are created. 3D Gaussians have geometry parameters and color parameter. Geometry parameters are position (mean), covariance and opacity. Color parameter is directional color. These 3D Gaussian parameters are optimized to minimize the synthesis error by using stochastic gradient descent techniques. Optimization of the 3D Gaussian parameters alternates with adaptive control of the Gaussian density, i.e. splitting and merging of ellipsoids.

3D GS gives compact scene representation and has much shorter training and rendering times than NeRF. It is achieved by avoiding unnecessary computation in empty space.

4 INTEGRATION OF ANALYTICAL AND AI APPROACHES

The next-generation FTV requires sparse camera setup, real-time processing and photorealistic synthesized views. None of current scene representations can meet all these requirements. We aim to meet these requirements by integrating analytical and AI approaches in the "Sampled 4D Ray-Space + Geometry".

Fig. 2 shows the proposed processing of the next generation FTV, which integrates the analytical and learning approaches. The feedforward flow is based on the analytical approach of MVS and the feedback flow is based on the learning approach of 3D GS. Input MV images are segmented and surfaces are detected analytically. Free-viewpoint images are synthesized by using detected surfaces and MV images.

However, incorrect segmentations lead to errors in surface detection, resulting in the synthesis error. Incorrect segmentations are refined by splitting and merging in a manner similar to Gaussian density control in 3D GS. The splitting and merging are controlled to minimize the synthesis error.

5 CONCLUSION

The next-generation FTV requires sparse camera setup, real-time processing and photorealistic synthesized views. Although there are many scene representations for FTV, none of them meets all these requirements. The features of major scene representations for FTV are clarified within the common framework of the ray-space. The most promising candidates are MVS and 3D GS in "Sampled 4D Ray-Space + Geometry". We propose to integrate the analytical approach of MVS with the learning approach of 3D GS to meet all requirements of the next generation FTV.

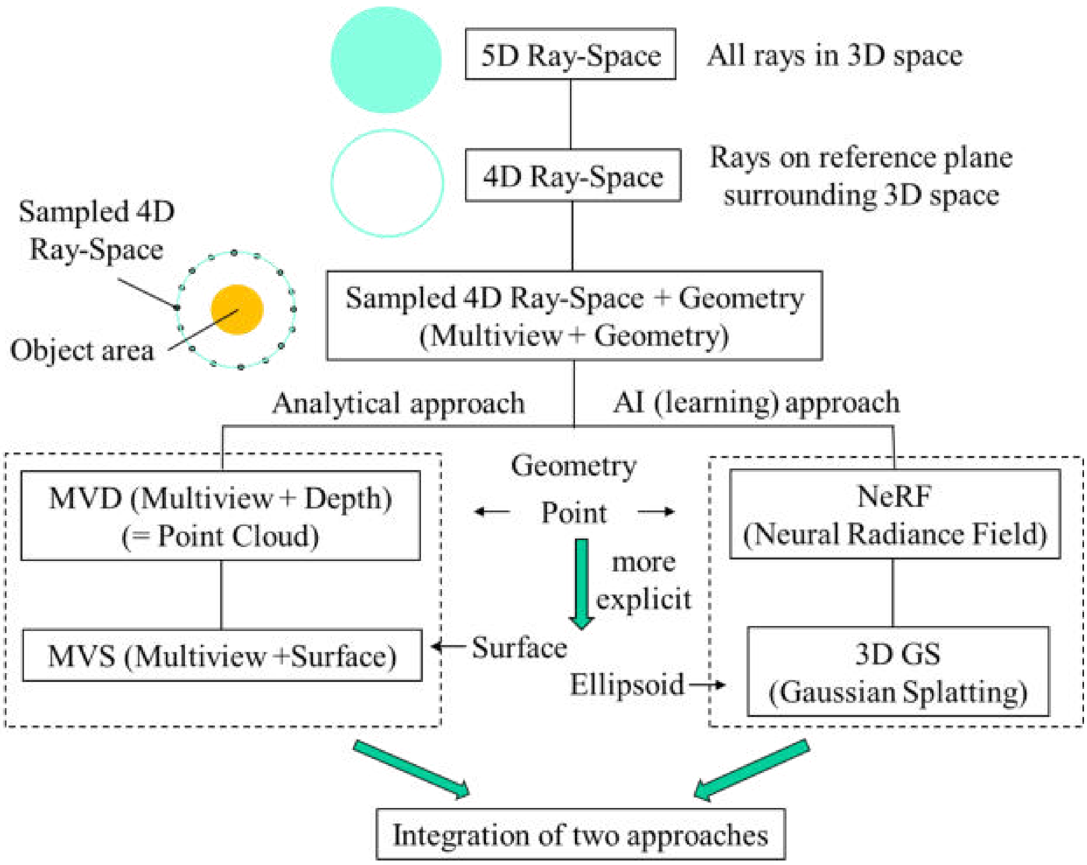

Figure 1 Relation among major scene representations for FTV.

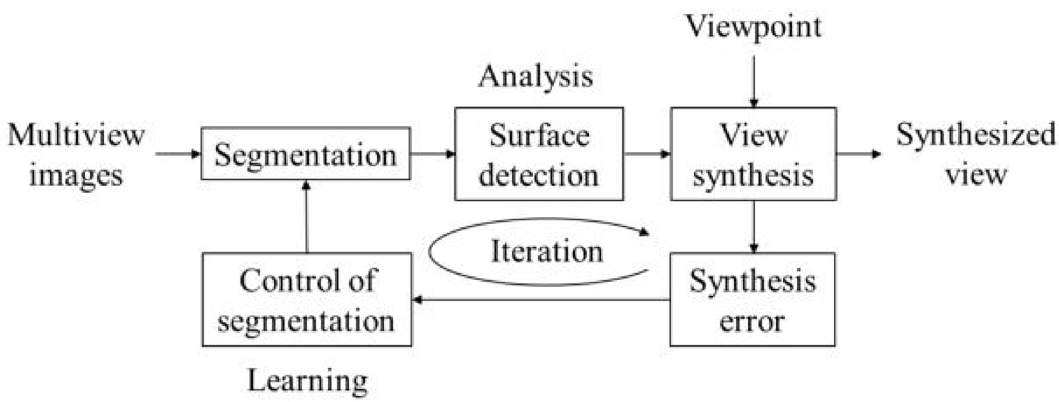

Figure 2 Processing of next-generation FTV.

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Critical aspects in bringing artificial intelligence from the laboratory to the clinics: the role of Ethics Committees

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The integration of artificial intelligence (AI) technologies into clinical research is progressing at an unprecedented pace. From predictive analytics to diagnostic support, AI is increasingly being used in various stages of the clinical research process [1], including patient stratification, outcome prediction, image analysis [2,3,4] and even protocol optimization, therapy and surgery. This widespread adoption is evidenced by a rapidly growing scientific literature, reflecting a shift towards data-driven approaches in medical science. Despite its potential, the use of AI in clinical research raises significant ethical and regulatory issues.

Ethics Committees, traditionally responsible for protecting the rights and well-being of patients and participants to clinical studies, are tasked with approving clinical research using new drugs and medical devices, including the software used as the device. In recent years, they have had to deal with the additional complexity of evaluating studies involving AI systems to support clinical trials under very different application conditions. Given their crucial role in advancing clinical research, which consists in granting or denying authorization to conduct such studies, they have often had to deal with issues such as opaque algorithms [5,6], large-scale data processing and automated decision-making systems [7,8]. These developments are reshaping the landscape of ethical oversight. This communication aims to highlight and discuss some of the emerging critical issues in the design of AI-based clinical trials subject to ethical review. Drawing on recent literature, current regulations and practical experience, we explore the complex ethical challenges and considerations that arise when AI enters the field of clinical research, with a particular focus on the evolving expectations and roles of Ethics Committees in this context.

In the case of Ethics Committees operating in the European Union, this framework has recently been the subject of new regulatory developments, with the issuance in August 2024 of the “Regulation (EU) 2024/1689 laying down harmonised rules on artificial intelligence”, the so-called AI Act. This regulation classifies artificial intelligence systems as high-risk systems, when used in the clinic as medical devices or as software integrated into existing medical devices. Therefore, in addition to the rules established for the certification of medical devices in Europe (Regulation (EU) 2017/745 for Medical Devices), for AI systems there are some additional provisions in the AI Act that must be observed, specific to the processes that imply the use of artificial intelligence methods. In detail, these more stringent provisions concern specific requirements on: Data Governance to train AI systems, based on a proper choice of data sets for training, validation and test (Art. 11); a specific Technical Documentation for high risk AI systems, to be provided before the operative use of the system and that shall be kept up-to date (Art. 12); Human Oversight, during the period in which AI systems are in use, carried out by persons who should be able to properly understand the capacities and limitations of the AI system and to decide, in any particular situation, not to use the AI system or interrupt it, if necessary, for safety reasons (Art. 14); Accuracy, Robustness and Cybersecurity, which should be must be maintained throughout the lifecycle of the AI system (Art. 15).

For the practical application of these regulations in the medical field and clinical research, specific guidelines for their use are expected in the future, but they have not yet been released. There is thus a need to establish operational criteria in this transitional period, in order to balance, on the one hand, the need not to delay the progress of AI testing in clinical research, and on the other, a careful assessment of the risks that have a direct impact on patients participating in clinical studies.

Ethics Committees are currently evaluating to authorize the experimental use of AI systems, according to general aspects, such as, for example, the scientific validity and the proposed methodology. Since there is no standard for medical use yet, the researchers proposing clinical studies including AI should justify their approach, providing a clear objective and a solid scientific basis, a solid background and documentation on how it can promote research and clinical benefits, being appropriate for the specific purposes of the research and comparing its performance with traditional methods. Furthermore, it is important that the researchers could clearly state, when this is the case, that the experimental use of AI represents only a preliminary phase of research, whose main purpose is the training of the AI system, where the use of patient data does not have a direct impact on their care and does not interfere with medical decisions. From a regulatory point of view, one can assume that in such cases the study does not qualify as a clinical investigation and does not fall under the European Medical Device Regulation (MDR), since the research involves a prototype AI system that cannot yet be defined as a medical device. This preliminary research phase should therefore be favoured as much as possible by Ethics Committees, because it will allow to test new algorithms and methodologies for the analysis of clinical data without causing a significant impact on patients.

On the other hand, at least in Italy, there are still few clinical studies that concern the subsequent development phase where AI system are proposed in real clinical conditions, as a tool to support medical decisions. In these cases, the classification of the AI system as a medical device cannot be excluded and therefore a careful case-by-case evaluation must be carried out, at least until the guidelines for the use of AI in the medical field that we mentioned previously are released.

In any case, Ethics Committees should also ensure that the informed consent guarantees the patient's right to be informed about the use of AI technologies, about the advantages, in diagnostic and therapeutic terms, about the risks deriving from the use of the technology, as well as about the responsibility of the decision-making process. In general, as outlined also by the Declaration of Helsinki 2024, the inclusion of patients and citizens in the co-design phases of AI-based clinical studies can help to reduce perceived opacity of algorithms, increase the understanding of information, identify and correct any bias related to potential discrimination in training data.

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FAMILIE – SCAILABLE COMMUNITY ASSISTANCE WITH ETHICAL AI IN SMART CITIES

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Abstract – The FAMILIE project leverages advanced AI to address the fragmentation and lack of digitalization in-home services by developing a scalable, community-based platform for families in smart cities. Through pilots in Oulu and Rovaniemi, the project will commercialize a mobile application and a community economy-based operating logic powered by AI. This approach ensures that AI-driven service needs are met locally, reducing unnecessary logistics and environmental impact. The AI-enabled platform's foundation can be scaled and implemented in other urban areas in Finland and abroad, promoting sustainable development and equitable distribution of profits within the service ecosystem.

INTRODUCTION

The project contributes to the smart city [20], social economy [16] and digital platforms [17] research with an artificial intelligence perspective. There are already some novel studies that build smart city criteria [21] from the social economy view or that comprehend local social capital as a fundamental fountain for the smart city [13]. However, these two concepts are just intertwining together, and accelerating AI development is transforming their relationship.

The families in Europe undeniably increase the need for home services, prompting many countries to develop new hybrid and platform models to improve service availability. From this perspective, home services are not only internal matters of countries but also inter-country services, business, and competition. Internationally, the growth of the market and the impact of digitalization can be assessed as follows in OECD (2023). Currently, home services are not sufficiently digitized in many countries, and the market is fragmented, making it difficult to find and access services.

Therefore, the problem is not only the lack of digitalization but also its siloed implementation tied to individual companies. Many business and foresight studies suggest that so-called "born global digital platform" companies will become more common in the future [19] These companies are often technology-driven and seek new digital solutions and Artificial Intelligence algorithms as the basis for their business [1] [2] [3] [5] [6]. Many of these companies are looking for their niche market in the global economy [4]. Social responsibility and reliability are key competitive advantages in the changing platform economy, which currently operates under VUCA conditions [5] [19] [4] [8].

Business foresight methods also create their own competitive advantage for start-up companies, growth companies, and Quadruple Helix actors [7] [14] at the European Commission level, the importance of intermediary markets in platform services has been examined, particularly from the perspective of the 'gig economy.' The biggest problems identified are the unethical nature of platform services and the uneven distribution of profits. Only a few companies have the capabilities to create and maintain a platform. Digital platforms are, now and in the future, at the center of new value creation.

Platform services have not been developed in-home services from the perspective of the community economy, where profits and benefits are distributed to the entire service ecosystem instead of a single company. However, this does not have to be the case, as Schmidt's [17] review shows that platform economy profits can be distributed more evenly and utilized more broadly for the development of communities and societies.

FAMILIE – SCAILABLE COMMUNITY ASSISTANCE WITH ETHICAL AI

The FAMILIE project addresses the growing need for home services in Europe by developing a scalable, community-based platform powered by advanced AI. As the population increases, many countries are exploring new hybrid and platform models to enhance service availability. However, the home service market faces significant challenges, including fragmentation and insufficient digitalization. By leveraging AI, first in the smart cities, [10] the FAMILIE project aims to overcome these obstacles and create a seamless, efficient, and sustainable home service ecosystem. Through pilots in Oulu and Rovaniemi, the project will commercialize a mobile application and a community economy-based operating logic, ensuring that service needs are met locally while reducing environmental impact. This innovative approach promotes equitable distribution of profits within the service ecosystem and paves the way for the platform's scalability and implementation in other urban areas in Finland and abroad.

RESEARCH

This study validates the significance of a regional home service platform based on a three-tier community economy logic for family customers through two pilots (Oulu and Rovaniemi urban areas). The project commercializes the platform's foundation: 1) the mobile application and its 2) community, economy-based operating logic. After the project, the home service platform can be scaled and implemented in other urban areas in Finland and abroad. Home service platforms have not previously been developed based on the customer's location. Responding to service needs in three tiers (family, neighbors, region) is new from a sustainable development perspective, as the customer's needs can always be met as closely as necessary. This eliminates unnecessary logistics and the resulting environmental burden.

METHODOLOGY

The methodology to develop scalable community assistance with ethical AI involves five product development phases: 1) applied research and service platform modeling, 2) user testing and prototype development, 3) preparation for commercialization and business model testing, 4) preparation for international scaling, and 5) predictive AI quality analytics.

Applied Research and Service Platform Modeling phase focuses on developing an AI algorithm-based service targeting model using a three-phase logic (family, neighbors, region) and testing its suitability for the home service market. The process begins with analyzing current home service operating models and platform solutions, mapping existing practices, and assessing market needs and service targeting challenges. Based on this analysis, a service guidance algorithm is developed, defining selection criteria for service providers such as proximity, service needs, and resource availability [9]. User paths are designed for different parties to ensure a smooth service guidance process. Initial trials of the graphical service platform (UX) are conducted in Oulu and Rovaniemi regions to evaluate functionality and usability. Necessary AI algorithms optimizations are made based on trial results to improve communal utilization of the platform economy in-home services, where economy profits are distributed more evenly and utilized more broadly for the development of communities and societies.

User Testing and Prototype Development phase aims to conduct a usability study to gather information on the home service needs and usage habits of families. Test users, including home service users and service providers, are recruited, and pilot tests are conducted in Rovaniemi and Oulu. The functionality of the platform model and AI algorithm, as well as user experience, are evaluated in a real environment. Based on the usability study results, the service platform prototype is improved.

The preparation for Commercialization and Business Model Testing phase focuses on preparing for the commercialization of the service platform and testing the business model based on the platform economy [11]. A revenue model is developed, and services are priced and organized at different levels (family, neighborhood, region). Regulatory requirements of different markets are analyzed, and preliminary cooperation agreements with potential business partners are made. A report on the business model, including an analysis of revenue logic, market regulation, and partnerships, is produced to support commercialization.

Preparation for International Scaling. The fourth phase prepares for the international scaling of the home service platform by identifying potential market areas and mapping cooperation partners [14]. A market analysis is conducted to determine suitable areas for piloting, focusing on the Nordic countries and Central Europe. Negotiations with potential international partners are held, and participation in startup events and investor meetings is planned to build international networks and seek contacts with financiers and cooperation partners.

Predictive AI Quality Analytics phase in product development ensures efficient coordination, monitoring, and fulfillment of family service obligations [18] [12]. The predictive AI oversees the home service schedule and resource use, as well as analyzes and evaluates service quality progress and impact. Dynamic AI-based reporting provides an up-to-date picture of the home-services progress, and evaluation work supports the achievement of service goals and enables necessary corrective actions.

This structured methodology ensures that the FAMILIE project progresses systematically through research, development, testing, commercialization, and scaling phases, ultimately aiming for a scalable and economically sustainable home service platform.

CONCLUSION

The FAMILIE project demonstrates the potential of leveraging advanced AI to address the fragmentation and lack of digitalization in home services. By developing a scalable, community-based platform for families, the AI-driven approach ensures that service needs are met locally, reducing unnecessary logistics and environmental impact. The project's structured methodology, encompassing applied research, user testing, prototype development, commercialization preparation, and international scaling, provides a comprehensive framework for achieving its goals.

The successful implementation of the FAMILIE platform in the pilot regions validates the significance of a regional home service platform based on a three-tier community economy logic. This innovative approach promotes sustainable development by ensuring that customer needs are met as close as necessary, thereby minimizing environmental burden. The project's focus on ethical AI and equitable distribution of profits within the service ecosystem further strengthens its competitive advantage in the changing platform economy.

The scalability of the AI-enabled platform foundation allows for its implementation in other urban areas in Finland and abroad, fostering international collaboration and market expansion. The project's emphasis on social responsibility and reliability aligns with the evolving demands of the global economy, positioning it as a key player in the future of home services.

At the end, the FAMILIE project provides valuable insights into the application of AI in home services, highlighting the importance of community-based solutions and sustainable development in smart cities. The project's outcomes contribute to the broader discourse on digital platforms and their role in enhancing service availability and efficiency, paving the way for future research and innovation in this field.

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SOUND VOIDING: AUDIO EXPERIENCES IN CULTURAL ONLINE XR PROJECTS

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Immersive experiences are usually presented as affecting different senses of the user at the same time, including hearing. However, in reality, many resources, in particular virtual visits and augmented reality (AR) applications, do not always use audio, or use it in a very limited way. Nevertheless, the case studies identified a range of compelling examples demonstrating techniques that can be used in future projects to make virtual spaces feel more alive, hold the viewer's attention, encourage exploration, simplify navigation, add semantic depth and emotional resonance to narratives, and personalise the user's experience.

INTRODUCTION

Sound is one of the most important tools for immersive experiences and digital storytelling. It is also an essential tool for capturing and holding the viewer's attention and concentration, evoking an emotional and sensory response. Sound design can complement and enhance the depth of narratives conveyed through text and visual imagery. And through all these combined effects (attention, emotion, additional information), sound facilitates remembering the experience and recalling it. In addition, sound can significantly influence or even determine the audience's attitude and degree of enjoyment of viewing immersive experiences, as well as the return to those experiences and likelihood of reusing the content.

When creating stationary immersive exhibitions in museums, sound is also an organic part of the experience created. However, in online projects, the role of sound becomes more ambiguous, despite the potential for online formats to allow highly personalised auditory experiences. To assess the prevalence and key roles of audio content in cultural extended reality (XR) projects, we propose to turn to a review of cases and possible sources of inspiration for sound design development in XR experiences.

PREVALENCE AND MAIN ROLES OF AUDIO CONTENT IN MUSEUM XR PROJECTS

Summarising the experience of multiple museum projects utilising XR technologies (including spherical panoramas, 3D models of spaces, and augmented reality) and functioning online via a browser or special applications, we propose to turn to a case study.

As a result of content analysis of official and satellite websites of 207 museums and galleries in Slovakia, 96 virtual visits based on panoramic images and videos were identified, including those with VR mode, as well as 4 mobile applications with AR.

Of these, only 21 panoramas and 3 apps used audio:

- 3 panoramas and 1 app used only background audio (music or environmental sounds);
- in 15 panoramas and 3 applications the sound was an audio guide or audio commentary;
- another 3 panoramas had both background and audio narration.

In only two examples were the background sound and audio narration interconnected, played simultaneously and automatically switched as the user moved around the map. Audio fragments recorded for individual exhibits or locations are usually triggered by clicking on the corresponding icon within the panorama and immediately interrupted when switching to another point. The 14 panoramas include the option for the user to scroll or pause the audio.

Our other sample survey of online resources identified 35 examples of panoramas and apps with XR created for museums in other countries, of which 13 had background audio or voice audio commentary.

Thus, we can conclude that sound is definitely not a mandatory element of such projects. It typically takes one of two forms:

1) a single-voiced audio guide that enables simultaneous consumption of information alongside visual content; as a rule, special buttons are provided to interact with such audio content, but in some cases the audio guide may start automatically when moving to a new area;

2) background music or noises that often do not depend on the user's actions and does not significantly affect the perception of information.

At the same time, in cases of projects using AR or gamification, audio accompaniment is much more common than among virtual visits.

Based on the analysis, it can be assumed that the omission of audio features in virtual visits may be due to, among other things, being tied to specific platforms. For example, many of the identified examples are implemented on the basis of Google Street View (19 out of 96 Slovak examples), which does not offer embedded audio accompaniment, as well as some other platforms of similar functionality. Perhaps, in the case of creating such experiences, the starting point is the simplest idea of a visual walk based on a familiar platform, and the possibilities of enriching the environment with audio are not even considered.

If the challenge is to create immersive environments, selected examples show that there are both opportunities and technical tools to do so. In this case, discussing successful practices and inspiring examples will help to overcome conceptual blindness and see new opportunities for creating more immersive online XR resources.

SOUND IN CULTURAL XR EXPERIENCES

In order to maximise the possibilities of audio accompaniment, it is proposed, firstly, to turn to the experience of a number of cultural XR experiences that use various sound elements.

Perhaps one of the easiest ways to bring the experience closer to reality and make it more informative with sound is to use background environmental sounds that are characteristic of the recreated space, which should not be interrupted in case of overlaying audio guide or other audio content. For example, in the virtual visit to the Museum of the Liptov Village [1], the background accompaniment is "nature sounds" natural to the given location, and upon the user's click, audio comments to individual objects are played, overlaid on the background. In the church location, the background is organ music. The difference between the volume of different layers of the sound environment is close to the real one. In the virtual visit to the Museum Ship "Dar Pomorza" [2], in addition to the sounds of the environment and the overlaid audio narration, there are also inbuilt noises of objects with which the user can interact. Therefore, in this case, in addition to revitalising the virtual visit, the task of increasing its interactivity and semantic depth is achieved, because creaks, rustles and other noises significantly supplement the user's ideas about the properties of individual objects, including materials and weight.

The effect of presence can be enhanced by using binaural audio and Audio-Augmented Reality (AAR)[4]. Binaural audio was used, for example, in "Visitors to Versailles" experience by the Metropolitan Museum of Art [3]. In this case, the user not only hears the noises of the environment, but can also get an idea of the direction of sound propagation, the distance to sound sources, the movement of these sources in space, and thus feel like a participant in the action. AAR also performs well in hybrid resources that are created to accompany a real visit and present location-based information. For example, in the immersive Cutty Sark audio guide [5], in which a soundscape is generated in real time, taking into account the user's individual route. Separately, it is worth noting that the sonic experience in XR can also be a tool for recreating and/or preserving natural acoustic spaces [6], like the "Listen To the Theatre" project [7].

The element of environment noises can also be the sounding of the user's movement, primarily the noise from footsteps, including taking into account the difference in movement on different surfaces. This kind of noises is used in the VRuseum project [8], which resembles a video game with a first-person view. In addition to footsteps, transitions between locations are also emphasised with sound, and several zones have their own audio accompaniment, which is part of the digital exhibits. The area of the virtual museum is large and is expected to take a lot of time to explore, so it's not surprising that the background music is neutral and soft, so as not to distract or annoy the user.

Another interesting practice that contributes to immersion and attention retention is digital storytelling with narration on behalf of characters. It is used in the online experience "Ebutius' dilemma" [9]: while exploring a virtual visit, one can listen to an emotional first-person narrative in which museum objects are woven into a personal story, and help the character to make an important decision in his life. This audio accompaniment helps to create a more vivid understanding of the objects' meaning.

Sound cues can also be used to simplify navigation in XR. Although such examples were not found among the analysed resources, we can refer to the experience of creating AAR applications. An example of audio navigation in such applications is increasing the volume of a certain layer of audio when approaching a certain object and decreasing the volume when moving away from it [4]. The same technique can be used in virtual space. In addition, it is possible to simplify navigation even at the level of an audio guide, through verbal instructions on how to get to the next object of the route and what to pay special attention to (for example, such instructions are used in the audio guide of the Dresden City Museum).

INSPIRATION FROM THE VIDEO GAMES

It is also possible to draw inspiration from the practices of other spheres, especially video games. Although not all tools are easily transferable to museum contexts, projects incorporating gamification can benefit from video game inspired sound design. This extends even beyond sound: the use of mechanics from video games can make resources more intuitive, engaging, and appealing to broader audiences, as the average age of the target audience of video games is older than teenagers. Regarding audio specifically, following ideas can be adapted.

In cases where there is no specific soundscape for XR, and its role is fulfilled by background music, it is possible to use the idea of in-game radio systems. Interestingly, a similar idea was used in one of the early virtual museums – the Museo Virtual de Artes El Pais (MUVA) – the second version of which allowed the user to switch tracks from an in-built playlist. An inbuilt radio or playlist with unique tracks can be an effective way to engage the user and encourage prolonged exploration of the resource.

Audio cues anticipating or signalling changes in the environment are used in games to draw attention to important events, including activating a feature, approaching significant objects, opening a passage to a new location, and more. Such audio notification of moving to a new exhibition area is used in VRuseum, which should draw the user's attention to the fact that the next art object is nearby.

Sounds can also be used to encourage the user to take certain actions, such as interacting with an object or using specific function. A common example is the sound of a phone call or message notification to get the user to listen to or read an important message immediately.

The user's actions can be illustrated not only by the sounds of footsteps, but also by sounds of touching objects or noises that illustrate the unusual state of the character on whose behalf the user is acting (e.g., exclamations, sighs, etc.). One of the most elaborate examples of sound design reflecting a character's individual auditory experience can be found in the game Hellblade, where the trauma and mental state of the heroine is conveyed through the unique experience of hearing multiple voices, enhanced by the use of binaural audio. This experience shows that in the use of binaural audio it is not only possible to have an "audio theatre" where the user plays a passive role, but also an active immersion into the personal story and experiences of the character in a first-person perspective.

Some ideas can be drawn from the genre of rhythm games, where players must follow the rhythm of music to perform certain actions, as well as from games that use musical and sonic riddles and puzzles. Such mechanics could be used for gamification of cultural XR experiences, such as creating game tasks, or game zones for free creative interaction with the recreated environment. Hypothetically, this could encourage engagement, longer exploration of the resource and subsequent return to it.

Finally, the typical video game approach to flexible audio settings can be implemented in XR. For example, this type of setting is already used in VRuseum: the volume of music and environmental sounds can be adjusted separately. This gives the user the ability to make their experience as comfortable as possible, such as turning the music off completely if it interferes with concentration. In this case there is no audio commentary, but if an audio guide were available, this kind of setting would help users to adjust the volume of speech as well.

AI-DRIVEN SOUND TECHNOLOGIES

The use of AI in XR can elevate the overall user experience, create more immersive and engaging experiences, as well as enhanced personalisation and adaptation [10].

Although no use of AI was identified among the analysed projects, this does not exclude that the technology has been used (as the use of AI is often limited to technical processes and may not be publicised in the resulting XR experience), nor does it exclude the fact that AI provide valuable additional possibilities in working with audio.

If it is not a question of accurately recreating and preserving real sound environments, artificial intelligence can be applied to create audio content, from noise to music, tailored to specific requests. Another important area is audio processing: AI-driven technologies and tools speed up and simplify work with audio in a number of tasks, for example, when there is a need to remove noise or create multiple arrangements of the same track. Voice synthesis and automatic text-to-speech capabilities are significant in their own right and for the creation of virtual assistants and their personalisation at the user's request, including adjusting the assistant's voice and the pace of the narration. AI makes it possible to implement automatic personalisation of audio guides, including the creation of an individual playlist and route, such as the AI-powered digital visitor guide for the Smithsonian American Art Museum, implemented on Smartify platform.

Thus, advances in AI-driven technologies provide new tools and opportunities to address many of the challenges associated with sound design in XR projects, including generating character voices for digital storytelling, creating and editing soundscapes, and personalising the user’s audio experiences. Hypothetically, addressing these technologies should make it easier to incorporate audio experiences into cultural XR.

Conclusion

There is certainly some avoidance of sound among existing cultural online XR projects. However, there are also reverse examples. The use of audio in XR can range from simple idea of bringing the experience to life with background music or noises, to systemic sound design using the power of binaural audio and AI personalisation. The effect of audio can lie in its very content, such as emotionally telling a personal story or illustrating the sounds and noises produced by objects. Or it can be aimed primarily at personalising the gaming and cognitive experience, including by adjusting the volume and other characteristics of the audio, switching background music, and selecting the character's voice. As diverse as the possible functions and roles of XR experiences are, so diverse can be the functionality and role of audio in them. And at present, the realisation of this potential can be facilitated through the use of artificial intelligence.

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Human-Centric Digital Innovation: The Integrated Approach of Sesa Group

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Sesa Group is a leading Italian operator in the digital and ICT sector, supporting thousands of companies and institutions with end-to-end technology solutions—from business management software to advanced services in AI, cybersecurity, data analytics and cloud infrastructure. Sesa has an integrated and human-centric approach to innovation, where technological excellence meets domain expertise and social responsibility. While covering the full spectrum of digital transformation, the Group is currently focusing its strategic efforts on Artificial Intelligence and Cybersecurity, with a clear commitment to transparency, trust, and human oversight.

Indeed Sesa operates across the entire digital value chain, from traditional ERP systems and vertical business applications to next-generation technologies such as artificial intelligence, cybersecurity, cloud platforms, and advanced analytics. With a portfolio that spans SMEs, large enterprises, public administration, healthcare and retail, the Group's value proposition is based on a combination of technological depth and deep process knowledge within each sector.

With over 6.000 professionals and a decentralized structure rooted in local territories, Sesa enables digitalization for over 15.000 clients in Italy and abroad.

Digital transformation is not a product — it's a journey. Sesa's proprietary *Isquared*® method structures this journey through five iterative phases based on the integration of:

- Human Intelligence (client goals, user insights, governance),
- Process Intelligence (vertical workflows, domain know-how),
- Artificial Intelligence (models, automation, augmentation).

The method combines co-design, benchmarking, and continuous monitoring to ensure that AI systems and digital platforms remain understandable, controllable, and aligned with the needs of organizations and individuals.

While Sesa addresses the full ICT stack, current strategic attention is focused on two key themes: AI and cybersecurity. These areas are developed with a human-centric mindset: AI is not intended to replace, but to support human decisions; cybersecurity is not only about technology, but also about building a culture of digital responsibility and resilience.

The Group offers:

- AI solutions for vertical use cases such as predictive analytics, intelligent document processing, and recommendation systems tailored to industrial and service sectors.

- Cybersecurity services including 24/7 Security Operation Centers, vulnerability assessments, penetration testing, threat intelligence, incident response, and Red Team activities performed by ethical hackers.
- Compliance support for European regulatory frameworks such as the AI Act and NIS2, integrating legal, technical, and organizational dimensions.

Sesa’s innovation strategy is inseparable from its commitment to social value. The Fondazione Sesa promotes internal welfare policies, community programs, and environmental initiatives, while Fondazione Prodigi delivers ITS-level training in AI, cybersecurity and software engineering, in close synergy with businesses.

Together, these foundations support a long-term vision where digital innovation is inclusive, sustainable and ethically grounded.

Sesa’s participation in EVA 2025 and in collaborative frameworks like the Memorandum of Understanding with Regione Toscana reflects its ambition to act as a catalyst for secure, inclusive and sector-aware digital transformation. By combining full-stack ICT capabilities with a strong ethical and social orientation, Sesa offers a model of human-centric innovation that speaks to the challenges and opportunities of the AI era.

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CULTURAL ACTIVITIES - REAL AND VIRTUAL GALLERIES AND ACCESS TO THE RELATED INFORMATION

RE-ART Europe
By Smarticon

Author
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Restauratrice e ideatrice del brevetto per metodo Smarticon

ABSTRACT
The "ReArt Europe" initiative is born in provocative resonance with the project "ReArm Europe," with different paths but shared goals: unite and protect. The project aims to build a community that becomes a backbone for enhancing art as a resource for global collective well-being. At the core of this framework are the activities of Sapere Project by Sara Penco, restorer and owner of the patent for the Smarticon method: the thinking model that allowed the identification of Mary Magdalene in Michelangelo's Last Judgment.

THE GLOBAL SCENARIO
The global scenario that emerged in the first quarter of 2025 has highlighted the difficulties that each nation must face and resolve in order to preserve its identity, independence, and, consequently, the defense of its vital spaces.
We are witnesses to a reactive and courageous Europe, which "embraces challenges" and adapts to modern times through its commercial, financial, and military policies.
Our contribution aligns with this context: in an Europe that boasts the privilege of being the cornerstone of a strategic synergy, originating from an excellence recognized worldwide and for which Italy, in many ways, can be considered its "beating heart": **we possess the experience and expertise to generate the ARTifice**; the demiurge, the historical heir, and the fragile guardian of Humanism. The established crucible of artistic and cultural expression of mankind across all times and social, cultural, and religious backgrounds!

EUROPE: THE TEMPLE FOR A PLANETARY HUMANISM
Declaring Europe as the "*Temple of Humanism*" is an ambition that consolidates the premises based on the territory's physiological history, which ennobles it and makes it highly competitive: both in the global context and within the scenario imposed by other blocs in financial, commercial, and political sectors. Italy hosts the Vatican headquarters—with its 2.4 billion adherents—right in the heart of the "capital of the world": Rome. It is ecclesiastical patronage that has fueled, over the centuries, much of the most appreciated craftsmanship in the world. Just think that the Sistine Chapel receives about twenty thousand visitors a day.
In Europe, an invaluable Cultural Heritage is preserved and protected as a UNESCO World Heritage site. In European geographical areas, art history has seen artists converge, leaving an indelible mark; leaving future generations a powerful and timeless catalyst that fascinates tourists

from all over the world. Europe boasts a natural beauty and, for this reason, is an exceptional resource for sharing and cohesion.
Art is the most effective language to communicate in a dimension where the reflection of the soul can open a dialogue without time or borders. Because other countries also boast unique beauties, Europe's history makes it the reference point for safeguarding, conserving, preserving, and enhancing art—thanks to the experience gained over centuries, which makes us reliable and competitive in a highly vital but also strategic sector, as it is a source of inestimable wealth. This strength opposes and balances the most vulnerable aspects.
Europe can be the reference capable of creating a jewel of civilization, culture, and welfare; generating a centripetal movement of gathering and inclusion that the entire world has an interest in preserving: because destroying it would be a crime against humanity.

THE FRAMEWORK

At the core of this framework are the activities of Sara Penco's Sapere Project, a restorer and holder of the **patent for Smarticon method**. Sapere Project focuses on the conservation of the material that constitutes the artwork (restoration), but also on the efforts made to preserve, enhance, and make accessible the intangible heritage of the artifact, which represents its "reason for existence."
The patent for the "Smarticon" method is dedicated to organizing human knowledge to valorize it and make it accessible in a flexible and dynamic way, so that it can adapt to any need (institutions, universities, museums, experts, enthusiasts, law enforcement, cultural exchanges, etc.)[1].
The proprietary technological platform is developed and implemented with pioneering techniques that anticipate modern artificial intelligence. The scientific foundation of the method is verifiable through numerous recognitions; and above all, it is demonstrated by the success of the studies published in the volume "*Maria Maddalena nel Giudizio di Michelangelo*" of the Sistine Chapel, published by Scripta Maneant[2].

SMARTICON

The method allows for describing, recognizing, integrating, and encoding the iconographic attributes that characterize a work of art, leading to the correct identification of the depicted subject: because iconography is the discipline that investigates and encodes the meanings of images. The system interacts with the user and supports them by applying cognitive technologies within the knowledge database.
Once the depicted subject is identified, it is possible to deepen the research by retrieving various types of information (documents, images, archives, etc.), related and linkable to the investigated artifact.
Smarticon is suitable for collaboration (including with Asian countries) because it is designed to be multi-tenant and applies cognitive technologies on a proprietary multilingual database, constantly updated and validated by a scientific committee (https://sapereproject.com/smarticon-it).
The reassembly of the artifact's genetic code can be stored securely in a blockchain.

MARIA MADDALENA IN MICHELANGELO'S JUDGMENT

One thousand five hundred years after the creation of the Last Judgment in the Sistine Chapel (figure 1), Sara Penco — restorer and art enthusiast — **recognizes and explains the identification of Mary Magdalene** among the tangle of figures that crowd the wall welcoming the faithful, behind the altar.
At the extreme right edge of the wall, a man supports one of the most imposing crosses in the composition, and, turning in the opposite direction of the events, appears to be accompanying *the*

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1 www.sapereproject.com

2 https://sapereproject.com/media-sapere-project/maria-maddalena-nel-giudizio-di-michelangelo

blonde woman, dressed in yellow, depicted full-length, who is about to kiss the wood of the crossbeam: Mary Magdalene (figure 2). The intimate sharing of the cross — an object of desire for saints — provides the basis to hypothesize that the powerful man could be recognized as a "reiteration" of Christ the Judge in the Redeemer. The physical strength and facial features align perfectly, but it is the posture of the arm that cannot be considered a casual "projection" of such a meaningful gesture; because it is precisely in the force flowing from the Judge's raised arm that the whirlwind of events unfolds, animating every detail of the 180.21 square meters of the wall (figure 3 - 4).

The association of Magdalene with the Redeemer (figure 5 - 6), especially in the *Parusia*, would reaffirm the *concept of Resurrection and Christ's mercy*, announced in biblical testimony as "*God's Judgment on evil will be a Judgment of grace*": a message of love that goes far beyond the harshness of condemnation for the damned souls.

The reasoning leading to the identification of the Apostle of the Apostles is detailed in the volume "*Mary Magdalene in Michelangelo's Judgment*" published by Scripta Maneant, where every argument is supported by constant bibliographic references to sacred texts, theologians, and the words of Pope Francis.

The discovery was announced in conjunction with the inauguration of the Jubilee Year — a year of Grace — and the 550th anniversary of Michelangelo's birth.

This study offers a new perspective on the fresco, testifying to a *powerful theological message* and shedding light on an unprecedented aspect of the hermeneutics of the Judgment, giving one of the most famous and studied works in the world extraordinary relevance; a relevance that strongly aligns with the New Season of the Church inaugurated by Pope Francis and with the Holy Father's dedication to enhancing the role of the saint with timeless charm and charisma. The discovery of Mary Magdalene in the Last Judgment, along with the related research, has generated worldwide interest[3].

The Pope Francis has sent a letter of thanks for this research, and the *Dicastery for Evangelization and the Section for Fundamental Questions of Evangelization worldwide* have granted patronage "*… for the dissemination activities on Mary Magdalene in Michelangelo's Last Judgment during the Jubilee Year.*"

TECHNOLOGY EMBRACES ART

What is the fragile boundary that distinguishes the formulation of captivating hypotheses and theories from their actual reliability, trustworthiness, and credibility? Where should we look for confirmations of a truth that can be considered as verifiable, demonstrable, and "validatable" as possible?

Every work of art is like a *discourse*, and the process of recovering knowledge of its complex meanings necessarily involves the correct reconstruction of each phrase, the verification of the syntagms — whether correct or incorrect — and, as much as possible, the reconstruction of those that are missing.

Hence the need to organize information to enhance its accessibility, since it constitutes the fundamental knowledge patrimony for correctly reconstructing each discourse until its validation. These are the beating heart of any method capable of supporting the processes aimed at encoding hermeneutics in art.

The *Smarticon* patent is dedicated to organizing the knowledge accumulated by experts with the goal of enhancing its usability. The core of the method lies in its ability to investigate the artwork starting from the recognition of the iconographic attributes that characterize it, up to retrieving all useful information for identifying the depicted subject: because *iconography is the discipline that investigates and encodes the meanings of images*.

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[3] https://sapereproject.com/media-sapere-project/maria-maddalena-nel-giudizio-di-michelangelo

This "*thinking model*" is rooted in the virtuous cycle of knowledge as a resource for the preservation, enjoyment, and renewal of sources of knowledge through their organization.

THE MISSION

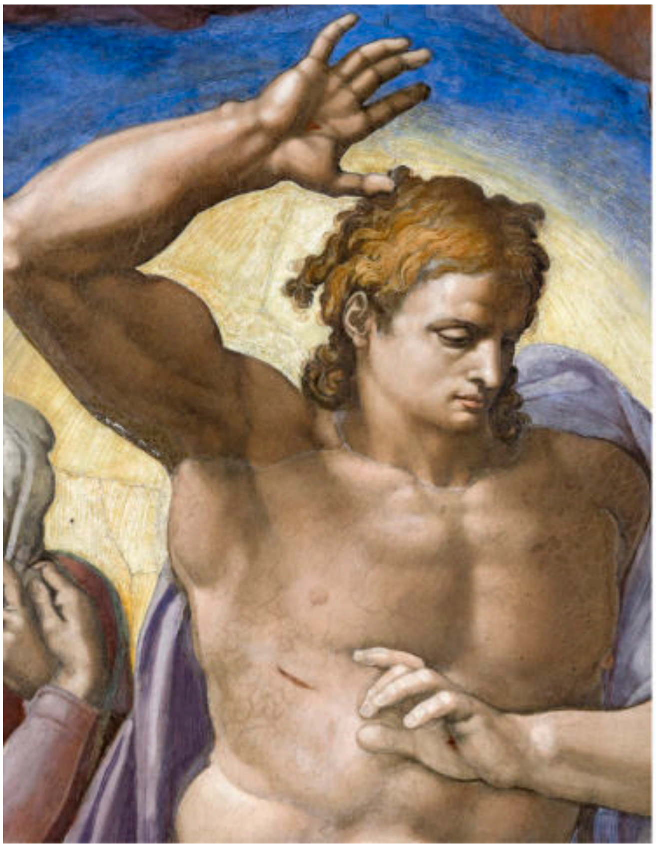
How to recognize in art that reflection of the soul capable of opening a timeless dialogue, which can help bridge social and cultural distances?

Sapere Project's mission is to contribute to enhancing art as a resource for global collective well-being, moving towards a "*planetary humanism*." This ambition is realized through initiatives like ReArt Europe; a project conceived by Delia Morea that gives rise to a new professional figure that no artificial intelligence can ever replace: the "**next-gen restorer**," dedicated to preserving the artwork both in its material aspect and in recovering, understanding, and encoding the language that represents the "reason for existence" of the work of art, which translates into its invaluable "*genetic code*."

The mission is to *recognize in art that reflection of the soul capable of opening a timeless dialogue, helping to bridge social and cultural distances.*

Figura 1. The *Last Judgement* in the Sistine Chapel

Figure 2. Particular



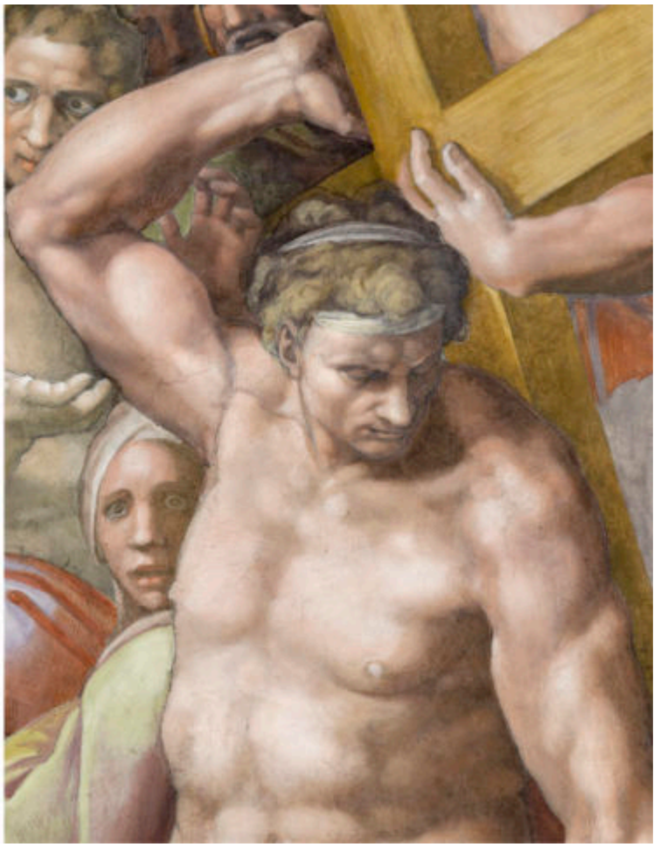


Figure 3. Christ the Judge

Figure 4. The cross-bearer

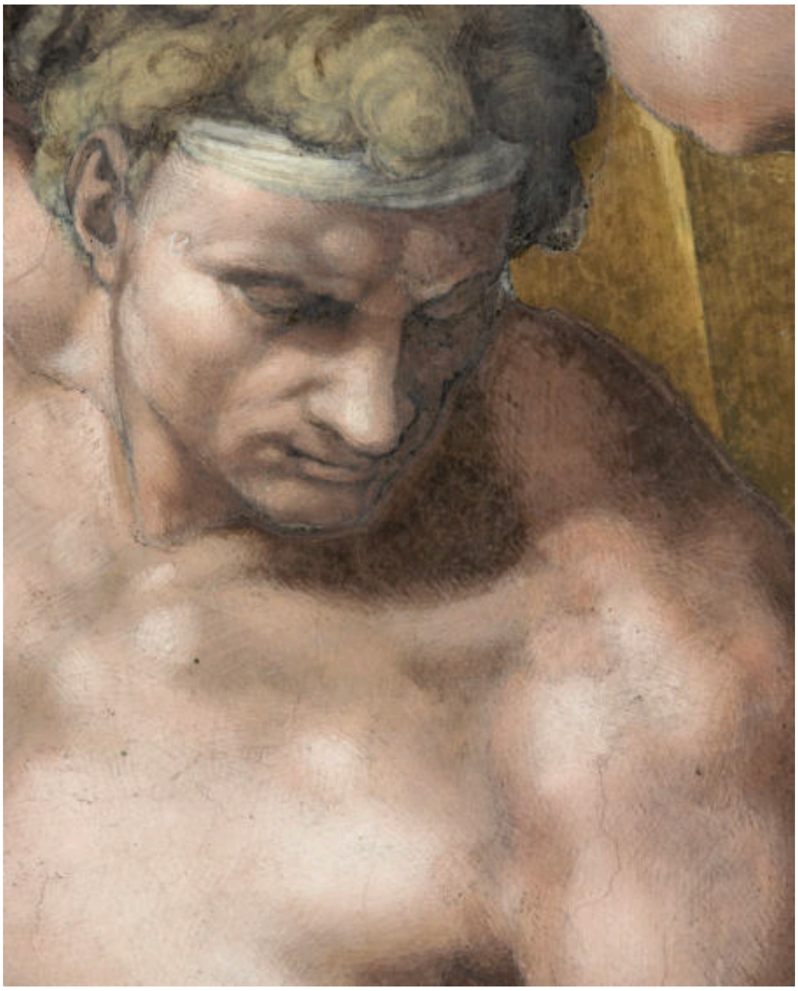


Figure 5. The cross-bearer. Particular

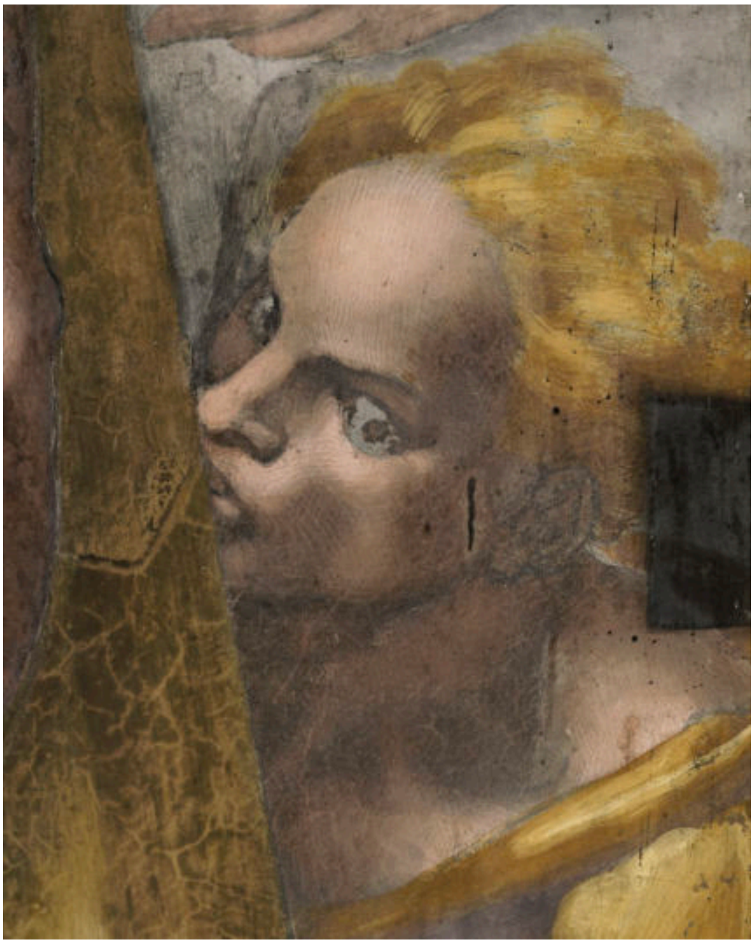


Figure 6. The woman who kisses the cross. Particular

CULTURAL INNOVATION THROUGH CO-CREATION IN SMART CITIES

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Smart cities nowadays represent a collection of best practices for urban development; they aim to enhance quality of life of the residents and other city-users by integrating digital innovations into the routine urban experiences [1]. The diverse range of services provided by the smart cities make the everyday lives of the citizens easier, trying not to leave smart city actors behind when developing new solutions [2]. Co-creation initiatives are essential for ensuring that smart city innovations are not only technologically advanced but also inclusive, sustainable, and citizen-centric [3]. The presence of cultural dimension in the urban environments is essential as it contributes to the place-making, raising the sense of belonging of the residents and other city-users [4]. The purpose of this study is to collect and analyze the scientific literature on the best practices from the smart city cultural co-creation activities, lessons learned, and possible paths for replication.

The present study adopts a scoping literature review in order to outline the main trends in the cultural co-creation initiatives in the smart city. The present methodology includes the analysis of more than 300 articles retrieved in the Scopus database from the period of 2014–2024. The authors consider this method well-suited for exploring the present topic, as scoping review uncover the main trends in the existing scientific literature [5]; this approach also provides a comprehensive overview to the key practices in the field, gaps in the literature, and opportunities for future exploration.

The authors expect that this research will shed light on the following dynamics of the cultural co-creation activities in smart cities: successful frameworks for involving smart city actors in these initiatives; the role of digital technologies for the facilitation of communication and collaboration; best practices of multi-stakeholder collaboration; challenges identified; lessons learned; and conditions for the replication of best practices.

This research contributes to the academic field by providing a comprehensive overview of co-creation practices in smart cities in cultural domain. Future studies could build on the findings of this research to investigate the impacts of specific co-creation models or the long-term effects of co-created services on urban cultural prosperity. The findings of this study could also support the development of policies and governance structures that foster cultural co-creation in smart cities.

However, the study is not without the limitations. The literature included in the review overlooks cultural co-creation practices in smaller cities and developing regions that can limit the generalizability of findings to urban environments with different cultural, economic, or infrastructural contexts. Future research could address this gap by exploring specific co-creation practices in diverse urban settings.

The originality and value of this study lie in the exploration of cultural co-creation activities in smart cities through a scoping literature review. While smart cities are a continuously evolving topic in academic literature, the specific focus on the dynamics and evolution of the cultural co-creation initiatives, where citizens, businesses, and governments collaborate in designing and implementing urban solutions should be made.

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THE CONSISTENCY OF A PHOTOMONTAGE IN THE TRANSITION TO VIRTUAL SPACE

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Generative artificial intelligence for image creation is well on its way to achieving absolute consistency. Once this goal has been achieved, it will be possible, for example, to reliably produce storyboards for future animations or even virtual spaces. The trade-off between costs and benefits, i.e. between absolute consistency and the associated additional effort versus minor deviations, will then become obsolete. But until then, scientific relevance will continue to be of uppermost importance, especially in the visual communication of cultural heritage. Random deviations or even hallucinations are contrary to the intention of the image material. While image generation is still struggling with its known weaknesses, the following project on the historical state of the Anna Amalia Library in 1766 aims to show the challenges facing the visual communication of cultural heritage, even when the goal is to create a photorealistic image that perfectly matches the training data of the artificial intelligence.

INTRODUCTION

The Duchess Anna Amalia Library [1], which is part of the UNESCO World Heritage Site ‘Classical Weimar’ [2], became known to the public through the devastating fire in 2004, which destroyed large parts of the unique Rococo hall. Photographs were available, and reconstruction began quickly. Only three years later, the library was reopened (Fig. 1). While the visible surfaces of the most important structural elements were restored largely true to the original, attentive visitors will notice a more economical design on less prominent surfaces, where some details have been simplified. What is more interesting than this obvious disruption in the authenticity of the material heritage is another circumstance whose roots go back to a much earlier transformation. In his book ‘Das Rokoko in der Herzogin Anna Amalia Bibliothek’ (Rococo in the Duchess Anna Amalia Library) [3], Achim Ilchmann describes how the hall was furnished and decorated in 1766, in contrast to its current state. The differences are not only of documentary interest, but also because the current furnishings were originally designed by none other than Johann Wolfgang von Goethe. Even though he added busts, paintings, and some architectural details from his time, classicism, the rest of the inventory is informative enough to get an idea of what it looked like before. The goal of our collaboration with Achim Ilchmann and the Herzogin Anna Amalia Library of the Klassik Weimar Foundation [4] was to turn this image, which is described in detail in the book mentioned above, into a visual representation (Fig. 2).

STAGES OF THE VISUALISATION

As in the authors' earlier projects spanning numerous eras [5], scientific uncertainty plays a role, though to a lesser extent, as the findings regarding the state of the library in 1766 are largely considered to be reliable. Strategically, therefore, a section of the room that could be reconstructed with certainty was chosen as the starting point. Strictly speaking, no reconstruction has been carried out here either, because, firstly, these are only virtual measures and, secondly, even if the differences from today can be described verbally with certainty, the traces of use on the altered surfaces are lost forever and are therefore fundamentally speculative. In order to ensure the accuracy of the verbal description, photomontage was used for the initial presentation of the project, whereby the term refers rather to the final appearance, whereas the production method itself already included, among other things, a virtual three-dimensional model. A first step towards a non-static perception of space is provided by camera movements through the virtual model textured with the aid of photomontage. This way of creating animation is not just a combination of photo montage and textured 3D models, but also a balance between how closely the model matches the photo montage and how closely the viewer believes it matches reality. This is because every single element that reveals surfaces not visible in the original photograph through the movement of the camera in space initially appears as stretched versions of the image points located at the edge where the surface passes from the visible side to the previously invisible side. On a small scale, this can be concealable in the multitude of visual stimuli, as is the case with practically every book. In a frontal shot of a bookshelf, this affects the left side of the left books and the right side of the right books, and thus practically every single book. These artefacts could be entirely avoided with a complete photogrammetric three-dimensional capture of the entire bookshelf with all its books. But since the long-term goal is not to show the current contents of the shelves, as these can be seen in physical reality, but rather to show historical, partly documented and partly hypothetical contents, the only way to visualise a complete three-dimensional representation of all conceivable arrangements of the books without artefacts would be to scan every single book in full three dimensions. This effort would be excessive. Instead, it should be examined whether the simplified representation is sufficient for the intended purpose, namely to convey the change in the appearance of the space, without taking into account the selection and arrangement of the books in 1766.

THE APPROACH – A GLIMPSE INTO THE FUTURE OF GENERATIVE AI

Although the result appears to be a pure photomontage, a virtual 3D model was used to draw the elements that were apparently exposed by removing the later fixtures and objects in a geometrically correct manner. The 3D model thus served as a spatial guide, helping to position the previously hidden elements in the two-dimensional drawing. It also served as a test space for the lighting situation that resulted from removing the objects. It is precisely this spatial consistency that is currently pushing generative AI to its limits, as the aim here was to create a vision that should appear to be unquestionably and flawlessly identical to the image that would be obtained if the fixtures were actually removed, the hidden surfaces restored to their previous state and a photograph taken. But while the mere description of this measure does not seem to reveal any difficulties, it is actually a creative decision in detail, almost comparable to painting with a brush, to arrange the colours and lights in such a way that the eye can completely immerse itself in the illusion that it is a photograph of an alternative, historical physical reality. Only through a high degree of iteration and critical examination of the intermediate results was it possible to achieve a level of realism that appears suitably realistic.

The virtual model did not only help with the photo montage, it also made it easier to plan the further visualisation of the historical state. Like a spatial sketch, the model allows the spatial consistency to be verified visually, hypotheses to be made and any gaps in the mental model of the assumed historical state to be revealed. The model was used to test the hypothesis that adding the top shelf and the two upper rows of books significantly impaired the incidence of light. Surprisingly, this influence on the actual light distribution is less than expected. Nevertheless, the exposed vault surfaces have a distinct visual presence in the perception of library users, because instead of book spines, they now see the open, empty, white surfaces above the books. The emptiness alone, the homogeneous white surface in the visitor's field of vision, gives them an impression of a brighter space.

In this respect, the realisation of the photomontage resembles the realisation of the archaeological hypotheses implemented in earlier projects. It is generally assumed that a clear verbal description of a hypothesis with reference to the current state of physical reality, which in archaeology sometimes amounts to nothing more than foundation walls, is sufficient for the understanding and interpretation of the finds. But because visual perception of something previously described in words causes it to be processed in a completely different way, new lines of thought can unexpectedly emerge in the pictorial version. This is why visualisation is so important, especially for hypotheses that are considered extremely uncertain [6]. For the same reason, photorealistic visualisation is not appropriate in cases of great uncertainty, because the purely speculative element of the image would then be so dominant that it would be virtually impossible to focus on the scientific substance. In the case of the library, the empty white views of the vaulted surfaces are just such a case. The fact that the open spaces do not contribute significantly to the amount of light, and thus to the actual illumination, is one aspect. But it is completely unexpected that their mere visibility and the associated spatial openness create a subjective impression of light and, at the same time, their formal similarity to the vaults above the passageways also serve to emphasise the spaciousness of the architecture, making it appear even lighter and thus brighter.

But there are not only confirmed changes within the library. The third floor was originally part of the open space, and the staircases between the floors are also not clearly defined in terms of their form and design. It will therefore be a challenging task, both spatially and visually, to visualise these ambiguities in a plausible manner and with the appropriate degree of uncertainty, so that the visualisations will be able to make a productive contribution to the upcoming architectural and art historical discussion. As with the visualisation project on the ancient amphitheatre in Dyrrachium [7], it will once again be a question of camera movement to evoke the impression of space, despite abstract surfaces, solely through the dynamics of movement.

CONCLUSION

Consistency is the key to credibility. AI is not yet capable of flawlessly implementing verbal statements, even if they are unambiguous, but it is only a matter of time before it will be able to do so. How exactly to decide on specific measures when questions arise during the translation from words to images will hopefully remain the task and responsibility of the creative disciplines, because even with the most detailed prompts, ambiguities will always remain. After all, with the right expertise, drawing and painting are simply faster than meticulously formulating brushstrokes. Ultimately, the uncertainty of knowledge in this project requires that the sometimes subtle differences between established knowledge and possibly even contradictory hypotheses be conveyed visually. Another objective will be to mediate between the photomontages and the inevitably more abstract components of the visualisation in such a way that, despite the obvious breaks in the mode of representation, a model of the library emerges in the viewer's imagination that allows them to understand and appreciate its distinctiveness and, above all, their spatial qualities. In consideration of the originator of the changes, it is virtually impossible to reverse the alterations, and so visual communication remains the only way, at least for the time being, to experience the original intention of the library's builders, at least to some extent. In the best case scenario, the state of today and the state of 1766 stand side by side as equivalent models in the imagination of the visitor, so that the model of the library as a whole spans its entire history.

Fig. 1 Anna Amalia Library - Shelf 5 in the Rococo Hall today, photograph

Fig. 2 Visualisation illustrating the spatial impression of the Rococo hall in 1766

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Picture credits:
Figure 1: Hannes Bertram, Stiftung Klassik Weimar, 2024
Figure 2: Lengyel Toulouse Architects, Berlin, 2025

“Flying with The Butterfly”

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Abstract

The Use of Immersive Audio in Opera
This paper originates from a question posed by Maestro Yoshida
“How would Puccini envision Madama Butterfly (Fig.1) **today?”**

To find a possible answer to this question, we must analyze the issue from all angles and strive to understand the present in all its complexity. From a historical perspective of Butterfly, we must begin with the London (1862) and Paris (1867) Expositions, during which Japanese culture began to spread within European artistic circles. Around the same time, Italian ships embarked on transoceanic voyages to the ports of Nagasaki, Kobe, and Yokohama (1866), initiating not only commercial and intellectual exchanges, but also the eventual dispatch of Italian artists by the government to teach at newly established Japanese academies (1874).

Throughout years of studying art, the creative process of a masterpiece has often been summarized in three simple yet profound words:

Inherit, Repeat, Innovate.

• **Inherit**: A work of art carries within it the history of all those that preceded it.
In the specific case of Madama Butterfly, it encapsulates deeply human emotions through powerful musical storytelling, keeping it within that timeless, liminal space typical of truly universal art.
At this stage, there is no need to alter it—only to study it.

• **Repeat**: This phase involves study, technique, and internalization to make the creator’s intent visible and clear. It includes preliminary gestures brought to near perfection by those who conduct and perform it.

• **Innovate**: Only afterward can one create something new, with the awareness that true innovation in art does not mean distorting it but rather adapting and amplifying the original message. Here, we can draw an analogy with translating a great Greek classic. Though the original language is little known and incomprehensible to most audiences, the goal is to preserve its entire content while rendering it into a language we can understand and appreciate in all its nuances.

At this point, another protagonist comes into play—one that has undergone the most rapid evolution due to major social and technological changes between the 20th and 21st centuries: the listener, the audience. An opera does not exist if no one listens to it. The audience holds the central role because everything is made for them, and they are a living part of the experience—from Puccini's (Fig.2) creation to Maestro Yoshida's (Fig.3) direction .It is therefore necessary to analyze the audience in its social evolution and technological context .Most scholars (**Jauss, Attali, Adorno, among others**) trace the first major transformation of the audience to the advent of sound recording. What is known as the "poietics of listening"—the construction of meaning through active, intentional listening—has been altered . Conversely, an immaterial art form like music becomes material and tangible, taking the shape of a medium such as an LP. The live musical event is accompanied by its recorded version, and technological evolution leads to an extreme pursuit of the "perfect recording": noiseless, error-free, and as faithful as possible to a presumed "authorial idea"—an idea likely never even envisioned by the author. As early as **1936**, **Walter Benjamin**, in his essay "The Work of Art in the Age of Mechanical Reproduction", suggested a loss of the "aura" surrounding a performance .A few decades later, the initial excitement waned. In his **1963** essay" Musical Uses of the Radio", **T.W. Adorno** already spoke of the flattening of musical sensitivity in the public and of the transformation of art into a consumer product meant to saturate the market. The "good listener" is disappearing, and behind this strong statement lies the breakdown of the dynamic and dialectical relationship between audience and performers—because the performance becomes frozen in an identity-less space and in repetitive sameness. Today we face the problem of shortened attention spans and the progressive forgetting of musical language. Music has lost its material, tangible form, becoming just files. A scientific approach is now necessary—as though treating a neurodegenerative disease. We must recreate the synapses that connect us to the work. Recent studies in neuroscience can help, especially those analyzing the nervous system, its maturation, and interconnection of brain areas. Particularly relevant are cognitive neuroscience studies, which examine the biological, neurological, and cerebral substrates involved in mental processes like memory, attention, emotion, and more "mechanical" functions like categorization and executive functions. From the earliest studies up to the more specific work of **Alvaro Pascual-Leone in 1995**, it has been observed that music promotes neuroplasticity, enabling the brain to adapt and change in response to experience, increasing speed and connectivity between different brain regions .Further studies—like those of neurophysiologist **Stefan Koelsch with Björn-Helmer Schmidt and Julia Kansok (2002)**—have analyzed how emotions induced by music activate the reward and emotional compensation circuits in the limbic system and the amygdala, which assigns emotional meaning to stimuli .After this journey—necessarily condensed and simplified—we must take one final step. Having identified the protagonist, the active agent of innovation, what can we do with today's technology? Let us take a few more moments to discuss user experience .In the essay **Musei di narrazione by Studio Azzurro (2011),** the "spectator trapped in a continuous and obsessive present" is discussed, as is the need to resist instant entertainment solutions. Instead, we should create spaces where one can return and rediscover—shifting from a collection museum to a storytelling museum, where each experience is unique. The goal is not simply to display a Greek amphora, but to evoke the place or story that produced it—to give space to the invisible.

So, back to the question:

"How would Puccini envision Madama Butterfly today?"

We may never know.

But since Madama Butterfly exists in its artistic, emotional, and narrative dimensions, the real question becomes: "How should Madama Butterfly live today in a way that allows the audience to grasp its true essence and spirit—unchanged over time—and remain faithful to what Puccini uniquely wanted to express?"

In light of this, one possible path is sound and its perception, which must be updated to match the evolving profile of the opera's true life-giver: the audience.
The stage of the action becomes the "museum" where the story lives: the bay of Nagasaki. The objective: **"augmented emotion"** and **democratized listening**, where every spectator, regardless of seat, enjoys a superior auditory experience.
We imagine a new form of direction—not just visual but also acoustic-spatial.

Let us now technically address this new "mission."
We envisioned that Puccini would have exploited technology to paint the environments and present them as the foundation for his beautiful musical tale. The reflection driving this project is the desire to let the spectator experience the emotions within Puccini's mind.
To achieve this, the most effective method is to physically place the audience between the stage and its story, immersing them within the environments brought to life by the music.
We propose an ideal space: **the port of Nagasaki**—returning the opera to the setting Puccini imagined. Located in the Mitsubishi industrial area, a mobile stage allows the orchestra to be either a protagonist or a respectful accompanist.
The layout: behind the stage and in front of the audience, the city's hills—backdrop to Cio Cio-san's story; behind, the port entrance—arrival point of the "White Ship" and stage for unscored emotions.
Here, the need for Immersive Audio becomes central.
It will transport the audience into the environment and events:
the sound of the sea, the bustling hills, the ships, the haunting and sorrowful Humming Chorus, the cannon announcing Pinkerton's return…

The audience is welcomed by the sounds of the joyful terrace and garden, where Act I begins; in the distance, the port.

A 9.6.1 system will reproduce custom-recorded sounds using various microphone techniques (Fig.4).
The main system includes an LCR, Back Stereo, and two Side Stereo points—9 total.
The upper area is covered by High Back Stereo and two High Side Stereo—6 additional points.
A single LFE source will handle the low-frequency immersive content as well as the orchestra's bass range.
The orchestra and actor sounds will be reinforced by a separate system utilizing object-based mixing and processing algorithms.
Traditional audio mixing combines multiple sources and routes them to left and right speaker groups.
Object-based mixing adds a multidimensional layer: instruments can be located, resized, and moved in space—either to their actual positions or where the imagination places them.
Within a multi-array speaker configuration, each object's distinct position and separation are naturally reproduced, allowing the listener to perceive subtle mix dynamics, spatial positioning,

frequency response, and dynamic depth (Fig.5).
The performers' voices will be captured using close-miking and tracked in real-time with automatic stage tracking, ensuring precise spatial placement—even in motion—freeing the listener from any cognitive stress due to psychoacoustic misplacement (Fig.6).
The opera begins with the power of Puccini's music, with the orchestra center-stage, classic and commanding—demiurge of this powerful tale. Then, the stage moves, placing the orchestra in the role of "respectful accompanist" as the actors take over.
The story unfolds.
The immersive system will help listeners detach from their physical surroundings and, with the orchestra, immerse themselves among the characters inside the story.
Other scenes in the production design also use immersive audio:
the dreamy, passionate atmosphere at the end of Act I continues into the intermission, accompanying the audience into Act II, where the dreamlike space fades into a confined room filled with sorrowful anticipation. The only moment when the music detaches from the front and floods the audience almost oppressively is during the Humming Chorus.
Here, the chorus becomes a collective character, expressing the protagonist's pain—deprived even of the relief of speech.
Surrounding the audience, the aim is to make them feel Butterfly's longing sorrow.
From behind us—but in front of Cio Cio-san—the cannon sounds, signaling Pinkerton's return and the distant sailors in the harbor.
Now the audience is at the center of the scene, between the protagonist and her gaze.
The story's tragic end arrives in Act III. The immersive system quickly withdraws all the poetic environments that had cradled us.
This is where the journey ends: the music, like wind, disappears behind us.
But, like the wind, it will return—never quite the same, but always of the same essential substance.
Each spectator will have experienced different emotions and will remember different moments—recreated by the maestro responsible for rendering an immaterial moment material, for evoking a ghost destined to live again briefly during the opera, and then vanish, leaving behind only the memory of emotion.
The ghost will return again and again, in another place, in another time.
Technology is a new instrument in the hands of the artist, to be measured like an invisible musical section —used to rekindle the human nature of "feeling," dulled by today's informational storm and the monotony of daily life that imprisons spectators in the hic et nunc of a continuous and immutable present outside the theater. Technology is used as one more natural element—meant to be noticed only when it's gone.

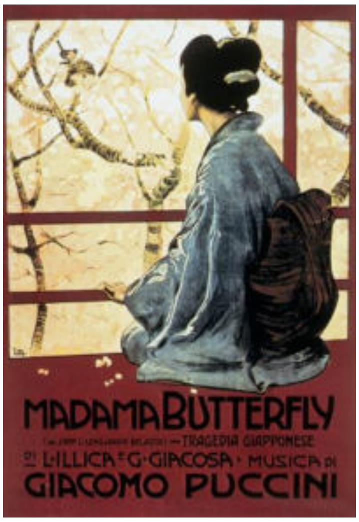

Fig.1


Fig.2


Fig.3

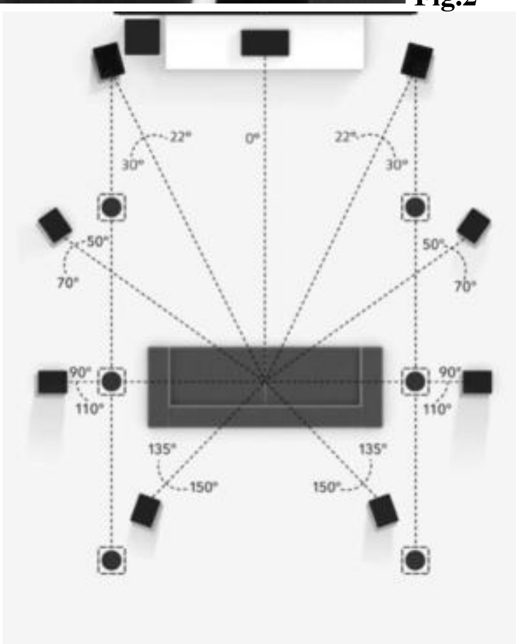

Fig.4

Fig.5

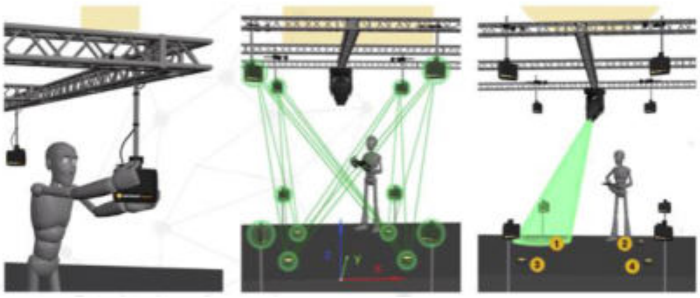

Fig.6

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RECENT ADVANCES IN THE APPLICATIONS OF ARTIFICIAL NEURAL NETWORKS TO THE ANALYSIS OF ANCIENT EGYPTIAN HIEROGLYPHS

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Abstract

Advances in machine and deep learning present new opportunities to build tools that support the work of specialists in areas apparently far from the information technology field. One example of such areas is that of ancient Egyptian hieroglyphic writing. This article presents an integrated review of research efforts towards the application of convolutional neural networks (CNNs) and hyperspectral imaging (HSI) to the analysis of ancient Egyptian hieroglyphs. More specifically, we explore the ability of different CNNs to face different tasks related to the analysis of pictures of ancient Egyptian hieroglyphs and artefacts: first, hieroglyph classification by using well-known CNN architectures (ResNet-50, Inception-v3 and Xception) as well as a purposedly designed one, denoted as Glyphnet, is discussed; then, segmentation of complex images containing an amount of different hieroglyphs by leveraging on the Mask R-CNN architecture is described; eventually, the use of HSI for improving the legibility of degraded inscriptions is addressed.

1. Introduction

Artificial Intelligence (AI) and machine learning applications are spreading in many fields of science, strongly impacting our life. Fields such as archaeology, philology and human sciences are now beginning to be permeated from AI, with an interest in the new technologies continuously growing. In this paper, we review recent advances of our research group, a joint University of Florence – CNR-IFAC effort, in the analysis of ancient Egyptian hieroglyphs classification, segmentation and acquisition [1][2][3].

The problem of ancient Egyptian language retrieval and classification has been addressed, with different purposes, in several works. In [4], image descriptors and image matching techniques are proposed to classify a database of more than 4000 hieroglyphs. Computer vision methods for hieroglyph recognition are used in [5] [6] [7] [8]; recently, the world of hieroglyphs recognition has witnessed new interest from the Google team [9]. In [1], we focused on single hieroglyph classification using a deep learning approach, and in particular employing Convolutional Neural Networks (CNNs), which can be considered the best choice for visual recognition tasks. Starting from labelled datasets of ancient Egyptian hieroglyphs, three well-known CNNs - successfully proposed for image recognition tasks - were tested as well as a new CNN - referred to as Glyphnet - specifically tailored to the complexity of the classification problem at hand. Experimental classification tests were performed to compare classical CNNs and the new proposed one.

The classification of multiple objects contained in an image is a complex task that involves a preliminary step, i.e., the segmentation of the instances of the objects. This problem is typical in computer vision and CNNs have demonstrated to be an effective alternative for its solution [10][11][12]. In [2], a finely tuned version of the well-known framework Detectron2 was evaluated when applied to the segmentation of ancient Egyptian hieroglyphs and the performance was assessed based on images taken from public datasets.

Hyperspectral imaging (HSI) is an advanced imaging technology, originally born for remote sensing applications, but today it is widespread in several sectors, including the Cultural Heritage (CH) field. In the CH context HSI has proven its effectiveness for the investigation of several types of artworks, thanks also to its property of being non-invasive [13][14]. A sequence of reflectographic images of the same scene is collected over an extended region of the electromagnetic spectrum, usually spanning the Visible and Near Infrared (VNIR) up to the Short-Wave InfraRed (SWIR) ranges. Therefore, a HSI acquisition represents a 3D array (or datacube*)* that includes two spatial (x,y) and one spectral (λ) coordinate. Such a richness of information is especially suited for providing, at once, the non-invasive analysis of pigments and materials and documentation of the artwork conservation status through augmented images such as false color maps, selected spectral bands, etc. . In [3], we describe an application of the HSI imaging technique to the study of ancient Egyptian hieroglyphic inscriptions on a coffin from the 25th Dynasty, housed at the Franciscan Ethnographic Museum in Fiesole, Italy, acquired with a portable HSI camera. In that work, HSI imaging was combined with AI segmentation methods to make degraded hieroglyph symbols more easily separable from the background: this achievement aims at showing the feasibility of combining HSI and CNNs as a novel methodological approach in the wider context of AI methods applied to hieroglyphic language analysis.

2. Classification of hieroglyphs using CNNs

The study in [1] focuses on the classification of individual hieroglyphs using various CNN architectures. Traditional approaches to hieroglyph recognition rely heavily on manual annotation and expert interpretation, a process that is not scalable given the vast corpus of inscriptions awaiting analysis. By leveraging the strengths of deep learning, a system that automates the classification of hieroglyphs based on image data is introduced.

Several popular CNN architectures, including ResNet-50, Inception-v3, and Xception, were tested. These architectures, initially designed for general image recognition tasks, were adapted for hieroglyphic classification through transfer learning and fine-tuning. A custom CNN architecture named GlyphNet, optimized for the nuances of hieroglyphic symbols, was also tested. GlyphNet showed superior performance in terms of classification accuracy and computational efficiency.

The study used two datasets: one publicly available, containing grayscale images from the Pyramid of Unas, and a second, custom-built set of colored hieroglyphs gathered from diverse materials and historical periods. Both datasets were labeled according to Gardiner's sign list, a standard classification scheme for hieroglyphs. To address dataset imbalance and ensure generalization, the authors implemented data augmentation techniques, such as rotation, scaling, translation, and horizontal flipping. Ultimately, the datasets were merged and curated to include only hieroglyphs present in both sets, resulting in a unified dataset suitable for training.

GlyphNet outperformed the benchmark CNNs in classification accuracy across all evaluation metrics. This success indicates the potential of custom CNN architectures tailored to domain-specific image recognition tasks. The study lays the groundwork for automated hieroglyph classification tools, which can significantly reduce the time and expertise required to analyze ancient inscriptions.

3. Segmentation of hieroglyphs images

Building on the classification framework, the study in [2] addresses a more complex problem: the segmentation of hieroglyphs within images containing multiple symbols and other visual elements. Segmentation is a critical step in automating the analysis pipeline, allowing systems to detect and isolate individual glyphs from complex inscriptions before classification.

In [10][11][12], Detectron2, specifically the Mask R-CNN architecture, was utilized for implementing the task of instance segmentation. Mask R-CNN extends Faster R-CNN by adding a branch that predicts segmentation masks for each detected object, making it well-suited for identifying individual hieroglyphs within scenes. The original network was finely tuned for hieroglyph segmentation. The dataset for this study was curated from museum archives and online repositories, supplemented with original photography. Each image underwent manual segmentation using the VGG Image Annotator tool. Hieroglyph instances were annotated with polygonal masks to create accurate ground-truth data for training.

The training involved transfer learning, where a Mask R-CNN model pre-trained on the COCO dataset was finely tuned on the hieroglyph dataset. Various hyperparameters, such as the number of epochs and objectness score thresholds, were systematically adjusted to optimize performance.

The study demonstrates that automated segmentation using CNNs is feasible and accurate, providing a foundation for more advanced tasks like transliteration and symbol interpretation. The modularity of the Mask R-CNN approach allows it to be integrated with other tools in a larger digital humanities workflow.

4. Hyperspectral imaging for the analysis of ancient artefacts

In [3], a possible integration of AI and hyperspectral imaging is demonstrated for CNN-based segmentation. While traditional RGB images based on the capture of visible radiation, HSI captures spectral data across a broader range of wavelengths, from visible to near-infrared. This capability makes HSI particularly valuable for examining ancient artifacts with faded or damaged inscriptions. By using proper signal processing methods, HSI is able to reveal features invisible to standard cameras, thereby augmenting the segmentation and recognition process. In real-world conditions characters in inscriptions may be eroded or covered by centuries of dust, thus hindering the CNNs performances in automated segmentation. The objective of the study illustrated in [3] was to test whether combining HSI with CNNs could improve the readability of hieroglyphs.

The pilot project in focused on a coffin from the 25th Dynasty housed at the Franciscan Ethnographic Museum in Fiesole (Florence), Italy. The coffin's inscription had suffered significant degradation, making it a suitable testbed for the proposed methodology. Using a Specim IQ portable hyperspectral camera, data cubes composed of 204 spectral bands were captured. Typical HSI preprocessing tools, such as Principal Component Analysis (PCA), were taken into consideration to reduce dimensionality while preserving critical information.

The enhanced images were then used as input for segmentation using Mask R-CNN. Two primary workflows were tested: performing PCA on HSI data to generate enhanced images before applying segmentation (PCA-Seg); directly applying the segmentation model to raw spectral bands and aggregating the outputs (Raw HSI-Seg). Both approaches improved segmentation performance compared to RGB inputs. In particular, PCA-Seg proved effective in revealing glyphs obscured by surface degradation. The study demonstrates that HSI can serve as a valuable preprocessing step, enhancing the interpretability of ancient texts.

5. Conclusions

In this paper, we have reviewed recent advances in building a robust, AI-driven pipeline for hieroglyphic analysis. Classification provides the foundation for symbol recognition, segmentation isolates individual glyphs from complex scenes, and hyperspectral imaging enhances visibility, even in compromised conditions. Together, these components form a comprehensive solution for the digitization and interpretation of ancient Egyptian texts.

Despite promising results, several challenges remain. First, the availability of labeled datasets is limited, particularly for the classification task. Expanding the corpus and incorporating crowdsourced annotation platforms could accelerate progress. Second, computational costs for training and deploying models on large datasets or hyperspectral data are significant and may require specialized hardware or cloud-based solutions.

Future research may also explore the integration of linguistic models for automatic transliteration and translation, further bridging the gap between symbol recognition and textual understanding. Additionally, developing user-friendly software interfaces will be crucial for enabling non-experts, such as archaeologists and museum curators, to leverage these advanced tools.

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AI ArtCentrica Stories

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ArtCentrica is an EdTech/CultTtech startup spinoff of Centrica (https://www.centrica.it) that innovates art-based learning and art appreciation.
ArtCentrica EDU is a straightforward, creative, and engaging art-based application, providing access to more than **8,000 artworks from 21 global museum collections** (Uffizi Galleries, MET, Rijksmuseum, ...). Due to the tools of the platform and the high-resolution of the artworks images (till 10 GigaPixel), ArtCentrica EDU gives the possibility to students, learners and art lovers to have a completely **new immersive experience with art**. With our multidisciplinary approach, art can be a means to explain the chemical periodical elements or to recognize emotions, to speak about fashion or sustainability. Human beings are at the center as opposed to an increasingly scientific and mathematical/computing world. Moreover ArtCentrica EDU empowers students with essential soft skills to tackle today's and tomorrow's challenges, as well as to support teachers in their mission to educate in an ever-changing society.
In this paper we present a unique educational tool where human and artificial intelligence converge to create interactive multimedia narratives centered around works of art: **AI ArtCentrica Stories**. Through this innovative tool, art pieces turn into dynamic elements as both the object of the narrative and a vehicle to illustrate heterogeneous concepts. The R&D is done together with **Prof. Mauro Barni** and his team from the **Information Engineering and Mathematics Department of University of Siena**, thanks to the **TuscanyX.0 project** funded by the **Next Generation EU programme** and **CTE COBO** acceleration program of Bologna Municipality. Artificial Intelligence enhances this process as it enables learners and educators to seamlessly craft beautiful narratives, allowing them to focus on the essence of the story. Once the Story has been told, AI analyses it and identifies points of attention (moments during playback in which the image moves dynamically towards a portion of the artwork aligned with what is being told). Authors can then verify and adjust these points of

attention to achieve the desired outcome. We see a great impact on **teachers**, who can create powerful lessons in less time, engaging native digitals. Students love to create Stories: they can add their voices, or use AI with text to speech, create sounds, songs. Stories can be correlated to the meaning of the artwork itself, or they can communicate other concepts. It is a way for students to understand artworks with content creation. A very famous Italian artist, designer, inventor and educator, Bruno Munari said: "boys and girls learn by doing". And Gianni Rodari, an Italian writer, educator, poet said "Is it worth it for a child to learn with effort what he can learn while having fun?". It is not a case that Munari designed numerous covers and illustrations for books by Gianni Rodari. This is what we try to do with Stories: **students** understands the meaning of the artworks, connect the details to concepts, design the animations and associated text/voice, creating a multimedia and interactive story while improving their knowledge and soft skills. For **art lovers** they are an opportunity to appreciate art in a new way and be able to better understand it.

In the following we present some examples, with a different use of AI:

- Sandro Botticelli's "Birth of Venus" is available at: https://stories.art.centrica.it/shared/PX6vJo8eqRGiAQYY
- "What are ArtCentrica Stories?" https://rb.gy/4u3sfy
- A letter from Van Gogh - Dear brother (letter from Vincent to his brother Theo): https://stories.art.centrica.it/shared/Dr555hvj2weu8FZG
- "Renaissance and the Silk Road" https://stories.art.centrica.it/shared/9QNQ5hsxGANbbetE

Due also to this innovation ArtCentrica has been awarded in latest months with important international prizes:

- chosen between 4,500 startups in the **100 finalists** in **South Summit 2024**
- chosen between 5,000 startups in the **We Make the Future 2024 in "The future of Learning"** pitch session
- **winner** of **Digital Innovation in Art Award /Allstars-dotART** in London 10th Oct. 2024
- **winner** of **AccelNet special track of GESA Awards 2024** for self-regulation based on balance, wellness and rituals.

We're excited to see how teachers, students and art lovers will use AI ArtCentrica Stories to discover the vast and fascinating world of art and how it will increase the impact on education and in our lives.

Learn more at http://www.artcentrica.com and follow our evolution.

INDEX

STRATEGIC ISSUES

NEW SCIENCE, TECHNOLOGY AND CULTURE DEVELOPMENTS & APPLICATIONS

CULTURAL ACTIVITIES – REAL AND VIRTUAL GALLERIES AND ACCESS TO THE RELATED INFORMATION