

Data Collection and Reuse in Digital Heritage: Approaches and Results from the Digital Cultural Heritage Cluster

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Abstract.

This paper presents the Digital Cultural Heritage Cluster, uniting six Horizon Europe-funded projects to develop interoperable digital workflows for the sustainable preservation and valorization of cultural assets.

1. Introduction

The DCH cluster projects – MEMENTOES, SHIFT, PREMIERE, PERCEIVE, MuseIT, MEMORISE– are leveraging various state-of-the-art digital technologies to support the preservation and enhancement of cultural heritage. These research projects explore how digital transformation can open new opportunities for the heritage sector, including improved access to cultural objects, innovative approaches to safeguarding and preservation, and the development of new forms of public engagement and experiences. The projects demonstrate a broad range of activities and highlight both the innovation potential of digital tools and their practical value in addressing social challenges, such as improving accessibility to cultural heritage. In this sense, the diversity of data collection and reuse practices illustrates the tools, workflows and applications proposed and tested by the cluster projects to ensure the preservation and advance the state of the art of digital cultural heritage experiences. The six research projects were funded to address the Horizon Europe call “preserving and enhancing cultural heritage with advanced digital technologies” (HORIZON-CL2-2021-HERITAGE-01-04).

2. PREMIERE – Performing arts in a new era: AI and XR tools for better understanding, preservation, enjoyment and accessibility

PREMIERE conducts interdisciplinary research with AI and XR technologies to digitally extend the whole lifecycle of performances. The project’s research focuses on theatre and dance, seeking to develop and demonstrate ways in which the performing arts can use state-of-the-art technologies from production and curation, to audience engagement and understanding, as well as analysis and interpretation. In this joint workshop, we will present the main project outcomes on both technological and artistic levels. Data acquisition takes place through various ways: archives transferring data archives, AI semantic analysis, professionals contributing annotations, and motion capture with cameras or suits. We will showcase the ecosystem of the 3D Virtual Theatre and the different environments it hosts for data reuse as (1) semantic analysis and VR browsing of video archives, as well as (2) VR streaming for live performances, co-creation and knowledge transmission. We will also present the approach and features of the AI Toolbox for interactive dance creation, based on motion capture data. The project’s work and outcomes have also provided insights for policy making regarding digital technologies in the heritage

and the arts. By engaging with digital technologies, professionals in the field can not only produce innovative experiences, but also challenge state-of-the-art solutions, and position cultural institutions as active agents of the digital and social transformation. Finally, the integration and development of digital practices for preservation and enhancement culture, leads us to also rethink the how we preserve and experience CH today.

3. PERCEIVE – Perceptive Enhanced Realities of Colored Collections through AI and Virtual Experiences

In the PERCEIVE project, data collection and reuse in digital heritage are realized through an evidence-based workflow that begins with the systematic acquisition of analytical datasets—including multispectral and hyperspectral imaging (MSI/HSI), X-ray fluorescence (XRF), reflectance spectroscopy (FORS), micro-fadeometry, high-resolution photogrammetry, and multi-angle spectrophotometry on purpose-built mock-ups for spatially varying BRDF (SVBRDF) modelling—which together enable precise mapping of pigment presence, material properties, and degradation pathways. These heterogeneous data are ingested into a centralized, FAIR-compliant Colour Knowledge Repository built on InvenioRDM, where tailored metadata schemas ensure interoperability, provenance tracking, and controlled access policies, thereby transforming raw measurements and historical/iconographic references into reusable resources. Leveraging a microservice architecture, researchers and practitioners can access the repository and PERCEIVE platform, to use a suite of interoperable tools—such as the AI-driven Colour Reconstruction, Regeneration, and Prediction Service; the Light Damage Estimator for risk assessment under varied illumination scenarios; the MuLaX WebXR multi-layer visualization environment; and specialized modules for textile fading simulation, autochrome defect removal, and semantic shading—all of which demonstrate practical reuse of the integrated datasets to generate scientifically grounded reconstructions and predictive models. Data produced by these tools can be also re-used to co-design and evaluate interactive museum digital experiences adopting specific PERCEIVE prototypes, dedicated to authenticity and sense of care. Methodologically, PERCEIVE’s hybrid approach fuses physics-based rendering with data-driven neural techniques, ensuring that reconstructions remain both perceptually plausible and traceable to empirical data. The principal results include validated methods for reconstructing lost polychromy in classical sculptures, for quantifying chromatic aging in paintings and textiles, and restoring historical photographic materials. By

embedding data reuse at its core, PERCEIVE has fostered long-term sustainability, cross-institutional collaboration, and inclusive public engagement through co-design and open data principles [Pes25].

4. MuseIT – Multi-sensory, User-centred, Shared cultural Experiences

MuseIT aims to advance inclusion, accessibility, and equal opportunities in cultural heritage (CH) by developing innovative, multisensory digital technologies. Recognizing that traditional CH initiatives have focused on visual and auditory experiences, the project prioritizes the needs of people with diverse perceptual and functional abilities, particularly those with disabilities (around 1B people—15% of the world’s population—of which 110-190M experience significant disabilities). MuseIT explores real user needs, promotes co-design, builds immersive and inclusive experiences, enables creative content generation for all, preserves cultural context using semantic technologies, and ensures wide societal and scientific impact. More specifically, MuseIT’s strategic objective is to promote inclusion, participation, accessibility, and equal opportunities for all by developing a platform for remote, immersive, and co-creative engagement with cultural heritage. This platform addresses three main challenges: (1) the co-design and development of multisensory representations of cultural assets that cater to diverse perceptual modalities; (2) the creation of remote, inclusive services that support co-creation of born-digital cultural content and shared experiences; and (3) a formal specification of methodologies and a repository for long-term preservation of cultural assets that ensures accessibility and inclusion are embedded from the outset. MuseIT’s results to date are: 1) A framework and collection of datasets and knowledge graphs that leverage Generative AI (Transformer-based LLMs, Diffusion models, etc.) and contoured-based sonification and haptification techniques for generating multimodal transformations (text, speech, images, music, Braille, 3D shapes) of digital cultural assets from open collections (Europeana, Wikidata). 2) Contributions in Affective computing through algorithms for emotion analysis from wearable sensors; and then feeding them in full immersive experiences through VR in virtual museology experiences implemented with a game engine 3) Music remote co-creation contributions through low latency architectures for Internet music streaming (JackTrip); live EEG audification and music search; Mood (FER) and stress estimation (SEA), and Music Generation; Emotion induction systems; and haptic heartbeat communication modules. 4) A MuseIT customised instance of Dataverse, a digital repository for FAIR sharing of scientific datasets, where all project outputs are published and further enriched with the novel metadata standard Croissant; semantic drift models to account for data change over time; and multimodal fact-checking frameworks for safety and trustworthiness. 5) An integrated infrastructure compiling all the above in the form of various pilot demonstrators and their evaluation frameworks.

5. SHIFT: Digital Heritage Preserving - Between the Authenticity of Cultural Assets and the Need for Monetization

In the SHIFT project, data collection and reuse in digital heritage revolve around a conceptual framework that reconciles the preservation of asset authenticity with the imperative of sustainable monetization. This begins with high-fidelity 3D and multispectral scanning combined with semantic metadata enrichment—capturing both provenance and material composition—to produce digital surrogates that remain traceable to their physical counterparts. These authenticated replicas are managed within a decentralized asset repository built on FAIR

metadata principles and an immutable, blockchain-based ledger, which together ensure tamper-proof authenticity certificates and transparent chain-of-custody records. Leveraging a modular API and microservice architecture, GLAM institutions can then deploy AI-driven watermarking, dynamic smart-contract licensing, and micro-payment gateways to establish diversified revenue streams—ranging from pay-per-view access and tiered subscriptions to NFT-based tokenization and public-private partnership platforms. Methodologically, SHIFT integrates digital curation best practices with information-economic modelling and ethical valorization, employing hybrid approaches that fuse distributed-ledger verification, data-driven market analysis, and stakeholder co-design workshops. The principal outcomes include: (1) an authenticity metadata ontology aligned with CIDOC-CRM and PROV-O standards; (2) a blockchain proof-of-concept for rights management and micro-licensing; (3) an open-source toolkit for AI-enhanced watermarking and smart-contract deployment; and (4) policy guidelines for ethical monetization co-developed with heritage professionals and industry partners. By embedding monetization strategies directly within preservation workflows, SHIFT demonstrates how cultural heritage institutions can uphold the integrity of their digital collections while generating the economic viability necessary to support ongoing and future initiatives.

6. MEMENTOES – iMmersive gamEs for Museums as vehicles to Engage visITOrs in Empathetic reSponses

While museums and video games can foster empathy through similar experiential and narrative mechanisms, the potential of video games to serve as meaningful tools for memory and transitional justice remains underexplored. MEMENTOES aimed to combine museum principles and storytelling in video games to create meaningful player experiences. Museum experts and game developers collaborated to develop three games, each exploring a different historical tragedy or injustice by incorporating stories that are based on or inspired by real people’s memories and experiences. MEMENTOES also explored the impact of video games as digital tools to preserve memories (remembrance), and as a way to learn on perspectives of people in the past and reflect on issues of modern society (social change). Within MEMENTOES, an Accessibility SDK was developed to support developers in making their games accessible, and players in engaging with CH content based on their interaction needs. Finally, a series of Artificial Intelligence (AI) web services was developed to support the 3D reconstruction of Cultural Heritage (CH) objects for the games’ content.

7. Conclusion

The projects of the DCH Cluster demonstrate how advanced digital technologies—ranging from AI-enhanced imaging and 3D scanning to immersive XR environments and blockchain-backed asset management—can be orchestrated to preserve, interpret and valorize CH in a sustainable and inclusive manner. By embedding FAIR data principles, ethical guidelines and co-design practices into each workflow, the cluster generated interoperable toolkits, open repositories and methodologies that address technological and social dimensions of heritage stewardship. The convergence of these approaches promises to foster deeper cross-institutional collaboration and broaden public engagement.

References

[Pes25] PESCARIN, et al. “Perceptive Enhanced Realities of Coloured Collections through AI and Virtual Experiences”. *Digital Heritage (2025)* (in print).