

DigiCURE: Building a Digital Humanities Infrastructure for Preserving and Studying At-Risk Cultural Heritage

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Abstract

The preservation of cultural heritage has become an urgent societal, policy, and scientific priority in the context of climate change, armed conflicts, and rapid urbanisation. Monuments, archaeological sites, and fragile materials are increasingly at risk of loss or irreversible damage. In response, DigiCURE (Digital Cultural Resilience and Protection) establishes a technologically advanced and institutionally anchored research infrastructure dedicated to the digitisation, preservation, and analysis of endangered heritage. The aim of this paper is to present the DigiCURE research infrastructure, which provides high-quality tools, expertise, and training to support sustainable digital preservation through multimodal documentation, spatial visualisation, and data modelling. Its online platform enables researchers, heritage professionals, and the public to explore, analyse, and annotate complex multimodal datasets with AI-assisted methods, even in cases where physical access is no longer possible. Developed within the framework of the Gothenburg Research Infrastructure in Digital Humanities (GRIDH), DigiCURE functions as both a national and international hub for innovative research, ensuring the long-term accessibility and resilience of vulnerable cultural heritage.

Keywords

Digital cultural heritage, research infrastructure, multimodality

Introduction

Cultural heritage is an indispensable resource for many disciplines and plays a vital role in shaping a shared historical consciousness in increasingly fragmented and globalised societies. Yet around the world, cultural resources face growing threats: archaeological sites erode under rising seas and extreme weather; fragile materials deteriorate due to shifting environmental conditions; museums, archives, and historic monuments are damaged, destroyed, or displaced by war; and increased tourism places additional stress on vulnerable sites. These developments underscore the urgent need for reflective, resilient, and accessible preservation strategies to safeguard information for research [1] [2]. Hence, Swedish and European policy frameworks increasingly recognise the importance of digitisation as a crucial component in preserving cultural heritage. In line with EU recommendations, all member states have committed to digitising at-risk monuments and major sites by 2030, as outlined in the 2019 EU declaration on digital cultural heritage and reaffirmed in the Swedish National Heritage Board's digital strategy (2024).

While there is widespread consensus on the importance of digitising cultural heritage and that digital methods offer powerful means of documentation and preservation [3] [4] [5] [6] [7], the research community faces notable gaps as many disciplines and institutions lack the necessary infrastructure, technical expertise, and sustainable workflows [8]. Furthermore, the multimodal and diverse nature of the data required to accurately capture heritage sites or monuments often leads to the datasets being stored in disparate silos. This fragmentation hinders more in-depth and comprehensive analysis as well as the application of computational approaches. Consequently, digitisation efforts frequently result in

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digital resources that fall short of researchers' needs concerning quality, depth, and focus [9] [10] [11] [12].

As a response, the Gothenburg Research Infrastructure in Digital Humanities (GRIDH) and the Department of Conservation (DC) at the University of Gothenburg established an infrastructure to address these critical gaps while advancing digitally supported research across the humanities and a range of related fields. The purpose of this initiative was to provide a long-term, research-oriented infrastructure that supports high-quality digitisation, preservation, reuse, and analysis of at-risk heritage materials.

Multimodal Research Infrastructure

The aim of this paper is to present DigiCURE (Digital Cultural Resilience and Protection), a research infrastructure designed to address these gaps by providing a multimodal platform, advanced digitisation tools, and expertise for the sustainable preservation and analysis of at-risk cultural heritage. DigiCURE offers an institutionally embedded infrastructure built around three core components:

Multimodal platform: Development and maintenance of a robust multimodal platform that facilitates digital preservation and remote access to endangered cultural assets. The platform integrates various data types – including high-resolution images, 3D models, and metadata – to ensure comprehensive documentation and accessibility for research purposes and public engagement.

Multimodal digitisation: Provision of cutting-edge software solutions for digitisation, metadata structuring, and secure archiving. DigiCURE also equips researchers with high-resolution imaging, 3D scanning, and digital reconstruction tools to support detailed documentation and analysis of heritage materials.

Multimodal expertise: Facilitating expert consultation services and providing open-source resources to build capacity in digital preservation practices. DigiCURE ensures adherence to best practices and standards, promoting responsible and sustainable stewardship of cultural heritage. Built from the ground up for long-term sustainability, DigiCURE offers a growing online platform with tools, expertise, and workflows that promote accessibility, interoperability, and analytical depth. It provides a solid technical and methodological foundation for producing interoperable, analysis-ready data, ensuring that at-risk heritage material can be made reliably accessible and reusable for researchers, institutions, and the public.

Today, the DigiCURE infrastructure offers scholarly access to a range of multimodal resources, combining advanced technologies with user-centric design [13]. The infrastructure is hosted and developed by GRIDH, a cross-university research infrastructure at the University of Gothenburg established in 2015 to support digital tools, methods, and platforms in humanities research and to engage in Swedish and European infrastructure consortia. Consequently, DigiCURE's resources and services are published and maintained through GRIDH's resource portal, ensuring long-term visibility, accessibility, and usability. It brings together a team of senior experts in research infrastructure and software engineers with complementary expertise.

Context-Sensitive Design

Integrated Methodology

DigiCURE's methodological design is grounded in the understanding that digitising cultural heritage is not a neutral technical procedure, but a critical and epistemologically charged practice [14] [15]. As Drucker [16] argues, the systems we build to structure and access cultural data actively shape how knowledge is produced, interpreted, and valued. Svensson [17] similarly highlights the importance of "humane infrastructures" that embed interpretive nuance, scholarly judgment, and cultural accountability into the design of digital systems. DigiCURE builds on these insights by approaching heritage as a form of information organisation – an active process of selecting, classifying, and preserving what holds cultural significance for specific communities. This perspective aligns with Harrison's [18] view of heritage as a present-day practice that reflects both contemporary systems of order and the urgency to safeguard identities and their tangible or intangible expressions under threat.

DigiCURE treats digital cultural heritage as a socially embedded, ethically aware, and critically informed practice by involving users as active participants rather than passive recipients.

Hence, by building on established models for interdisciplinary collaboration [19] [20] it combines hands-on training, tailored consultations, and seminars to develop both technical skills and critical understanding within a knowledgeable user community. This conceptual foundation informs DigiCURE's integrated, interdisciplinary methodology, which combines critical heritage studies, digital humanities, conservation science, and archival practice. The infrastructure translates these perspectives into practical workflows through:

- Context-aware metadata modelling co-developed with scholars and heritage professionals;
- Implementation of open standards such as IIIF, GeoJSON, and Linked Open Data to ensure interoperability and long-term usability;
- FAIR-aligned data workflows for sustainable curation, access, and reuse;
- Ethical review protocols for working with sensitive, conflict-affected, or community-based heritage materials;
- AI-assisted analysis that leverages machine and deep learning to support the semi-automatic interpretation of multimodal heritage data – including legacy formats and high-resolution 2D/3D documentation – while ensuring transparency, expert validation, and adherence to ethical standards.

By embedding these principles across all stages – from digitisation and data modelling to AI-supported analysis and spatial exploration – DigiCURE enables a critically informed, context-sensitive, and sustainable engagement with endangered cultural heritage.

Technical Implementation

DigiCURE's technical foundation is a modular, research-driven infrastructure that supports the structured, interoperable, and sustainable management of multimodal cultural heritage data. It consists of two tightly integrated components: *Diana*, the backend data management platform, and *MuM* (Multimodal Map and Viewer), the interactive frontend for visualisation and spatial exploration.

Diana – Data Management Backbone: Diana, a Django-based data management platform, enables place-based modelling, multimodal data integration, and versioned, standards-compliant APIs. It supports multiple data formats and real-time updates and offers user-friendly administrative tools. The platform ensures security, flexibility, and long-term interoperability. Compliance with the FAIR principles [21] is ensured through persistent identifiers, open APIs, and licensing models that facilitate long-term accessibility, interoperability, and reuse. Additionally, the platform offers built-in support for version control, encrypted storage of sensitive data, and real-time data updates with performance optimisation features such as indexing, caching, and asynchronous processing. As such, it is central to DigiCURE's ambition to offer sustainable, research-driven digital heritage environments grounded in scholarly and technical excellence.

MuM – Multimodal Exploration Interface: The MuM frontend, based on Vue3 and Express frameworks, connects to Diana via REST APIs and is organised around four interlinked views. These enable users to filter and examine cultural heritage data across scales – from regional mappings to the detailed examination of visual data. To handle complex visual content, MuM incorporates various open-source libraries for high-resolution 3D models, point clouds, RTI photography, spatial data, and high-resolution imagery. Through its integration with Diana, MuM functions not only as a visualisation tool but also as a conceptual framework for structuring digital documentation in a research-driven way [22].

Collaborative Ecosystem

DigiCURE complements existing digital heritage infrastructures by filling a critical gap and integrating advanced tools for digitisation, spatial and multimodal data management, long-term preservation, and remote scholarly access – functions often fragmented or missing elsewhere.

Relationship to Other Infrastructures

Nationally, DigiCURE aligns with infrastructures like Huminfra, Språkbanken CLARIN, and InfraVis, contributing a specialised platform for high-resolution documentation, digital preservation, and context-sensitive analysis of at-risk heritage. While collaborating with initiatives such as SveDigArk and DARK Lab's Dynamic Collections, DigiCURE offers a distinct approach through tools like MuM and Diana, supporting seamless workflows from field documentation to spatially anchored exploration.

The DigiCURE infrastructure is interoperable by design, and its data models adhere to international standards, allowing for integration and data exchange with existing repositories and platforms. Through GRIDH, DigiCURE collaborates with the national search service for cultural heritage, K-Samsök, and has implemented the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH), which makes DigiCURE a national data provider for heritage data.

At the European level, DigiCURE complements DARIAH and ARIADNEplus [23], and Europeana [24]. By offering archival interoperability, along with tailored tools and training for researchers and others working with endangered heritage under real-world constraints, DigiCURE contributes to EU and UNESCO-linked projects, where GRIDH infrastructure components are already deployed in crisis-driven cultural preservation initiatives. In dialogue with the National Heritage Board (RAÄ) and ARIADNE, DigiCURE will also interface with ECCCH (www.echoes-eccch.eu), which expands the reach of digitised resources and provides sustainable access for researchers.

Taken together, DigiCURE strengthens the national and international infrastructure ecosystem by developing a dynamic multimodal platform, connecting existing nodes, standardising workflows, and providing a previously missing expertise infrastructure and enhanced access for digital cultural heritage preservation.

3.2 Current Collaborations

Since 2019, DigiCURE has supported numerous research projects and institutions through digitisation expertise, development resources, training, and consultation focused on at-risk heritage. While primarily serving researchers at Swedish universities, the infrastructure hosts significant heritage materials from Sweden, the Arctic, Antarctica, the Faroe Islands, Ukraine, Spain, and Italy that are accessed online more than 20.000 times annually. Through these projects, DigiCURE has built strong ties with scholars and institutions who rely on its services or benefit from its state-of-the-art approach.

Notably, DigiCURE serves as a foundational infrastructure for the project DigiCURE:UKRAINE (funded by the Swedish Institute) that provides the Ukrainian heritage sector with expertise, training and a software platform for preserving heritage assets threatened by the war (digidure.dh.gu.se/ukraine/), including the National Museum of the History of Ukraine and the National Library of Ukraine. High-profile research projects, infrastructures, and organisations using DigiCURE include:

- Digital Documentation of Inscriptions in the Saint Sophia Cathedral in Kyiv employs advanced digital documentation techniques to preserve and analyse inscriptions within the historic cathedral, ensuring accessibility for research and conservation [25].
- CHAQ2020 – Cultural Heritage in Antarctica (KTH, Luleå University, University of Gothenburg, the Argentinian Antarctic Institute) utilises DigiCURE's digital imaging and data archiving to safeguard historical sites threatened by extreme environmental conditions [26].
- Swedish Rock Art Research Archives (SHFA) is the world's largest database of rock art documentation and makes use of DigiCURE's accessible tools for analysing high resolution images and 3D models [27].
- Swedish Institute in Rome (SIR), renowned for its Etruscan studies, collaborates with DigiCURE's expertise for advanced digitisation and research-driven platforms for the documentation of inaccessible Etruscan chamber tombs [28].

DigiCURE is collaborating on two additional major initiatives where data collection is planned but has not yet begun. Preserving La Pileta focuses on documenting the Paleolithic art of La Pileta Cave in Benaoján, Spain is an international collaboration between DigiCURE and the Universidad de Sevilla to ensure long-term preservation through the multimodal platform; Pulse of the Weddell Sea (base funding, the Polar Secretariat) is a multidisciplinary research expedition where DigiCURE will provide expertise to secure data and develop methods for digital accessibility of Antarctic cultural heritage.

DigiCURE also contributes to helping Norsk Polarinstitutts plan for digitally preserving built cultural heritage on Svalbard threatened by climate change and supports RISE (Research Institutes of Sweden) with the tools for annotation of online point cloud visualisations. Outside academia, DigiCURE has, through expertise, supported, among others, the International Council of Museums (ICOM), the National Heritage Board (RAÄ), the Regional Museums, Europa Nostra, the National Museum of the Faroe Islands, Instituto Antártico Argentino, Tecnópolis Buenos Aires, and the National Historical Museums of Sweden.

Availability

Primary academic users of DigiCURE are scholars in fields such as art history, history, archaeology, conservation, heritage management, architecture, religion, ancient languages, and digital humanities, whose needs mirror the current projects. The infrastructure is also a resource for heritage organisations in need of a knowledge boost and expertise to help them digitise endangered monuments, sites, and collections in ways that serve the research community. Notably, computational researchers – including those developing or training models in computer vision, natural language processing, and multimodal AI – will benefit from DigiCURE’s structured, high-quality datasets designed for ethically grounded, research-driven machine learning applications.

DigiCURE’s online and open-sourced resources are available to anyone and do not require formal requests or fees. Its online platform is designed from the ground up to be accessible, reusable, and openly available to researchers across institutions, disciplines, and national borders, and it facilitates remote access to heritage materials worldwide. Through its modular architecture and standards-based APIs, it allows external users to access, contribute to, and build upon existing datasets via secure, role-based authentication.

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