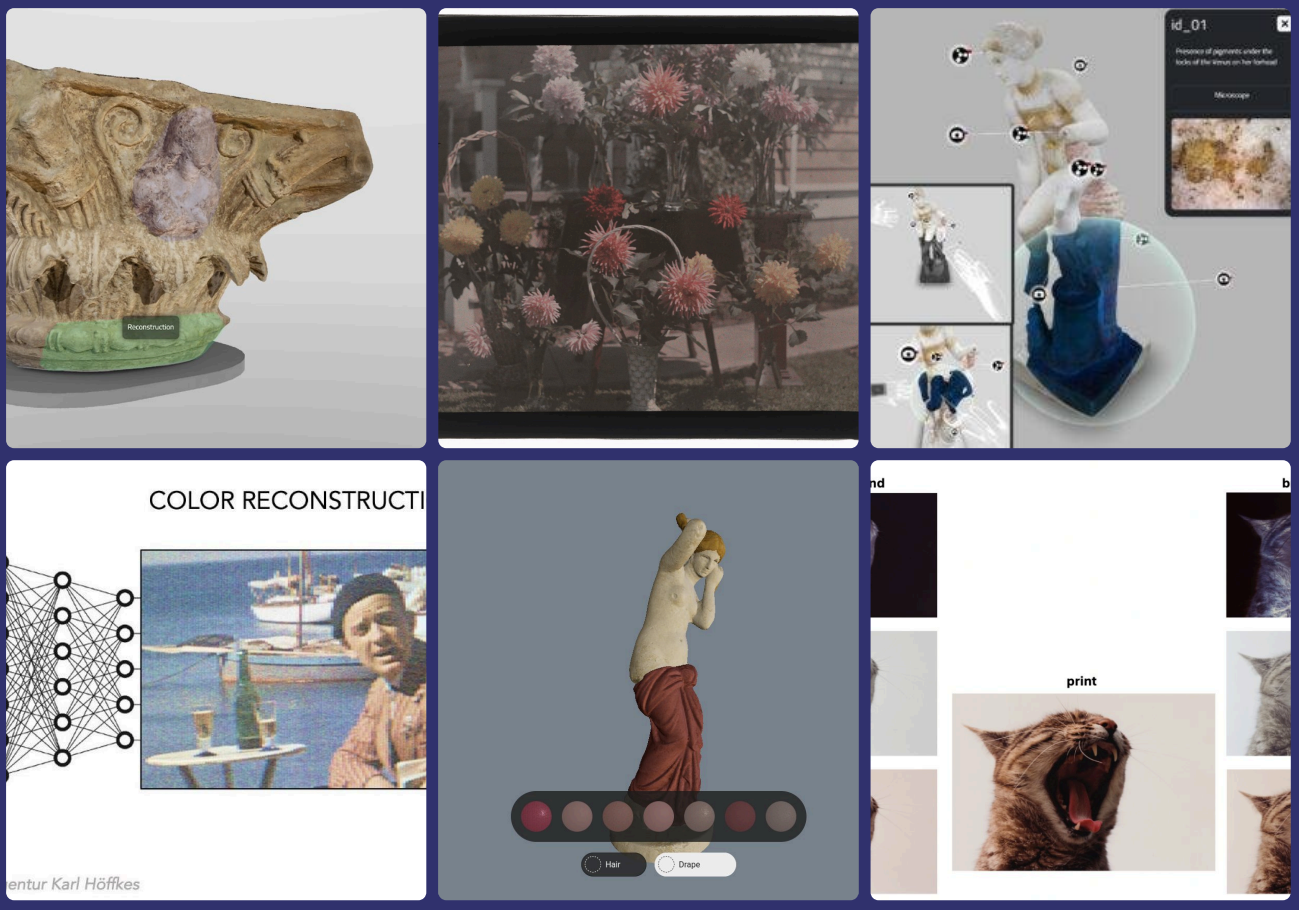
COLOURS Toolkit

Digital tools and services for the conservation-restoration of coloured heritage



Funded by
the European Union

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COLOURS-ECCCH.EU

About COLOURS

COLOURS (Collaborative On-cloud Lab for the conservation and digital restoration of ColOUred heritage collectionS) develops digital tools for the analysis, simulation and restoration of colour in heritage objects.

Colour is one of the most fragile and meaningful features of cultural heritage. Fading, discolouration and loss affect objects from classical polychrome sculpture to paintings, textiles, early colour photographs and historical films, and restoration decisions are often complex. COLOURS brings together heritage science, computer science and conservation-restoration practice to give professionals better ways to study colour, test hypotheses before acting, restore it digitally and share it with the public.

DURATION
October 2025 – September 2028

COORDINATOR
CNR ISPC (Italy)

PART OF
the ECCCH initiative, coordinated by ECHOES

THE TOOLKIT

The COLOURS project delivers a specialised ecosystem of digital tools and services for the conservation-restoration of coloured heritage, while opening new ways to communicate and engage with it.

The toolkit offers high-precision analysis and simulation tailored to very different artefacts, from polychrome sculptures and paintings to textiles, photographs and historical films. Fully interoperable with the European Collaborative Cloud for Cultural Heritage (ECCCH), the tools allow conservator-restorers, heritage scientists, curators and other professionals to work with digital twins in real time, supporting decision-making and collection management, fostering inclusive approaches and ensuring the authenticity of restored colours.

Some tools build on results of the PERCEIVE project and are being further developed in COLOURS; others are new. Most are still in development and will be released step by step until 2028.

HOW TO READ THE TOOL SHEETS

- Overview and key features: what the tool does
- Why on the Cultural Heritage Cloud: what the ECCCH adds
- A user story: the tool in a real working situation
- Who can use it, expected timeline and contacts

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COLOURS TOOL · PERCEIVE LEGACY

StyleShade3D

Enhancing 3D mesh reconstruction with deep learning segmentation.

3D Semantic Segmentation | Region-Based Shading & Stylization | WebGL 3D Visualization Tool

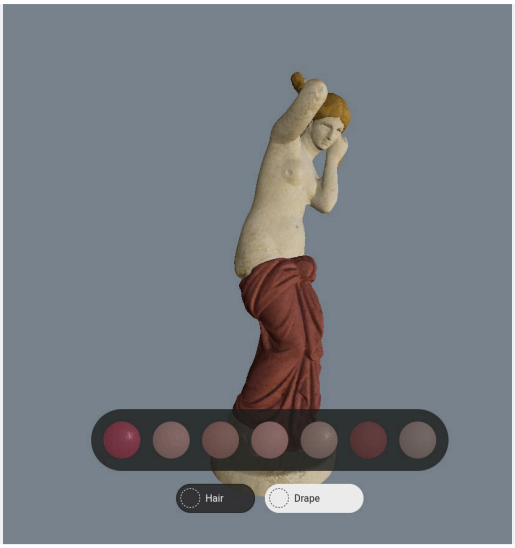


Fig. 1: Virtual reconstruction of the Anadyomene Venus (MANN – PERCEIVE project). StyleShade3D was used to stylise (marble) and shade (hair and drapery) different regions of the statue. Different hypotheses can be tested in real time.

OVERVIEW

StyleShade3D is an existing WebGL-based tool originally developed within the PERCEIVE project. It enhances 3D mesh reconstruction by integrating deep learning segmentation into a conventional geometry and material pipeline. The system incorporates models such as Segment Anything Model to generate a semantic segmentation atlas – a 2D parameterized map aligned with the 3D surface - enabling region-aware shading and stylisation. Different materials, rendering models, and artistic effects can therefore be assigned to specific parts of a mesh. The workflow begins in BlenderProc, where a full-orbit camera animation captures optimized multi-view images to ensure complete surface coverage. Inspired by path-planning strategies, the pipeline minimizes the number of views while preserving geometric completeness. Using SAM's tracking features, consistent multi-view segmentation maps are generated and consolidated into a unified atlas. Since CAD models often lack UV coordinates, a texture atlas is created using Blender's Smart UV Project algorithm. The segmented projections are merged into a 2D semantic atlas, which drives region-specific shading and deep stylisation models.

Within the COLOURS project, StyleShade3D will be further extended and technically enhanced, expanding its capabilities for advanced semantic control, material modeling, and artistic rendering of 3D assets.

KEY FEATURES

- Deep learning–driven semantic segmentation integrated into a 3D reconstruction pipeline
- Automatic creation of a 2D semantic atlas aligned with the 3D surface
- Region-specific shading and material assignment for fine-grained visual control
- Optimized multi-view acquisition and consistent segmentation tracking
- WebGL-based interactive tool designed for extensibility and advanced stylisation

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IN PRACTICE: A USER STORY

Tom is a digital heritage researcher. His team has recently completed a high-resolution 3D scan of the Venere Anadyomene, one of the museum's iconic sculptures and a key case study in the PERCEIVE project. While the geometry is accurate, Tom wants to explore hypotheses about its original appearance, experimenting with different materials and surface treatments, without manually segmenting the mesh.

Tom uploads the 3D model with UVs coordinates into StyleShade3D. The system automatically processes it through a multi-view rendering pipeline, generating segmentation maps from multiple viewpoints and consolidating them into a semantic atlas. Instead of spending hours defining regions by hand, Tom immediately sees the statue divided into meaningful parts (hair, drapery, skin, pedestal) ready for semantic editing.

Using the WebGL interface, he selects the drapery and applies a marble shader, then experiments with a subtle polychrome stylisation on the hair using a deep style transfer model. The shading remains physically plausible, preserving the sculpture's volume and fine details. Inspired by conservation studies on ancient polychromy, he tests different material assets and compares results in real time.

Meanwhile, Anna, a museum curator, joins him remotely. Together, they create multiple visual scenarios: a neutral conservation rendering, hypothesized coloured reconstructions, and several interpretations for an interactive exhibition. Each version can be exported for web visualization or immersive storytelling applications.

Within hours, what once required complex manual workflows becomes an intuitive, semantically guided process, bridging research, conservation, and creative dissemination of cultural heritage.

WHY ON THE CULTURAL HERITAGE CLOUD?

Building StyleShade3D on top of the ECCCH is technically coherent with both the COLOURS vision and the Cloud's objectives. From a technical perspective, ECCCH provides a shared infrastructure for storing primary data, digital twins, and associated documentation, ensuring long-term preservation, versioning, and secure access. StyleShade3D benefits from this by consuming high-quality 3D scans, semantic metadata, and conservation records directly from the Cloud, while writing back segmentation atlases, material hypotheses, and stylized variants as traceable research outputs.

Cloud deployment also enables distributed processing, browser-based WebGL access, and real-time collaboration between conservator-restorers, curators, and scientists across institutions, fully aligned with ECCCH's goal of supporting interdisciplinary, data-driven heritage workflows at European scale.

WHO CAN USE IT

StyleShade3D can benefit multiple communities within the cultural heritage ecosystem. Conservator-restorers and conservation scientists can use it to test colour hypotheses and simulate restoration outcomes on digital twins. Curators and museum professionals may employ it for exhibition design and interpretation, while art historians and archaeologists can explore material and stylistic reconstructions. Creative industries, including digital artists, game developers, and XR designers, can leverage the tool for high-quality, semantically controlled 3D assets.

EXPECTED TIMELINE

Alpha 2026
Stable core functions

Beta 2027
Pilots with heritage institutions

Release 2028
Production-ready on the ECCCH

COLOURS project runs from 1 October 2025 to 30 September 2028. Within this timeframe, StyleShade3D will transition from its existing PERCEIVE prototype to a fully cloud-integrated service aligned with the ECCCH.

An alpha version is expected in 2026, focusing on stabilizing the core functionalities. A beta version is planned for 2027, enabling pilot deployments with selected heritage institutions. By the end of the project in 2028, the tool is expected to reach a production-ready release fully interoperable with Cloud.

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COLOURS TOOL · PERCEIVE LEGACY

Light Damage Estimator (LDE)

Predicting and mitigating light-induced colour changes in sensitive art.

Light-Induced Damage Prediction | Colour Fading Simulation | Preventive Conservation | Spectral Analysis | Risk Assessment for Cultural Heritage

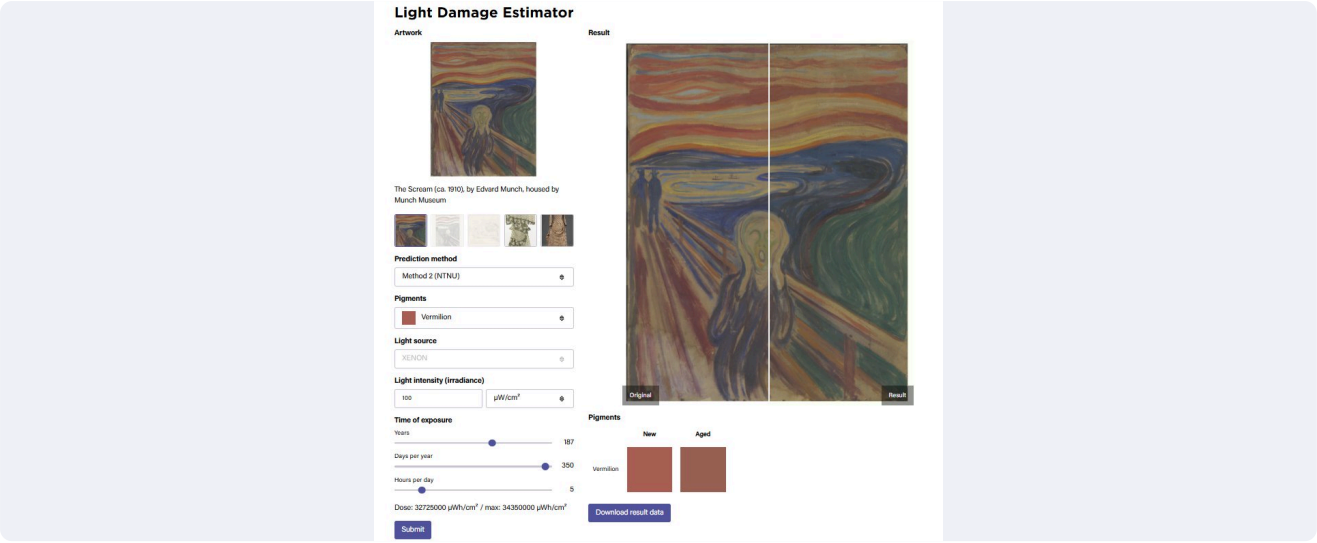


Fig. 1: Main dashboard of the LDE.

OVERVIEW

The Light Damage Estimator is a decision-support tool developed within the framework of the PERCEIVE project and currently under improvement in the COLOURS project. It addresses a critical challenge in cultural heritage preservation: predicting and mitigating light-induced colour change in sensitive artworks.

Designed for researchers, conservator-restorers, and museum professionals, LDE estimates how pigments and materials may fade or alter when exposed to specific lighting conditions over time. By combining the spectral power distribution of a selected light source with scientific datasets describing pigment sensitivity and fading behaviour, the tool simulates potential long-term visual changes.

LDE enables users to define exposure durations, compare lighting scenarios, and establish safe display thresholds. Rather than reacting to irreversible damage, professionals can proactively assess risk and optimize exhibition strategies. The tool supports both preservation and presentation, helping institutions balance conservation requirements with public access.

KEY FEATURES

- Simulation of pigment fading based on spectral light profiles
- Integration of scientific datasets on material sensitivity
- Customisable lighting configurations (LED, halogen, daylight, etc.)
- Exposure time modelling and cumulative dose calculation
- Definition of safe display thresholds and risk levels
- Visualisation of predicted colour change over time
- Comparative scenario analysis (multiple lighting setups)
- Cloud-based data storage and traceability of assessments
- Interoperability with digital twins hosted in ECCCH

IN PRACTICE: A USER STORY

Maria is a conservation scientist at a national museum preparing an exhibition of 19th-century watercolours, highly sensitive to light exposure. Before installation, she wants to ensure that the display lighting will not accelerate fading.

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She logs into the Cloud platform and opens the LDE. The digital twin of the artwork, previously uploaded to the Cloud, is already available. Maria selects the specific LED lighting system planned for the exhibition and imports its spectral profile. She then defines the expected daily exposure time and overall exhibition duration.

Using embedded pigment sensitivity data, LDE calculates the cumulative light dose and predicts potential colour shifts in different areas of the painting. A visual overlay highlights zones at higher risk. Maria adjusts the lighting intensity and tests an alternative filter. The simulation updates instantly, showing a significantly reduced predicted colour change.

Later, she shares the assessment report with the exhibition curator and lighting designer through the Cloud environment. Together, they compare multiple scenarios, balancing visitor experience with conservation constraints. The final setup uses a slightly warmer light with reduced intensity, maintaining visual quality while staying within safe exposure limits.

Months later, the documented simulation remains archived in the Cloud, linked to the object's conservation record. Future professionals can review the decision-making process, ensuring transparency and long-term preservation planning.

Through LDE, Maria moves from reactive conservation to preventive, data-driven risk management.

WHY ON THE CULTURAL HERITAGE CLOUD?

Deploying LDE on the ECCCH ensures direct access to high-quality digital twins, spectral datasets, and conservation documentation.

From a technical standpoint, ECCCH provides secure storage, version control, authentication services, and shared metadata standards. LDE can retrieve object-specific information (materials, prior restoration history) and store risk assessment results as structured, traceable records. Cloud deployment also enables collaborative scenario testing among geographically distributed teams, supporting interdisciplinary decision-making.

WHO CAN USE IT

LDE primarily serves conservator-restorers, conservation scientists, and preventive conservation specialists responsible for managing light-sensitive collections. Museum curators and exhibition designers benefit from scenario-based lighting optimization. Heritage scientists and university researchers can use the tool for studying material degradation and validating predictive models.

The tool also supports policy-makers and collection managers by providing standardized, data-driven risk documentation. In the long term, LDE may be adopted by galleries, archives, and libraries, expanding its relevance across the broader cultural heritage ecosystem.

EXPECTED TIMELINE

Alpha 2026
Spectral engine and exposure modelling

Beta 2027
Visualisation, scenario comparison, pilots

Release 2028
Production-ready on the ECCCH

During 2026, an alpha version will focus on implementing the core spectral calculation engine and exposure modelling, with internal testing by consortium partners and initial integration with ECCCH data storage services. In 2027, a beta version will introduce advanced visualisation modules, scenario comparison tools, and pilot testing with selected heritage institutions. By 2028, before project completion, LDE is expected to reach a stable, production-ready release fully interoperable with ECCCH infrastructure.

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MORE IMAGES

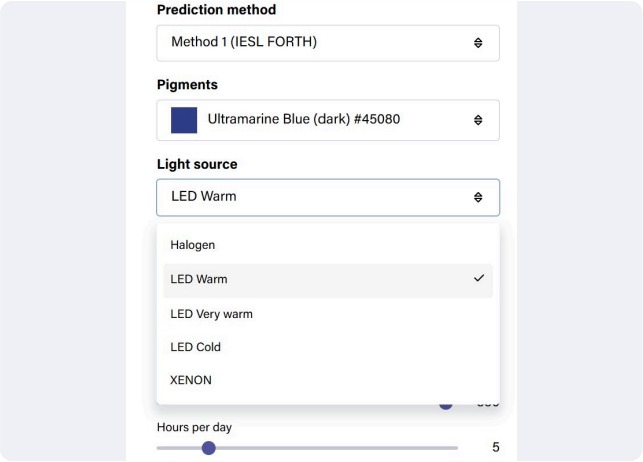


Fig. 2: Selection of a light source with specific spectral characteristics, to ensure accurate colour change estimation.

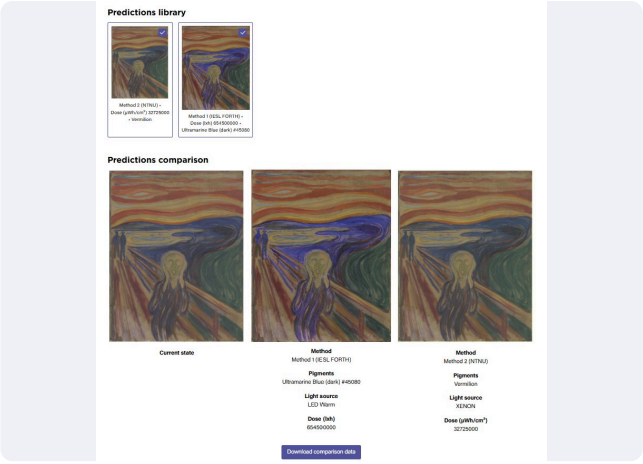


Fig. 3: Comparison of predicted colour changes across different lighting set-ups, with downloadable results to guide conservation decisions.

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COLOURS TOOL · PERCEIVE LEGACY

Multi-Layer eXtensible eXplorer (MuLaX)

Interactive exploration of multi-layered 3D cultural heritage collections.

Web3D / WebXR Cultural Heritage | Multi-Layer Diagnostic Visualization | Interactive Semantic Annotation | Digital Twin Inspection | Immersive Heritage Exploration

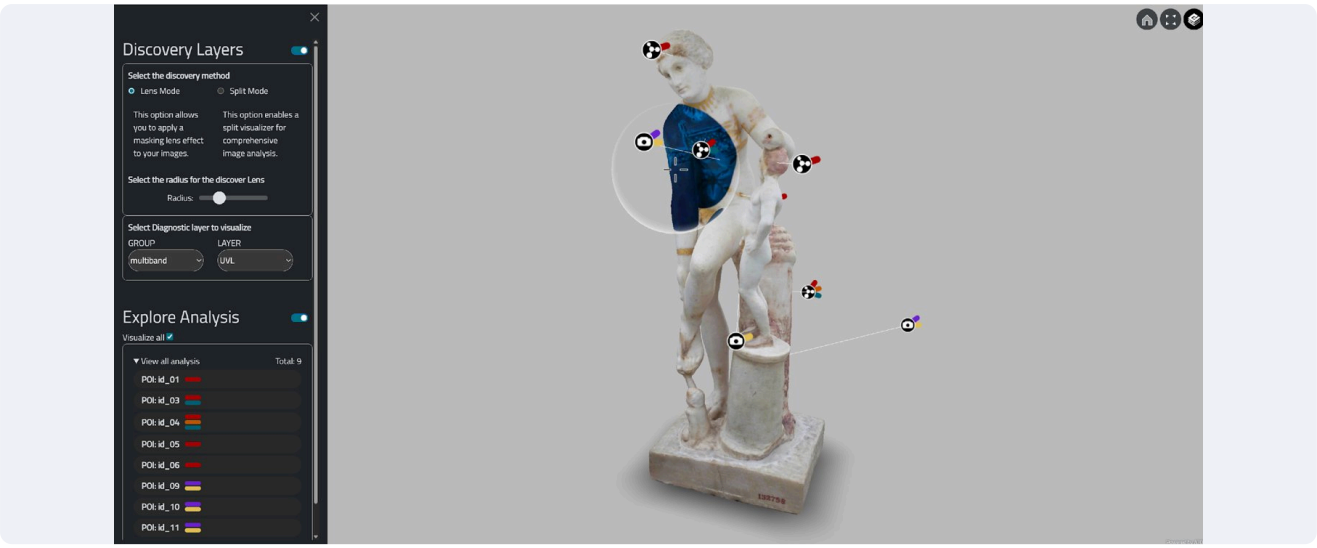


Fig. 1: Main dashboard of the MuLaX tool.

OVERVIEW

MuLaX is an interactive Web3D/WebXR tool designed and developed under the PERCEIVE European project. It enables the online exploration of multi-layered 3D cultural heritage collections enriched with diagnostic and analytical data. Built on the open-source ATON framework developed by CNR ISPC, MuLaX integrates high-resolution 3D models with multi-band imaging datasets (e.g., VIS, UVL, VIL) and punctual analyses (e.g., XRF, microscope, FORS), allowing users to visually compare and inspect heterogeneous scientific results within a single environment.The tool supports advanced multi-layer discovery techniques, such as lens and split modes, semantic annotations, texture-based masks, and interactive semantic painting. It is accessible directly via web browser on any device, from smartphones to immersive XR headsets, ensuring wide interoperability and remote collaboration.

By integrating analytical datasets into spatially referenced 3D environments, MuLaX facilitates documentation, monitoring, interpretation, and communication of diagnostic processes for both experts and broader audiences.

KEY FEATURES

- Interactive multi-layer discovery (lens and split modes) for analytical imaging (UVL, VIL, VIS)
- Integration of punctual analyses (XRF, microscope, FORS) as spatially referenced POIs
- Texture-based semantic masks and dynamic image-based masking
- Interactive Semantic Painting (ISP) to create expert-driven masks directly online
- Cloud integration for remote access to collections and analytical layers
- Responsive Web3D interface compatible with desktop and mobile devices
- WebXR immersive inspection in VR and AR modes
- Modular architecture supporting extension to paintings, textiles, and other domains.

IN PRACTICE: A USER STORY

Luca is a conservation scientist studying residual polychromy on a Roman statue.

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The statue has undergone multiband imaging campaigns, including VIS, UVL, and VIL acquisitions, along with XRF spot analyses.

Instead of navigating separate datasets, Luca opens MuLaX directly in his web browser. The digital twin of the statue loads instantly from the cloud collection. He activates the Discovery Layers tool and selects UVL. Using the lens mode, he moves a circular inspection area across the sculpture's surface, revealing luminescent traces invisible under normal light. Switching to split mode, he compares visible and hidden layers side by side, sliding along the Y-axis for direct visual contrast. Curious about a gilded detail, Luca selects a Point of Interest (POI) marked with a spot-analysis icon. A side panel opens, displaying XRF spectra and microscope images linked to that precise location. He zooms into the graph to confirm pigment composition.

Later, wearing a VR headset, Luca enters immersive inspection mode via WebXR. The interface appears anchored to his wrist, allowing him to toggle layers while walking around the virtual statue

Meanwhile, a colleague remotely adds a semantic mask to highlight areas of suspected Egyptian blue. The update appears instantly in Luca's session, demonstrating real-time collaborative workflows.

MuLaX transforms fragmented scientific datasets into a unified, spatially coherent experience, supporting analysis, interpretation, and communication.

WHY ON THE CULTURAL HERITAGE CLOUD?

MuLaX was conceived within the PERCEIVE cloud ecosystem and already integrates centralized collections and remote processing services. Deploying MuLaX on the ECCCH is a natural technical evolution. ECCCH provides structured storage for 3D assets, analytical layers, semantic masks, and metadata, ensuring interoperability and long-term preservation. MuLaX can retrieve and visualize these resources dynamically while allowing other services (e.g., AI-based segmentation or predictive models) to generate new layers directly in the cloud data layer.

This architecture supports distributed collaboration, version control, and secure authentication – core features for interdisciplinary heritage science. Cloud integration guarantees scalability, cross-institutional access, and alignment with European standards for digital heritage infrastructures.

WHO CAN USE IT

MuLaX serves conservation scientists, archaeologists, art historians, and diagnostic laboratories working with multi-band imaging and material analyses. Museum professionals benefit from integrated visualization for exhibition design and public communication. Researchers studying ancient polychromy, restoration history, and material degradation can use MuLaX to compare heterogeneous datasets within a unified spatial framework. XR capabilities also support education, outreach, and immersive museum experiences.

Within a cloud-based European infrastructure, additional users may include research infrastructures, universities, heritage agencies, digital humanities scholars, and SMEs developing analytical or visualization services. Its modular architecture allows extension beyond statuary to paintings, textiles, and works on paper broadening its impact across heritage domains.

EXPECTED TIMELINE

Prototype Done
Validated in PERCEIVE

Beta Ongoing
User feedback, support for paintings

Release ECCCH
Cloud-native, stable release

MuLaX was originally developed under the PERCEIVE project and has reached a functional, publicly demonstrated prototype stage. An Alpha version was achieved during PERCEIVE, validating core functionalities such as multi-layer discovery, semantic masks, and WebXR inspection. A Beta iteration is currently evolving, incorporating user feedback, UI refinements, and extended support for other artworks like paintings. Future integration within ECCCH infrastructure would enable full cloud-native deployment, interoperable APIs, and stable production release aligned with subsequent European initiatives.

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MORE IMAGES



Fig. 2–4: Diagnostic data visualisation with PERCEIVE MuLaX on desktop, AR and VR.

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COLOURS TOOL

Lenticular Colour Reconstruction Tool (doLCE 2.0)

Digital restoration of early lenticular film formats like Kodacolor.

Lenticular Film Restoration | Kodacolor Reconstruction | Digital Film Colorization | Audiovisual Heritage Preservation | Computational Image Processing

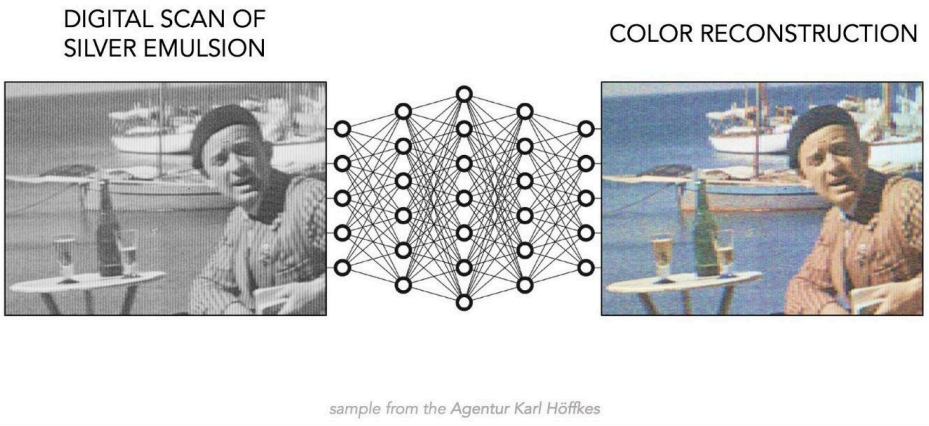


Fig. 1: From the digital scan of the silver emulsion to the colour reconstruction.

OVERVIEW

doLCE 2.0 is a digital restoration tool dedicated to the recovery of colour information embedded in early lenticular film formats such as Kodacolor. In the COLOURS project, the tool was initially referred to as Kodacolor Colorizer.

Kodacolor, introduced in the 1920s, used a black-and-white film embossed with microscopic lenticules. When combined with a red-green-blue filter during filming and projection, these lenses encoded colour information as fine vertical RGB components within the monochrome emulsion.

doLCE 2.0 computationally extracts and reconstructs this hidden chromatic data. By analysing the lenticular structure and separating encoded RGB signals, the tool digitally reassembles full-colour frames from deteriorated or fragile historical films.

The system supports heritage professionals in restoring rare home movies and archival footage, ensuring accurate colour recovery while preserving original material characteristics. It represents a bridge between historical optical technologies and modern digital preservation methods.

KEY FEATURES

- Automated detection of lenticular structures in scanned film frames
- Extraction of embedded RGB components from monochrome emulsions
- Digital reconstruction of full-colour imagery from Kodacolor films
- Correction of optical distortions and lenticule misalignment
- Frame-by-frame restoration workflow for archival films
- Integration with high-resolution film scanning pipelines
- Non-destructive processing preserving original film data
- Cloud-compatible processing for large audiovisual collections

IN PRACTICE: A USER STORY

Elena works at a national film archive. Recently, the institution digitised a collection of 1920s home movies shot on Kodacolor film. The footage appears black and white, but documentation confirms it was originally recorded in colour using a lenticular process.

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Elena uploads the high-resolution scans and launches doLCE 2.0. The tool automatically detects the fine lenticular pattern embedded in each frame. Using calibrated algorithms, it separates the encoded red, green, and blue components recorded as vertical stripes in the emulsion.

On her screen, a preview window shows the gradual reconstruction of colour. What first appeared as a grey-toned garden scene slowly reveals green foliage, blue sky, and warm skin tones. Elena adjusts alignment parameters to compensate for slight deformation caused by film shrinkage over time.

The tool processes frames in sequence, applying geometric correction and chromatic reconstruction. A side-by-side comparison allows her to evaluate the restored colour against the original scan.

Later, she shares the reconstructed footage with historians studying early amateur cinema. The restored film is archived together with metadata documenting the reconstruction parameters, ensuring transparency and reproducibility.

Through doLCE 2.0, Elena is not artificially colourising black-and-white film; she is recovering authentic historical colour information embedded in this optical technology, bringing early colour cinema back to life.

WHY ON THE CULTURAL HERITAGE CLOUD?

Within the COLOURS framework, tools are designed to operate as interoperable, cloud-based services. Hosting doLCE 2.0 on the ECCCH ensures scalable processing of high-resolution film scans, secure storage of audiovisual assets, and structured metadata management.

The reconstruction of lenticular films requires computationally intensive frame-by-frame analysis. Cloud infrastructure enables distributed processing and version-controlled workflows, while preserving links between original scans and restored outputs.

ECCCH integration also allows collaboration among film archives, researchers, and restoration laboratories across Europe, facilitating shared datasets, reproducibility of results, and long-term digital preservation.

WHO CAN USE IT

doLCE 2.0 primarily serves film archives, audiovisual heritage institutions, cinematheques, and restoration laboratories working with early colour film technologies. Conservation scientists and imaging specialists benefit from advanced reconstruction algorithms tailored to lenticular processes.

Within a cloud-based European ecosystem, additional users may include universities, digital humanities projects, and SMEs specialising in audiovisual digitisation.

EXPECTED TIMELINE

Alpha 2026
RGB extraction and alignment

Beta 2027
Pilots with partner film archives

Release 2028
Production-ready on the ECCCH

Under the COLOURS project, doLCE 2.0 will evolve into a fully operational restoration service.

An Alpha version (2026) will implement core RGB extraction and lenticular alignment algorithms, tested internally on selected archival materials.

A Beta version (2027) will support pilot deployments with partner film archives, integrating ECCCH storage and collaborative workflows.

By 2028, a production-ready release is expected, fully cloud-integrated and interoperable within the Cultural Heritage Cloud infrastructure.

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COLOURS TOOL

ATON

Open-source Web3D/WebXR framework for complex heritage data.

Web3D | WebXR Immersive Experiences | Cultural Heritage Visualization | Semantic 3D Interaction | Open Standards



Fig. 2: Example of annotation (from the Vani Virtual Experience project: vanivirtualexperience.com).

OVERVIEW

ATON is an open-source Web3D/WebXR framework developed by CNR ISPC to present and interact with complex and multi-dimensional data on the web. It allows to build interactive Web3D/WebXR applications without any installation required for final users. ATON provides a modular, cross-device platform for presenting and interacting with 3D models, scenes, and associated metadata in browsers using mobile devices, desktop workstation, museum kiosks, up to immersive VR/AR devices.

Built on modern web standards and large open ecosystems (Node.js, Three.js), ATON supports high-performance, responsive 3D visualization and collaboration. It offers a simple but extensible API for scene management, semantic annotations, measurements, advanced materials, synchronous collaboration, and spatial user interfaces for XR sessions. The framework embraces robust international formats (glTF, Cesium 3D Tiles) to ensure interoperability, streaming efficiency, and scalability for large geospatial or artifact datasets.

The framework also offers a plug&play architecture, to accelerate the creation and deployment of vertical applications (built on top of ATON features) - or extend horizontally its functionalities through plugins (“flares”) that may equip one or more web-applications.

ATON is thus a foundational framework for tools like MuLaX, traceable within COLOURS’ objectives to develop interoperable, web-based services for cultural heritage research and dissemination.

KEY FEATURES

- Adaptive 3D presentation across mobile, desktop, and XR devices
- Immersive AR/VR experiences through WebXR support
- Semantic annotations and volumetric shapes
- Multi-resolution streaming via Cesium 3D Tiles
- Support for open formats (glTF, Draco compression)
- Advanced rendering (PBR materials)
- Real-time multi-user collaboration features
- Spatial UI components for XR sessions

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IN PRACTICE: A USER STORY

Sara is a digital curator at a national archaeology museum tasked with presenting a newly scanned Roman villa for both remote audiences and on-site visitors. She needs an interactive viewer that can showcase the 3D model, allow annotations for educational content, support immersive exploration, and integrate seamlessly with existing heritage databases.

Sara logs into the main ATON instance via a web browser. Without any downloads or plugins required, she converts a painted statue's 3D model into standard Web3D formats and uploads it with associated metadata into her cloud collection. ATON's liquid presentation layer automatically adapts to her device. On her laptop, she customises the published scene by adding semantic annotations to highlight features, embedding multimedia descriptions, and setting custom viewpoints for guided tours.

Her colleague, a conservation scientist, joins remotely via link and interactively creates annotations on specific areas showing early restoration work. The real-time collaboration feature lets them discuss changes together synchronously in the same 3D scene.

Before the public launch, Sara inspects the same scene on a tablet and on a WebXR-enabled headset without any installation. In VR mode, she explores the dataset using spatial UI elements to toggle informational layers, play narrated media, and other content enriching the item.

Visitors on the museum floor can access the item directly on kiosk displays to explore different hypotheses interactively. School groups visiting the site can use mobile devices to scan QR codes to access the 3D scene without any installation.

With ATON, Sara bridges research, education, and public engagement, offering a scalable, interoperable Web3D experience that adapts to diverse audiences and devices, all grounded in open standards and cloud-ready technologies.

WHY ON THE CULTURAL HERITAGE CLOUD?

ATON provides the core Web3D/WebXR infrastructure for delivering interoperable, interactive 3D cultural heritage content, making it an ideal foundational service within the Cloud.

Cloud integration enables remote retrieval of 3D digital twins, analytical overlays, and semantic annotations, while supporting collaborative editing and version-controlled workflows. By coupling ATON's presentation layer with ECCCH's data infrastructure, institutions can deploy immersive, responsive environments directly in browsers without local resource constraints.

The plug&play architecture of the framework ensures vertical and horizontal extensibility to adapt presentation, logic and functionalities to a variety of scientific communities.

WHO CAN USE IT

ATON supports a wide range of cultural heritage communities. Heritage scientists and researchers can create interactive 3D viewers with annotations and analytical layers. Museum curators and educators can build guided virtual tours and contextual narratives. Conservation specialists can share annotated inspection results alongside 3D models.

Developers and SMEs can leverage ATON's modular API and plug&play architecture to craft custom applications tailored to projects like MuLaX or other analytical tools. Educators and students benefit from immersive AR/VR explorations of heritage sites. Within the ECCCH framework, national archives, research infrastructures, and heritage agencies can integrate ATON-based services into broader cloud-hosted ecosystems, facilitating shared access, collaborative workflows, and standardized digital asset dissemination across Europe.

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EXPECTED TIMELINE

Now Ready
Core features in production

2027 ECCCH
Cloud deployment and stable API

2028 Europe
Wider adoption and documentation

Although ATON exists as a mature open-source framework with ongoing development and adoption across projects, its integration within the COLOURS project and ECCCH infrastructure will follow incremental steps. Core features are already production-ready, with ongoing modular enhancements in 2026. Cloud-native deployment and API stabilisation for ECCCH integration are planned through 2027, with widespread European adoption and service-level documentation expected by 2028 in alignment with the project's end.

MORE IMAGES

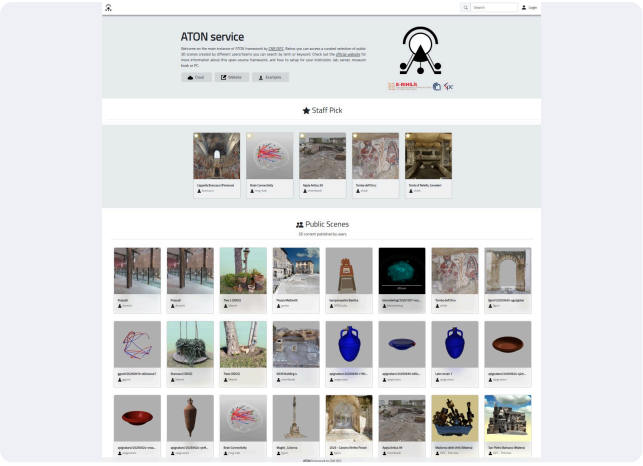


Fig. 1: Main page of the main instance of the ATON framework.

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COLOURS TOOL · PERCEIVE LEGACY

De-greening Tool

AI-driven restoration service for Autochrome photographic plates.

Autochrome Restoration | AI Image Restoration | Synthetic Defect Generation | Deep Learning Inpainting | Photographic Heritage Conservation



Fig. 1: Example of a greened (left) and de-greened (right) image, with spotting defects removed using the tool.

OVERVIEW

The Degreening Tool is an AI-driven restoration service developed within the PERCEIVE framework and further aligned with the objectives of the COLOURS project. It addresses one of the most critical conservation issues affecting Autochromes, among the earliest successful colour photography processes, namely “greening” defects caused by material degradation.

Autochromes are extremely fragile and light sensitive; once degraded, their chromatic alterations are often irreversible. Since no ground-truth restored references exist, the tool employs synthetic defect generation to train deep learning models. By analysing real greening patterns, small spot-like stains and larger leakage-style areas with multi-ringed green halos and subtle orange borders, the system creates realistic simulated defects on digitized plates.

Paired datasets (defected vs. clean images) are used to train neural networks with optimization techniques, emphasizing correction of stained regions while preserving original detail. The result is a restoration model capable of removing green artifacts and reconstructing colour balance.

An additional fine-tuned inpainting module refills pale residual areas, ensuring visually coherent, historically respectful digital restoration.

KEY FEATURES

- Synthetic simulation of greening defects based on real degradation patterns
- Randomized generation of spot and large-area leakage defects
- Deep learning restoration network trained on paired datasets
- Adam-based optimization with defect-focused loss weighting
- Generalization from synthetic to real Autochrome damage
- Fine-tuned inpainting for texture and colour re-synthesis
- Non-destructive, reversible digital restoration workflow
- Cloud-ready architecture for large photographic archives

IN PRACTICE: A USER STORY

Claire works in a national photographic archive preserving early 20th-century Autochrome plates. Many images exhibit severe greening: small circular stains and large discoloured patches that obscure faces, skies, and landscapes.

After digitizing a plate at high resolution, Claire uploads the scan to the Cloud and launches the Degreening Tool. The system first analyses the image, identifying areas consistent with known greening characteristics, green halos with faint orange borders and irregular leakage shapes.

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The restoration model, trained on hundreds of synthetic defect pairs, begins processing. Behind the scenes, the network applies parameters learned through iterative optimization, minimizing differences between predicted and clean chromatic structures while preserving fine photographic grain.

Then, Claire sees a preview: the green stains fade, colours rebalance, and details re-emerge. A comparison slider allows her to inspect before-and-after views. In areas where faint colour loss remains, she activates the inpainting module. Fine-tuned on clean Autochrome examples, the model synthesizes subtle textures and colour gradients, blending seamlessly into the original image.

All restoration steps are logged and stored as metadata, ensuring transparency and reproducibility. Claire exports both the restored image and a restoration report for curators and researchers.

Through the Degreening Tool, Claire does not physically alter the fragile plate; instead, she creates a scientifically informed digital surrogate, recovering visual legibility while safeguarding the original artifact.

WHY ON THE CULTURAL HERITAGE CLOUD?

Hosting the Degreening Tool within the ECCCH ensures scalable processing of high-resolution Autochrome scans and secure preservation of both original and restored versions.

Deep learning restoration is computationally intensive and benefits from distributed cloud infrastructure. ECCCH enables centralized storage, version control, and metadata traceability, linking restoration parameters to specific digital assets.

Moreover, synthetic defect datasets and trained models can be shared across institutions, promoting reproducibility and collaborative improvement of algorithms. Cloud deployment ensures sustainability, transparency, and European-wide accessibility for fragile photographic heritage.

WHO CAN USE IT

The Degreening Tool primarily supports photographic archives, conservation laboratories, museums, and research institutions preserving early colour photography. Conservation scientists and imaging specialists benefit from AI-assisted, non-invasive restoration workflows.

Historians of photography and visual culture gain access to clearer, chromatically accurate digital representations of Autochromes. Educators and exhibition curators can present restored images while maintaining full documentation of digital intervention.

Within the ECCCH ecosystem, universities, digital humanities scholars, and SMEs specializing in heritage imaging may adopt and extend the technology.

EXPECTED TIMELINE

Alpha 2026
Core models, institutional testing

Beta 2027
Pilots with partner archives

Release 2028
Production-ready on the ECCCH

Within the PERCEIVE framework, initial research and model prototyping established the synthetic defect generation and baseline restoration networks.

Under the COLOURS project, development will continue toward a stable, cloud-integrated service.

An Alpha version (2026) will consolidate synthetic defect generation pipelines and core restoration models for controlled institutional testing.

A Beta version (2027) will support pilot deployments within partner archives, integrating ECCCH infrastructure for storage, authentication, and collaborative workflows.

By 2028, a production-ready version is expected, fully interoperable within the Cultural Heritage Cloud ecosystem and aligned with COLOURS deliverables.

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COLOURS TOOL · PERCEIVE LEGACY

PERCEIVE Colour Knowledge Repository (CKR)

Platform for collecting, structuring and sharing colour resources.

Colour Heritage Data Repository | FAIR Cultural Heritage Data | Open Science Infrastructure | Digital Preservation | Interdisciplinary Research Platform

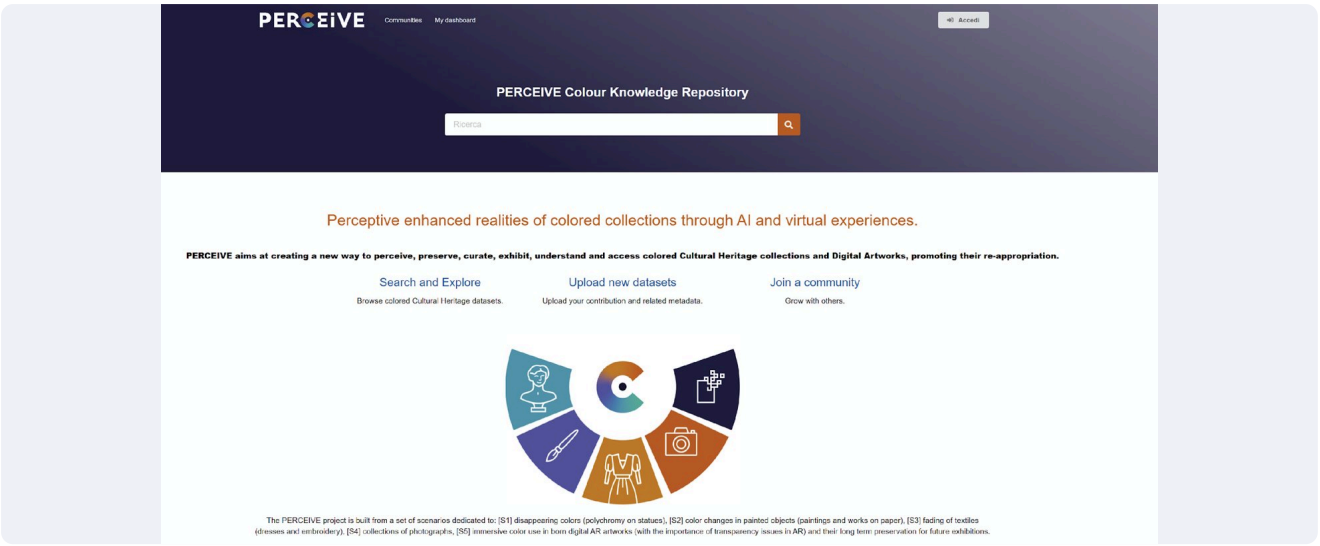


Fig. 1: Current homepage of the Colour Knowledge Repository.

OVERVIEW

The PERCEIVE Colour Knowledge Repository is an open data management platform designed to collect, structure, preserve, and openly share colour-related resources in cultural heritage. Developed within the PERCEIVE project and aligned with the objectives of the COLOURS project, CKR supports interdisciplinary research on colour in artworks ranging from ancient polychrome sculpture to paintings, textiles, and historical photography and film. The repository follows FAIR data principles supporting the full data lifecycle from acquisition to analysis and long-term preservation. It hosts 3D models, scientific datasets, high-resolution images, documentation, simulation outputs, and risk assessment data related to colour change and deterioration.

Built on the InvenioRDM framework developed by CERN, CKR ensures robust data management, advanced metadata description, and integration with external research tools. Through federated cloud storage and REST APIs, the platform enables secure, distributed access and interoperability with other digital heritage services, including PERCEIVE and future Cultural Heritage Cloud infrastructures.

Repository access: https://perceive-data.iesl.forth.gr

KEY FEATURES

- FAIR-compliant data management supporting the full data lifecycle
- Storage of heterogeneous resources (3D models, datasets, images, texts, simulations)
- Federated cloud storage for decentralized and secure data handling
- Advanced metadata schema describing acquisition, processing, and analytical methods
- Built on InvenioRDM for scalable, research-grade repository management
- REST API for interoperability and automation
- Batch uploads and metadata-only records linking to external datasets
- Community-based collaboration spaces
- Role-based access control and GDPR-compliant security framework

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IN PRACTICE: A USER STORY

Sofia is a conservation scientist studying colour fading in 18th-century dyed textiles. Her research team has produced spectral measurements, high-resolution macro images, and predictive models simulating light-induced fading.

She logs into the PERCEIVE Colour Knowledge Repository and creates a new dataset entry. Using the metadata form, she documents acquisition methods, instrumentation details, environmental conditions, and analytical techniques used. She uploads the spectral datasets, 3D scans of the textile surface, and simulation outputs. For large files stored on an institutional server, she creates metadata-only records linked externally.

Sofia assigns her dataset to a community focused on colour fading in historical garments. Within this space, collaborators, including museum curators and exhibition designers, can access shared resources and discuss preventive conservation strategies.

Meanwhile, Marco, an art historian researching ancient polychromy, searches the repository using keywords and filters related to “multiband imaging” and “Egyptian blue.” Advanced search tools allow him to refine results by technique, object type, and deterioration phenomenon. He downloads relevant datasets and integrates them into his comparative study.

Each dataset in CKR receives a persistent identifier, ensuring citability and long-term traceability. Privacy settings allow contributors to manage access levels, from restricted research groups to fully open access.

Through CKR, Sofia and Marco are not only storing data, they are contributing to a shared, interoperable knowledge ecosystem. The repository transforms dispersed colour-related research into a structured, collaborative infrastructure that supports innovation, transparency, and open science in heritage conservation.

WHY ON THE CULTURAL HERITAGE CLOUD?

Integrating CKR within the ECCCH ensures long-term sustainability, standardization, and European-wide accessibility. CKR’s FAIR-compliant architecture, REST API, and federated storage model align technically with ECCCH principles of distributed yet interoperable infrastructures. By hosting datasets, metadata, and simulation outputs within a shared cloud ecosystem, CKR enables seamless interaction with visualization tools (e.g., Web3D platforms), restoration services, and analytical pipelines.

WHO CAN USE IT

CKR serves a broad interdisciplinary community including conservation scientists, heritage chemists, art historians, archaeologists, museum curators, exhibition designers, and digital heritage professionals. It supports researchers studying ancient polychromy, painting degradation, textile fading, and historical photography colour processes.

Within ECCCH, CKR functions as a reference knowledge base for colour science, facilitating collaboration among institutions and promoting open science practices. Its community-based structure encourages thematic groups, such as polychrome sculpture, light-sensitive objects, textiles, and historical films, fostering cross-domain innovation in heritage preservation.

EXPECTED TIMELINE

Now Live
Operational, data ingestion

Beta 2026–27
ECCCH integration and visualisation

Release 2028
Production-ready on the ECCCH

CKR has been established within the PERCEIVE framework and is currently operational as a research data repository. Under the COLOURS project, further development will enhance interoperability with additional analytical and visualization tools. An ongoing Alpha phase supports active dataset ingestion and community creation. A Beta phase (2026–2027) will focus on expanded ECCCH integration, improved data visualization modules, and enhanced API-based interoperability. By 2028, CKR is expected to operate as a fully cloud-integrated, production-ready European knowledge infrastructure for colour in cultural heritage.

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COLOURS TOOL

Negative to Positive (neg2pos)

Calibrated digital conversion of colour photography negatives.

Colour Negative Digitisation | Photographic Heritage Restoration | Colorimetric Transformation | Reproducible Imaging Workflow

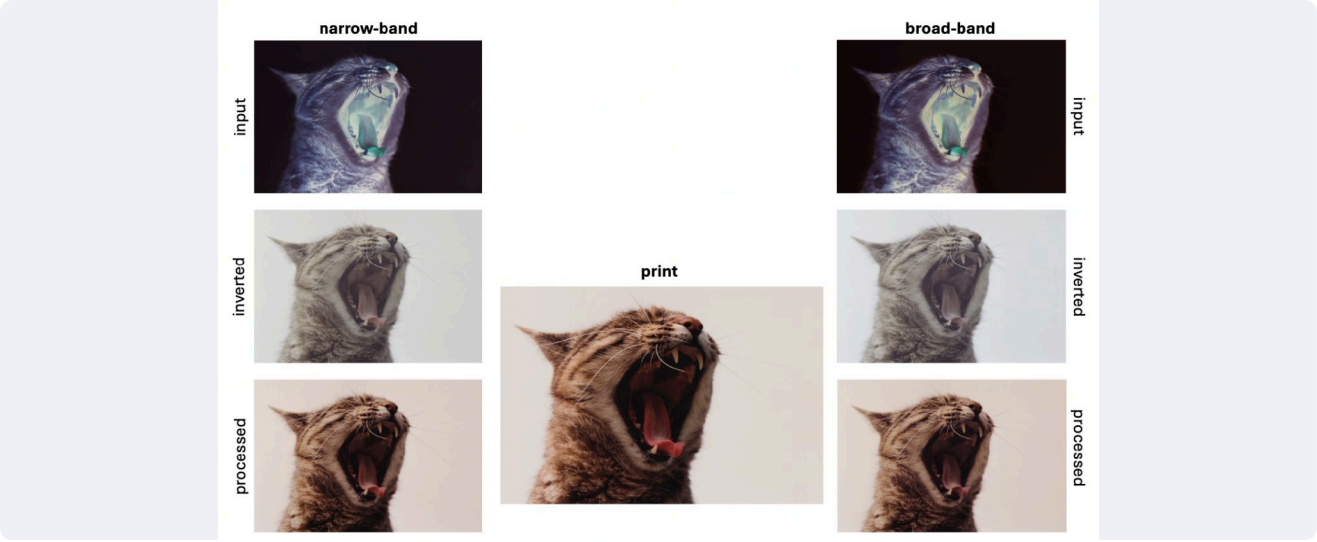


Fig. 1: Narrow-band and broad-band capture of the same negative: input, inverted and processed images, compared with the original print.

OVERVIEW

The widespread success of color photography is largely attributed to the negative-positive process. In fact, the vast majority of photographs were historically captured on color negatives. Positive prints from these negatives were traditionally produced using enlargers. Today, billions of color negatives are held in archives and private collections worldwide, often without corresponding prints. A common preservation approach is to digitize the negatives and use image processing techniques to invert them into positive images. While tools like Negative Lab Pro and FilmLab facilitate this process, research into optimizing both the image capture and processing workflows remains limited. neg2pos addresses this gap by introducing a calibrated transformation framework designed to minimize aesthetic deviation from chromogenic C-prints while producing accurate and reproducible positive renderings. Collaboration with peers is essential to accurately determine the parameters of this transformation. By consulting diverse negative/print pairs preserved in photographic archives, the process can be systematically evaluated and calibrated to ensure consistency, historical fidelity, and aesthetic accuracy.

KEY FEATURES

- Calibrated negative-to-positive transformation pipeline
- Minimization of aesthetic deviation from chromogenic C-prints
- Workflow optimization for both image capture and digital processing
- Colorimetric reproducibility across institutions
- Comparative evaluation using archival negative/print pairs
- Parameter tuning for historical fidelity
- Archive-scale applicability
- Cloud-ready processing architecture

IN PRACTICE: A USER STORY

Thomas works in a national photographic archive holding thousands of mid-20th-century colour negatives. Many of the original chromogenic C-prints have been lost, leaving only the negatives as historical records.

After digitizing a batch of negatives using a calibrated scanning setup, Thomas uploads the RAW files into the Cultural Heritage Cloud and launches neg2pos. Instead of applying a generic inversion, the system guides him through a calibrated workflow. He selects the film type and scanning conditions, and the framework applies transformation

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parameters designed to approximate the tonal and chromatic qualities of traditional C-prints.

A comparison interface allows Thomas to review the digital positive against a reference print from the archive. The system highlights colorimetric deviations and suggests parameter adjustments. Through iterative calibration—based on known negative/print pairs—the transformation becomes more precise.

Once satisfied, Thomas processes the entire batch with standardized parameters, ensuring reproducibility. Each transformation profile is stored with metadata, allowing future researchers to understand exactly how the positive rendering was generated.

The resulting images are not merely inverted negatives; they are calibrated digital surrogates that respect the historical aesthetic and material logic of chromogenic printing. neg2pos thus supports both preservation and scholarly interpretation of photographic heritage.

WHY ON THE CULTURAL HERITAGE CLOUD?

Within the COLOURS framework, interoperable and cloud-based services are central objectives. neg2pos benefits significantly from deployment within the ECCCH. Calibration requires comparison across diverse archival collections. ECCCH enables shared access to digitized negative/print pairs, standardized metadata, and distributed processing capabilities. The cloud environment ensures reproducibility by storing transformation parameters alongside digital assets.

WHO CAN USE IT

neg2pos primarily serves photographic archives, museums, libraries, and audiovisual heritage institutions managing large collections of colour negatives. Conservation scientists and imaging specialists benefit from standardized, reproducible transformation workflows.

Photographic historians and curators gain access to digitally reconstructed positives that more faithfully reflect historical print aesthetics. Research infrastructures and universities can use the framework to study chromogenic processes and historical colour reproduction.

EXPECTED TIMELINE

Alpha 2026
Calibrated inversion, reference tests

Beta 2027
Pilots with partner institutions

Release 2028
Production-ready on the ECCCH

An initial research prototype will focus on defining calibration parameters and evaluating negative/print pairs within partner archives.

Alpha (2026): Core calibrated inversion framework and controlled testing on reference collections.

Beta (2027): Pilot deployment within partner institutions, integration with ECCCH storage and metadata services.

2028: Production-ready cloud-integrated service aligned with COLOURS deliverables.

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COLOURS TOOL · PERCEIVE LEGACY

CoDesign Tool

Card-based framework for collaboratively creating heritage experiences.

Co-Design Framework | Card-Based Design Methodology | Participatory Heritage Innovation | Collaborative Digital Workshops | Visitor Experience Design



Fig. 1: Paper-based board game version of the tool.

OVERVIEW

The PERCEIVE CoDesign Tool is a structured, card-based framework developed by Consiglio Nazionale delle Ricerche (CNR ISPC) and Fraunhofer IGD within the Horizon Europe PERCEIVE project. It supports exhibition designers, curators, researchers, and cultural professionals in collaboratively creating engaging visitor experiences, physical, digital, or hybrid. The tool exists in two complementary versions: a paper-based board game, designed for in-person workshops; a web-based collaborative application, currently under development, enabling remote and hybrid sessions.

The framework builds on the open-access VisitorBox (Horizon 2020 GIFT project) and introduces an updated seven-step workflow, including the innovative Audience Goals stage focused on Authenticity and Sense of Care.

The tool will be adapted to support COLOURS' objectives in colour-driven exhibition and heritage design.

KEY FEATURES

- Seven-step structured design workflow
- Modular canvases and thematic card decks
- Audience Goals stage (Authenticity & Sense of Care)
- Disruption Stage for feasibility and resilience testing
- Inclusive participation model (no prior design expertise required)

IN PRACTICE: A USER STORY

Elisa, a curator, is preparing a new exhibition on ancient colour. She gathers educators, designers, and conservator-restorers around a large table. They begin with the Context Definition canvas, mapping audiences and institutional priorities. Cards are drawn, moved, and discussed. During the Audience Goals stage, the team reflects on "Authenticity" and "Sense of Care," debating how visitors might emotionally connect with fragile polychrome reconstructions.

In the Ideation phase, they combine motivations and constraints into concrete concepts. The Disruption Stage challenges their ideas - Are they sustainable? Inclusive? Environmentally responsible? Finally, they create a Storyboard, translating abstract ideas into a clear visitor journey.

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The tactile nature of cards and canvases makes the process intuitive and inclusive - even participants without design training actively contribute.

WHY ON THE CULTURAL HERITAGE CLOUD?

The CoDesign Tool aligns strongly with ECCCH objectives. As a collaborative design environment, it complements analytical and restoration tools by focusing on how colour knowledge is communicated to audiences.

Deploying the web version within the ECCCH enables distributed teams to co-design exhibitions using shared datasets and digital twins. Cloud deployment ensures scalability, accessibility, and interoperability, transforming the CoDesign Tool into a European-level participatory innovation platform for heritage experience design.

WHO CAN USE IT

The CoDesign Tool engages exhibition designers, museum curators, educators, conservator-restorers, researchers, and digital heritage professionals. It is particularly valuable for institutions exploring inclusive, emotionally resonant visitor experiences. International research teams benefit from the web edition's collaborative capabilities. Cultural institutions seeking participatory design approaches can use the cardboard version for workshops and strategic planning.

EXPECTED TIMELINE

Paper Ready
Available on Zenodo

Web ATON
Collaborative web version

COLOURS 2028
Adapted to colour narratives

The paper-based version is already operational and documented (Zenodo: https://zenodo.org/records/15632653). The web-based application has been implemented through the ATON framework.

Adaptation to COLOURS: Tailoring Audience Goals and design stages to colour-driven exhibition and conservation narratives.

MORE IMAGES

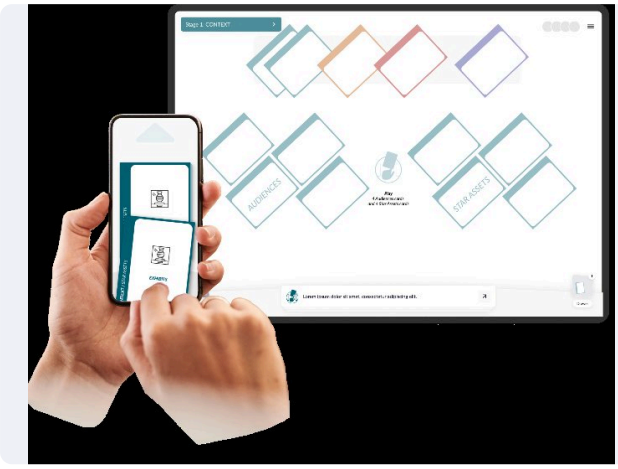


Fig. 2: Web-based version of the tool.

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Get involved

Join the Community of Practice

Share your needs, test the tools as they evolve and help shape them. The COLOURS Community of Practice brings together conservator-restorers, heritage scientists, curators and digital heritage professionals.
colours-eccch.eu/community-of-practice

Watch out for the COLOURS open call

COLOURS is preparing an open call to bring new organisations on board. Follow our website and channels to be the first to know when it opens.

Talk to the developers

Each tool sheet lists the people behind the tool. For general questions, write to **hello@colours-eccch.eu**.

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