ENIGMA

Endorsing Safeguarding, Protection & Provenance Management of Cultural Heritage

BEST PRACTICES BOOKLET

ENIGMA PROJECT
Training Materials

Funded by the European Union

Funded by the European Union. Views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

Funded by
the European Union

ENIGMA CONSORTIUM

Aristotle University of Thessaloniki (AUTH) Greece

Etaireia meleton ypiresion kai logismikou geochorikis pliroforias I.K.E. (KIKLO), Greece

Eratosthenes Centre of Excellence (ECoE), Cyprus

Cellock LTd (CLK), Cyprus

Turun Yliopisto (UTU), Finland

ROYAL MUSEUMS OF ART AND HISTORY
KONINKLIJKE MUSEA VOOR KUNST EN GESCHIEDENIS
MUSÉES ROYAUX D'ART ET D'HISTOIRE
Koninklijke Musea voor Kunst en Geschiedenis (KMKG), Belgium

Kentro Meleton Asfaleias (KEMEA), Greece

Hellenic Police (HPOL), Greece

Heritage Malta (HM), Malta

Noesis Technologies IKE (NOE), Greece

Anysolution SL (ASOL), Spain

Miralab Sarl (Mlab), Switzerland

Contents

ENIGMA Consortium 2
1. Best practices Introduction 5
1.1 Why best practices matter 5
1.2 How to use the best practices booklet 6
1.3 ENIGMA training resources overview 7

2. User roles and responsibilities 8
2.1 ENIGMA end users 8
2.2 Responsibilities 9

3. Enigma Best practices 10
3.1 ENIGMA Tools 10
3.1.1 Scenario Building Engine 11
3.1.2 Provenance Tool 12
3.1.3 Earth Observation Toolkit 13
3.1.4 3D Reconstruction Tool 14
3.1.5 Public Engagement Application 15
3.1.6 Similarity Report 16

3.2 Photography & Recording 18
3.2.1 Laser Scanning for 3D 19
3.2.2 From 2D to 3D Reconstruction 21
3.2.3 Photographing Details for LEAs 23
3.2.4 Measuring CGs for LEAs 24

3.3 Cultural Heritage & GLAM Practices 26
3.3.1 Museology and Object IDs 27
3.3.2 Museology and Heritage Vocabularies 28
3.3.3 Museology, CIDOC and CMS 29

3.4 Ethics & Data Protection 30
3.4.1 Data Quality 31
3.4.2 Data Ethics and Privacy 32
3.4.3 Public Engagement and Data Reliability 34
3.4.4 Data Licenses: Open Science and CCBY 4.0 35
3.4.5 ENIGMA Technical and System Requirements 36

3.5 AI: Machine Learning and Large Language Models 37
3.5.1 AI and Prompt Writing 38
3.5.2 AI and Critical Reflection 39

4. Feedback and improvement 40
4.1 Stakeholder engagement 40
4.2 ENIGMA Q&A / FAQ 41
4.3 ENIGMA Feedback loops 42

1. BEST PRACTICES INTRODUCTION

1.1 Why best practices matter

Best practices are more than guidelines — they are the distilled knowledge from experience, experimentation, and collaboration. In a complex environment like ENIGMA, where tools, users, and data intersect across domains, adhering to best practices ensures consistency, quality, and accountability. By following best practices, teams avoid reinventing the wheel, reduce errors, and promote interoperability. They also help new users onboard faster, while giving experienced practitioners a shared framework for collaboration and innovation and improve the efficiency and performance of tool application. As ENIGMA evolves, these practices become the foundation that supports scalable, ethical, and sustainable use of its tools and methodologies.

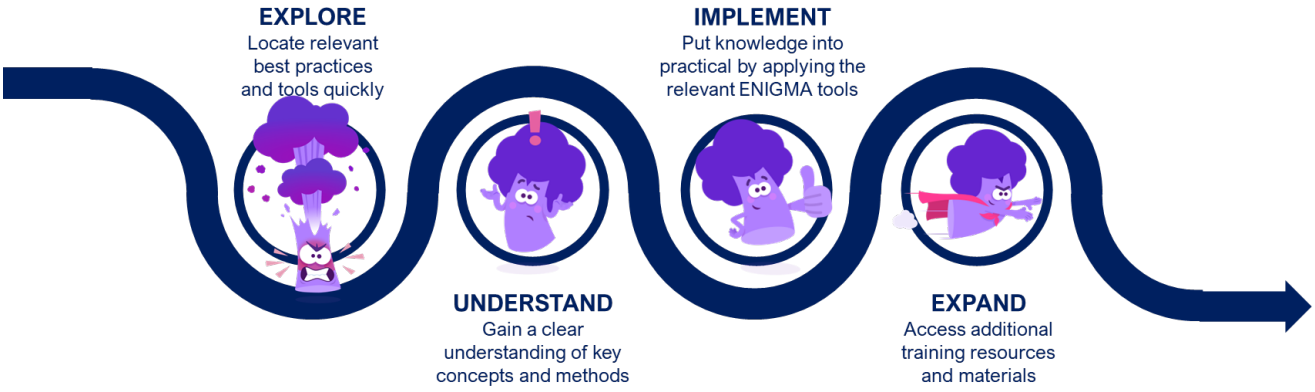
"In short: best practices matter because they turn isolated expertise into shared success"

1.2 How to use the best practices booklet

This booklet is designed as both a reference guide and learning tool. You can read it front to back, or use it modularly — jumping to the section relevant to your task, role, or tool. For maximum efficiency, the best practices provide a short and concise overview of the problem, written as a pitch. For maximized usability, the best practices are short and complemented with clear visual material to connect abstract principles to concrete results. Each best practice entry is organized using a consistent structure:

- **Description** – Overview of the practice, why it's important and when it applies
- **Ideal Scenario** – Describes the "proper" application in practice
- **Do's and Don'ts** – Quick guidance on what to follow or avoid
- **Further Resources** – Links to related practices, tools and/or standards

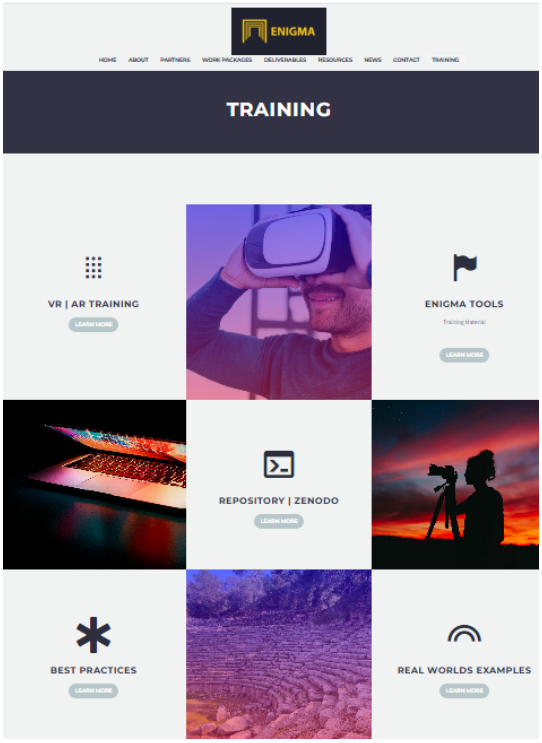
Whether you are just starting with ENIGMA or refining your advanced workflow, this guide is here to support you. You can navigate the online best practices on https://eu-enigma.eu/ or download this PDF booklet for navigating the best practices.



1.3 ENIGMA training resources overview

The ENIGMA platform supports its users not just with tools, but with a comprehensive ecosystem of training materials. These resources are designed to reinforce each other — from step-by-step tool instruction to immersive VR experiences and context-rich case studies, as well as the best practices. This section offers a quick guide to the types of training available and how they complement the best practices outlined in this booklet. The ENIGMA training infrastructure consists of the following found on https://eu-enigma.eu/training/ Together, they form a continuous learning loop — whether you're onboarding, experimenting, or scaling up your use of ENIGMA.

"How do these work together? Each of these resources complements the others, this flow mirrors how users often move from context to execution."



1. **Best Practices** – The foundation: sets expectations, mindset, and principles

2. **Real-World Examples** – Demonstrates application of those principles in context

3. **Tool Training** – Teaches hands-on usage of specific tools

4. **VR Training** – Deepens engagement through experiential and immersive learning

5. **Repository** – Supports ongoing exploration, inspiration and shared assets

2. USER ROLES AND RESPONSIBILITIES

2.1 ENIGMA end users

ENIGMA supports a diverse user base with distinct roles and expertise, each with their own responsibilities. By defining these roles clearly, the platform fosters secure, transparent, and collaborative use of its tools. Whether working solo or in teams, understanding one's role ensures proper use and strengthens the integrity and impact of shared work and identify the right best practices for each end-users workflows and needs. While the platform is flexible, three primary user groups are central to its mission:

Law Enforcement Agencies (LEAs) use ENIGMA for fast, secure documentation and tracking of cultural goods in investigations, supported by tools for 3D recording and provenance management.

Museum Experts enrich and verify cultural records using heritage standards, ensuring accurate contexts to verify, amend and refine LEA input data.
Archaeologists enrich and verify cultural records and site data using heritage standards, ensuring accurate contexts to verify, amend and refine LEA input data.

The Italian Carabinieri's retrieval of looted artefacts. 19 June 2018 http://www.theartnewspaper.com/, accessed 20 April 2025

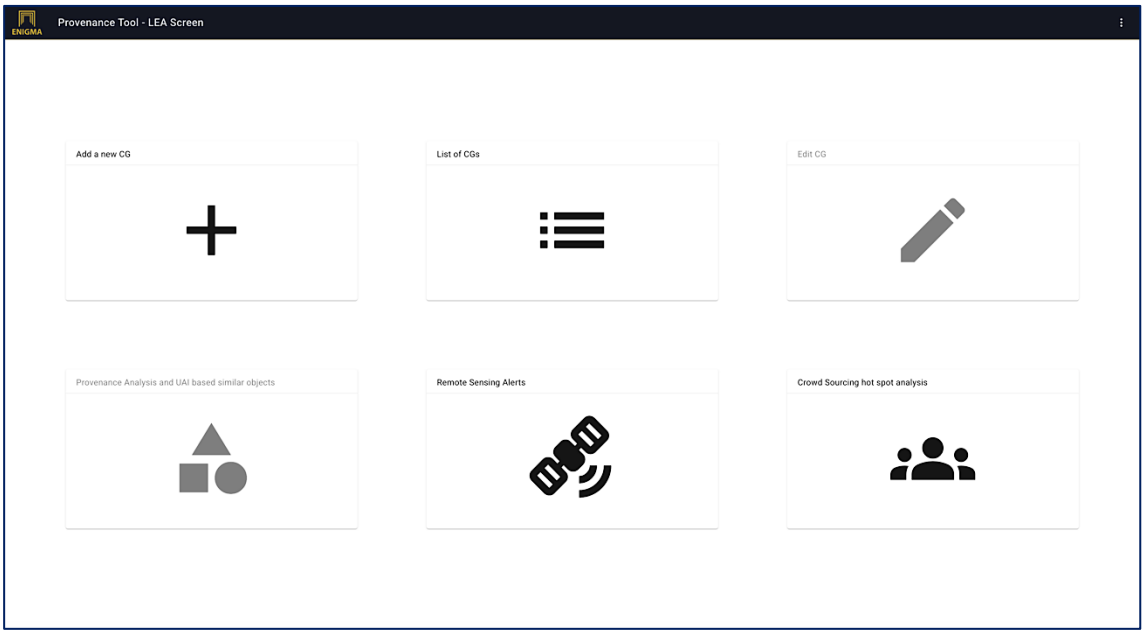
2.2 Responsibilities

ENIGMA brings together users from diverse professional backgrounds each with their own methods, operational priorities, and thus also with particular responsibilities. While responsibilities vary by role, all users are expected to uphold the shared values of accuracy, ethics, and integrity. LEAs work within secure environments that support case documentation, chain-of-custody tracking, and confidentiality, all with their respective regulations and privacy considerations. Museum experts and archaeologists contribute detailed object records and align documentation with heritage standards. Each group plays a distinct role which relies on mutual collaboration. By fulfilling their individual responsibilities within their tailored ENIGMA environment, users help build a shared ecosystem of trust, interoperability, and cultural preservation.

3. ENIGMA BEST PRACTICES

3.1 ENIGMA Tools

ENIGMA's suite of tools addresses the specific needs of cultural heritage professionals, museum experts, and law enforcement agencies in the pursuit of monitoring and protecting cultural goods against looting and illicit activities. From documenting cultural goods to building complex workflows, the tools offer a flexible, efficient, and secure environment for data management and analysis. The best practices in this section help end-users to use each tool efficiently. By following these best practices, users can maximize the potential of ENIGMA's tools and contribute to a shared ecosystem of high-quality, reliable data.



3.1.1 Scenario Building Engine

DESCRIPTION

The Scenario Building Engine (SBE) is a digital tool that enables structured, role-based workflows for managing cultural heritage cases. It supports the creation of standardized processes with defined statuses, transitions, and privileges, ensuring traceability, accountability, and collaboration across stakeholders such as LEA officers, archaeologists, and experts.

IDEAL SCENARIO

A well-designed SBE workflow reflects real-world procedures, with clear roles, logical status progressions, and secure transitions. Each case instance follows a validated template, ensuring that cultural heritage items are processed consistently, decisions are auditable, and data is enriched at every step.

TIPS

Do

- Define clear objectives and success criteria before building a workflow
- Use meaningful status names like *Pending Review*, *Validated*, *Archived*
- Assign roles and restrict transitions based on responsibilities
- Attach evidence and notes at the appropriate status
- Monitor metrics to identify bottlenecks and improve workflows
- Use the 'History' view to track progress and ensure transparency

Don't

- Don't allow transitions without defined conditions or responsible roles
- Don't duplicate statuses with overlapping meanings
- Don't bypass workflows with manual updates—use transitions
- Don't forget to review and update templates regularly

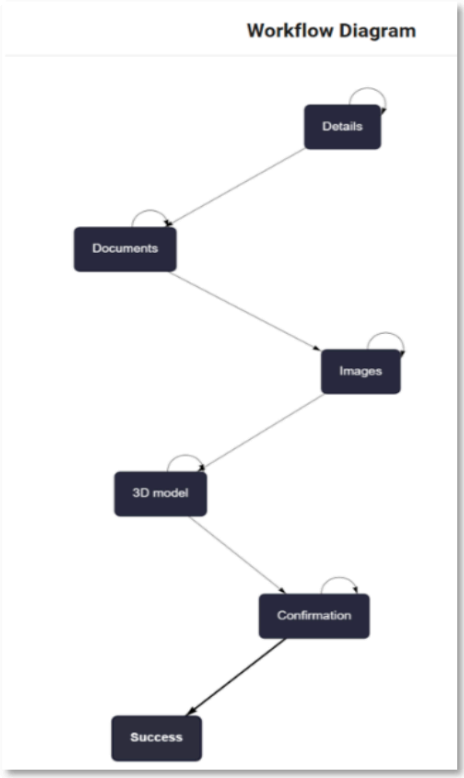


***Figure**: Main workflow of the Scenario building engine*

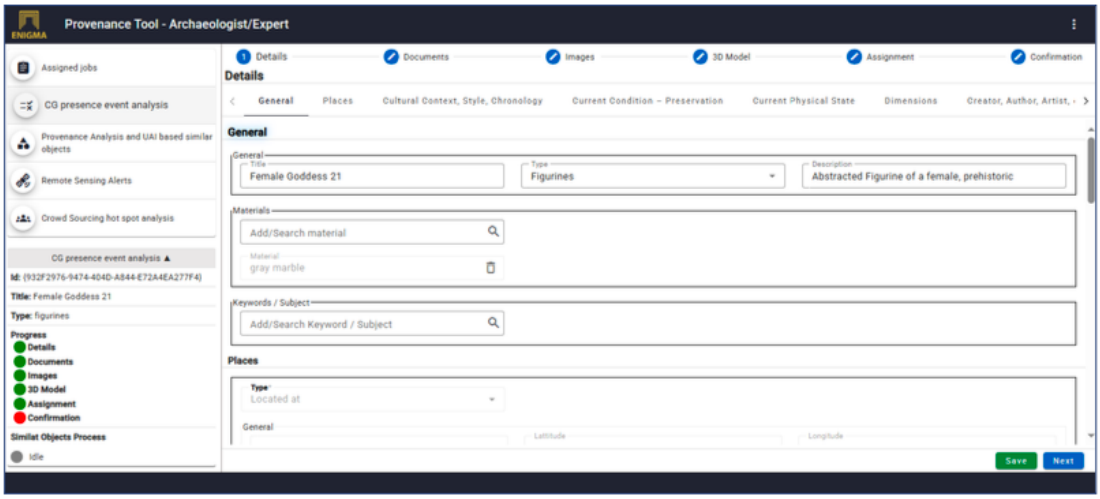
3.1.2 Provenance Tool

DESCRIPTION

This best practice focuses on providing comprehensive data in the Provenance Tool, used by both LEAs and Experts, even though each with different features. By entering every detail available, from images to documents, users create a complete record that prevents gaps and strengthens provenance research. This improves the tool's reliability and accuracy which is essential for successful investigations into illicit trafficking.

IDEAL SCENARIO

A LEA officer uploads data from a seized artifact and use ENIGMA to input core details, and attach high-quality photos, supplementary documents, and any observations. The LEA then assigns the item to an expert who adds historical context and expert analysis, providing suggestions regarding the authenticity of the object. All this information is linked, creating a complete and searchable history of the item.



TIPS

Do	Don't
- Input as much information as possible. Each piece of data helps - Upload all relevant media, including images and documents - Involve numerous experts for a more efficient and complete assessment	- Don't be afraid to fill in information, or make mistakes. Experts can correct the data if needed. - However, don't enter data that cannot be verified from the object or accompanying documents.

***Figure**: View of the main screen of the ENIGMA Provenance Tool*

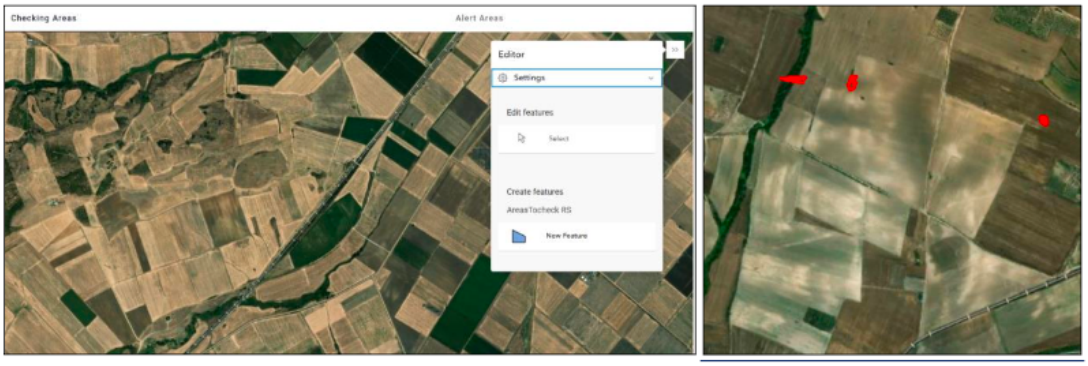
3.1.3 Earth Observation Toolkit

DESCRIPTION

This best practice focuses on collaborative monitoring using the Earth Observation (EO) Toolkit through satellite imagery analysis. It encourages multiple users to share and analyze information together, to improve the monitoring and this protection of heritage and archaeological sites. This approach enhances reliability and efficiency, leading to faster, more effective responses to potential illegal excavations.

IDEAL SCENARIO

A user sets up continuous monitoring for a site. When the EO detects an anomaly, it sends an alert. Multiple users can view, search and retrieve the information and share these with a local LEA. The officer then cross-references the data and dispatches a team for on-site verification, leading to a swift and coordinated response to protect the monitored site from potential threats.



TIPS

Do

- Actively monitor high-risk sites
- Respond timely when alerted
- Share insights with the relevant LEAs
- Verify EO alerts on the ground to actively protect the sites

Don't

- Don't use the tool passively
- Don't ignore alerts
- Don't forget to update the alert or system after checking the site on the ground

***Figures**: a)Impression of the Earth Observation Toolkit screen for drawing the area of interest polygon b) Impression of the Earth Observation Toolkit showing an alert from a monitored area in Greece*

3.1.4 3D Reconstruction Tool

DESCRIPTION

This best practice focuses on providing the right data input for an optimized use of the 3D Reconstruction Tool. The tool allows for 3D reconstruction based on inputs from either texts, videos or a series of images. Its AI generated models provides 3D models of damaged or incomplete objects, or where enough visual material is lacking to aid in experts assessment of cultural goods. Therefore, the 3D reconstruction tool enhances reliability and usability of the ENIGMA platform while also reducing time due to quick generation of 3D models.

IDEAL SCENARIO

An ideal scenario involves a LEA officer providing available digital evidence (photographs or a detailed textual description). The tool processes this input to generate a 3D reconstruction of the artefact, offering a 3D model for multi-angle visualization and expert assessment. This model can then be refined or validated by specialists as part of the investigative workflow.

Figure 1 – Example of 3D reconstruction from 2D input. Left: original 2D reference image of the artefact. Right: six different viewpoints of the 3D model generated using ENIGMA's AI-based reconstruction pipeline. Source image: Museum of Mediterranean and Near Eastern Antiquities (Medelhavsmuseet), Object ID 300518, (CC BY 4.0).

TIPS

Do

- Capture single or multiple, well-lit angles of the artefact to support accurate reconstruction.
- Document fine-grained visual features (cracks, erosion marks) through high-quality images to improve reconstruction fidelity.
- Experiment with different input modes (image, video, text) and compare outputs, certain types provide better reconstruction.

Don't

- Don't stop after the first attempt if the output is imperfect, refine and re-run the reconstruction.
- Don't dismiss a reconstruction simply because it is not a perfect match, experts often rely on these 3D models to understand the object's form and spatial characteristics.
- Don't process multiple artefacts together in a single reconstruction.

FURTHER RESOURCES

- Guidelines for Capturing Multiview Images and Videos for 3D Object Reconstruction
- Shooting for Photogrammetry

3.1.5 Public Engagement Application

DESCRIPTION

The Public Engagement Application allows effective reporting by the public of potential illegal activities. The app allows users to provide clear, concise, and verifiable information, ensuring that the reports are actionable and useful for LEAs and CH experts. The App adds value to ENIGMA since the public contributions can increase the scope and scale of reporting illicit activities.

IDEAL SCENARIO

An ideal scenario involves a member of the public using the app to report a suspected illegal activity, such as seeing a third party stealing an item from an antiques dealer or a heritage site. They use their phone to fill out the form, providing a map location and supplementary information from a safe distance. The report is clear, concise, and provides all the necessary to undertake further investigation.

***Figure**: Impression on the public engagement application and form*

TIPS

Do

- Provide an exact location via the GPS feature of the app
- Capture clear visual evidence
- Describe what you saw and include all relevant details

Don't

- Don't put yourself at risk
- Don't capture images including persons only objects or disturbances
- Don't report with no details as no action can be undertaken
- Don't report based on rumours, only use the tool based on your firsthand accounts

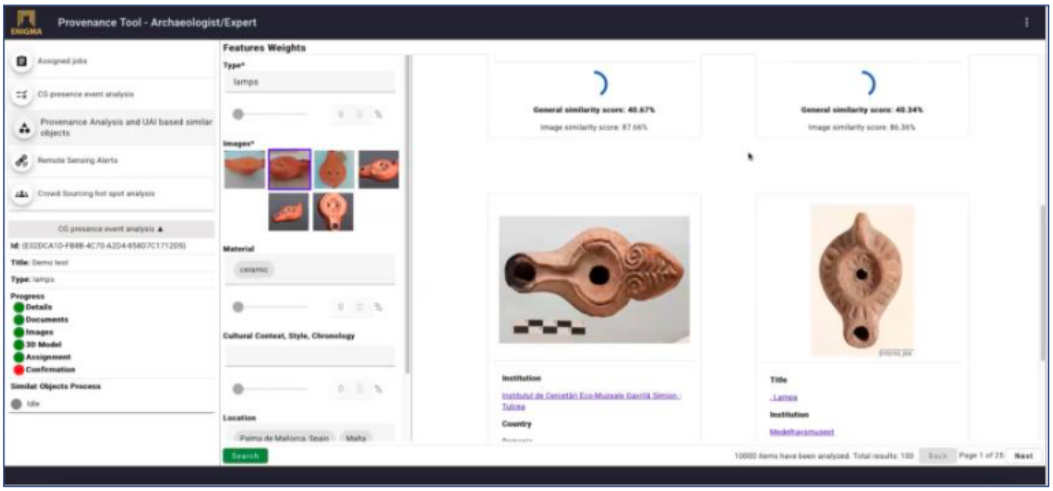
3.1.6 Similarity Report

DESCRIPTION

ENIGMA includes a similarity score as part of the Unique Authentication Identifier (UAI) and Provenance Analysis tools. Using AI, the similarity compares input of a suspicious and held object with artefacts from external databases, and provides a list of potential matches. The similarity can help LEAs with verifying the legal status, or may help Cultural Heritage Experts in determining authenticity and provide supplementary provenance data. Thus, the similarity score helps to identify the authenticity, provenance, origin, and legal status of the held object.

IDEAL SCENARIO

For example, a LEA officer uses ENIGMA to input data of a seized artefact. They provide a full set of metadata, including the object's category, material, and a detailed description. In addition, they upload a series of images. The AI processes a similarity score based on the available data and generates a report showing a few highly similar objects from the main database. This allows the officer to quickly identify a potential match and obtain crucial provenance information.



TIPS

Do

- Use the vocabularies from ENIGMA for better search results
- Include a clear object type, as this increases a successful similarity
- Upload fine quality images
- Be patient, the similarity score may take a while

Don't

- Don't solely rely on similarity, and compare matches to understand the context of the object
- Don't rely on only one search algorithm, use the three search options for better similarity scores
- Don't assume a low score means the object is authentic or unique

***Figure**: UAI and similarity results for the Expert provenance search*

MAIN IMAGE

Example of clustered artifacts generated as part of the similarity score analysis. Each three cluster groups in the image shows five example amulets grouped using clustering algorithm with deep learning features. Images contain also, for example, material, origin and period information (created with the description texts and GPT-5 model). This visualization demonstrates how clustering can reveal patterns and similarities supporting provenance and authenticity assessment.

FURTHER RESOURCES:

Vähämäki, BSc Santeri, Luca Zelioli, and Henri Nyberg. "leveraging text extraction and language models for coin image classification." (2025).

Troiano, Maurizio, et al. "A comparative analysis of machine learning algorithms for identifying cultural and technological groups in archaeological datasets through clustering analysis of homogeneous data." *Electronics* 13.14 (2024): 2752.

Pereira, Javier, et al. "Clustering and semantics preservation in cultural heritage information spaces." *RIAO*. 2010.

3.2 Photography & Recording

Photography and recording are critical elements in documenting cultural goods and ensuring accurate representations whether for analysis, or museological practices such as cataloguing and preservation. This section focuses on best practices for capturing high-quality images, transforming 2D photos into 3D models, and measuring physical and digital cultural goods. Following these best practices ensure that all collected data remains precise, reproducible, and ready for further processing. These best practices provide an essential foundation for collaboration between LEAs, archaeologists and museum experts.

3.2.1 Laser Scanning for 3D

DESCRIPTION

This best practice focuses on providing the optimal laser scanning data input for 3D model generation. Capturing a comprehensive and high-quality set of scans the geometric and textural accuracy of the resulting model, which is crucial for forensic and expert assessment of cultural goods. Following this practice significantly enhances the reliability and usability of model input in ENIGMA for provenance by CH experts.

IDEAL SCENARIO

A LEA officer scans an object using a handheld laser scanner around the object with high overlap between scans. The capture includes a full 360-degree rotation, multiple heights, and close-up views of intricate details. The final merged scan creates a high resolution and accuracy 3D model of the cultural good ensuring all surface areas are successfully rendered.

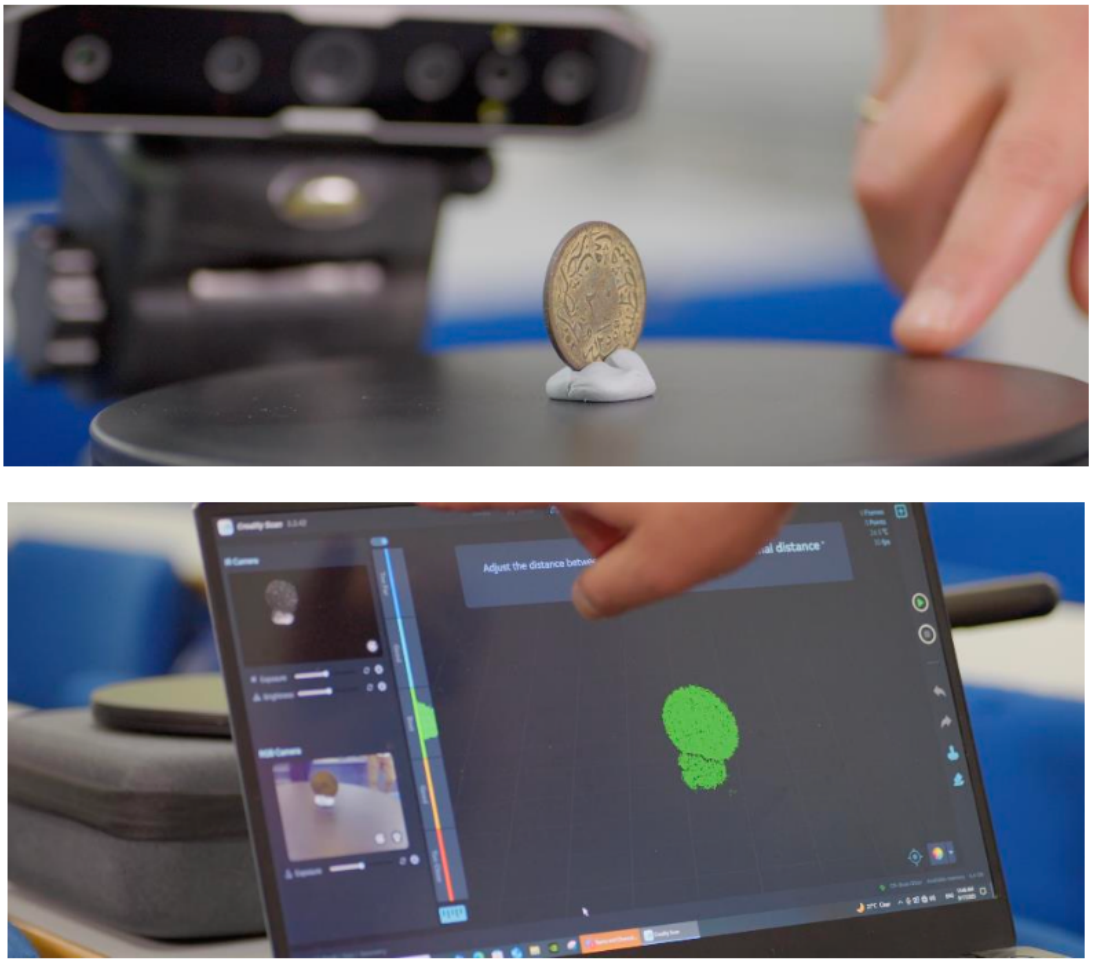


***Figure**: Scanning a coin using a handheld laser scanner*

TIPS

Do	Don't
- Scan from multiple angles and viewpoints to ensure full coverage - Ensure a high degree of overlap (at least 60% is common) to help the software align the scans. - Use a tripod and a turntable to ensure consistency.	- Don't change the lighting drastically - Don't rotate the turntable or change the position of the scanner in a fast or abrupt way.

FURTHER RESOURCES

- Ioannides, M., P. Patias (eds), 2023, 3D Research Challenges in Cultural Heritage III: Complexity and Quality in Digitisation, Springer LNCS 13125, Lecture Notes In Computer Science, ISSN 0302-9743, https://doi.org/10.1007/978-3-031-35593-6

- Georgiadis, Ch. P. Patias, G. Stylianou., (2009), Capturing the past and present: Tools and methodologies for 3D modeling of small objects , Proceedings of the CIPA XXII Symposium, Kyoto, Japan, CIPA Archives for Documentation of Cultural Heritage, Vol. XXII-2009, ISSN 2076-7730

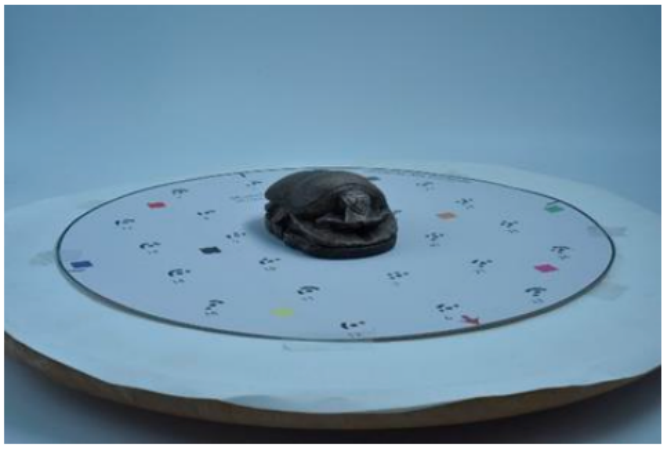
3.2.2 From 2D to 3D Reconstruction

DESCRIPTION

This practice addresses generating an accurate 3D model from a set of 2D images using photogrammetry methods. It solves the problem of unreliable or distorted digital representations by prioritizing data capture. Following this practice maximizes the maintainability of the digital asset and ensures the resulting model is a reliable resource for expert interpretation within ENIGMA.

IDEAL SCENARIO

An image collection input requires a high overlap (60-80%) with sharp detail. Photogrammetry software (e.g., Agisoft or Meshlab) aligns all images with minimal error. The resulting dense point cloud clearly defines the object's geometry. The 3D model is accurately scaled using reference targets. Check the 3D model before accepting the final, clean mesh. Archive the 3D model in common 3D file types (.glb; .obj; .stl; .ply).



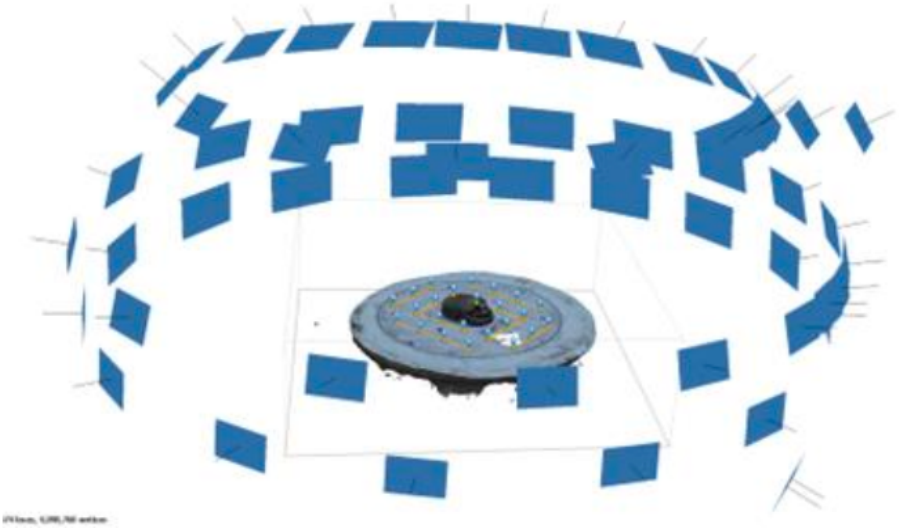


***Figure**: Image acquisition for creation of 3D models*

TIPS

Do

- Orbit around the object to check complete coverage of the 3D model.
- Include scale references or coded targets in the scene.
- Remove background noise and floating geometry before export.

Don't

- Don't expect reflective, transparent, or textureless surfaces to model well.
- Don't proceed with processing if the image alignment is poor.

FURTHER RESOURCES

- Ioannides, M., P. Patias (eds), 2023, 3D Research Challenges in Cultural Heritage III: Complexity and Quality in Digitisation, Springer LNCS 13125, Lecture Notes In Computer Science, ISSN 0302-9743, https://doi.org/10.1007/978-3-031-35593-6

- Patias, P. (2013), 13.5 Overview of applications of close-range Photogrammetry and Vision techniques in Architecture and Archaeology, C. McGlone (ed), Manual of Photogrammetry, 6th edition, ISBN 1-57083-099-1, American Society of Photogrammetry Publ., Maryland, USA, pp 1093-1107. (pdf) [www.asprs.org]

3.2.3 Photographing Details for LEAs

DESCRIPTION

Capturing high-quality photographic evidence of Cultural Goods is critical for cultural heritage experts to provide the best assessment. When photographing, Law Enforcement may focus on minute details like color, light, texture, and ornamental details or inscriptions which allows experts to authenticate and determine an object's provenance. This focus on detail significantly increases the reliability of the evidence and its usability in legal proceedings.

IDEAL SCENARIO

An investigator uses a high-resolution camera and a tripod. They use raking light (light at a low, oblique angle) to create exaggerated shadows, which highlights faint inscriptions, tool marks, or surface texture. A neutral grey card and a color checker (RGB legend) are included in a reference shot to ensure accurate white balance and verifiable color reproduction for experts.

***Figure**: LEA photographing a CG*

TIPS

Do

- Focus on fine surface details, textures and inscriptions.
- Include a grey/color card in a reference shot
- Photograph the object from multiple angles

Don't

- Don't use direct flash or reflective backgrounds, which may cause glare.
- Don't allow external shadows (e.g., equipment) to fall across the object.

FURTHER RESOURCES

- Caple, C. (2020). *Photographing archaeological objects: A practical guide.* London: Routledge.
- Canadian Conservation Institute. (2017). *Digital photographic documentation of cultural objects*. Ottawa: CCI.

3.2.4 Measuring CGs for LEAs

DESCRIPTION

Having reliable measurements for artefacts is essential for their identification and provenance. Measurements provide absolute dimensional data, and can be obtained by using rulers, or tape measures. This practice directly ensures the reliability and dimensional accuracy of the digital record, providing essential information for LEAs on how to measure cultural goods and send reliable data to cultural heritage experts.

IDEAL SCENARIO

Ensure that the object is clean before measuring. Use orthographic projections (plan and elevations) to established a unit of measurement (e.g., cm) and its physical quantity (e.g., length). Measure the furthest extents of the objects, which is your measurement. When photographing, use a high-precision, calibrated scale bar (e.g., IFRAO scale) to provide a visual record with scales.

***Figure**: LEA measuring CG (courtesy of KMKG)*

TIPS

Do	Don't
- Include a scale bar for size reference. - Assess the object before measuring. - Place the scale on the same plane as the object to avoid perspectival distortion.	- Don't move the scale bar during photography sessions. - Don't use different units of measurement and stay consistent. - Don't place the scale over the object and ensure you have an unobstructed image of the artefact.

FURTHER RESOURCES

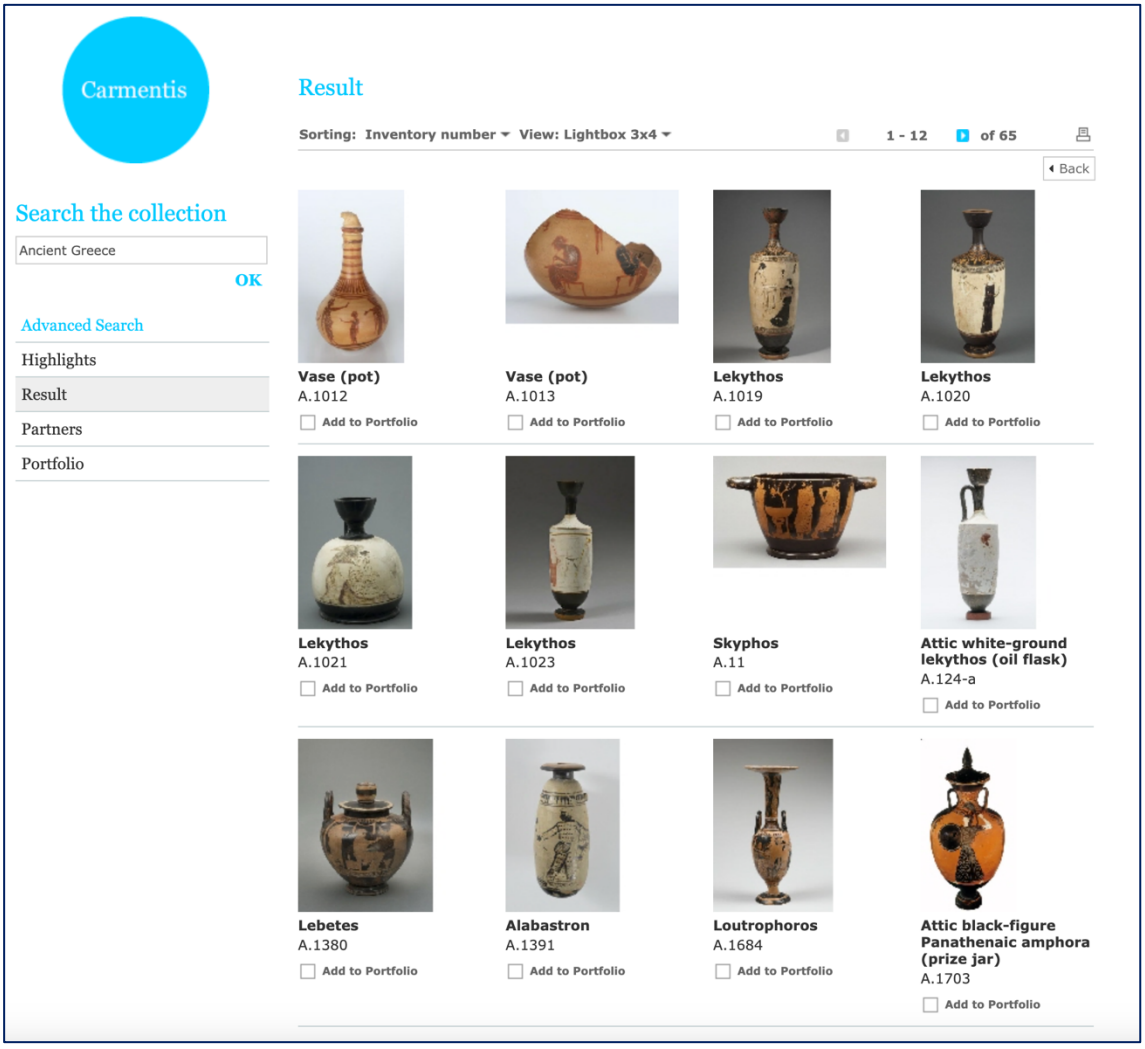
- Ioannides, M., Patias, P. (Eds.). (2023). *3D Research Challenges in Cultural Heritage III: Complexity and Quality in Digitisation* (Lecture Notes in Computer Science, Vol. 13125). Springer. https://doi.org/10.1007/978-3-031-35593-6

- Patias, P. (2013). *13.5 Overview of applications of close-range photogrammetry and vision techniques in architecture and archaeology. In C. McGlone (Ed.), Manual of Photogrammetry* (6th ed., pp. 1093-1107). American Society of Photogrammetry. ISBN 1-57083-099-1

- Georgiadis, C., Patias, P., Stylianou, G. (2009). *Capturing the past and present: Tools and methodologies for 3D modeling of small objects. In Proceedings of the 22nd CIPA Symposium* (Kyoto, Japan). CIPA Archives for Documentation of Cultural Heritage.

3.3 Cultural Heritage & GLAM Practices

Cultural heritage institutions like galleries, libraries, archives and museums, GLAMs in short, play a key role in preserving and interpreting cultural goods, as well as connect the past to the broad general public. GLAMs remain key in harnessing the past for future generations for which they rely on bespoke cataloguing systems and preservation practices. As such, this section offers best practices related to museology, object identification, digital cataloging, and heritage vocabularies, ensuring that cultural heritage data is structured, accessible, and ethically managed. Particularly relevant to LEAs, adhering to these best practices help maintain the integrity of collections, making data available for research, curation, and public engagement.



3.3.1 Museology and Object IDs

DESCRIPTION

Developed by the Getty, an object ID is a unique identifier assigned to each item in a collection, ensuring it can be tracked, referenced, and catalogued correctly. Using standardized Object IDs ensures consistent cataloguing and easy retrieval, particularly when linked to vocabularies. This prevents misidentification, enhances data integration, and ensures long-term data reliability.

IDEAL SCENARIO

Each object has a unique, standardized Object ID linked to accurate metadata. This ensures consistency across systems and databases. In an ideal scenario you assign unique Object IDs for each artefact, integrate the IDs in your database and link accurate metadata to the object. This improves data management and provides for efficient object tracking.

TIPS

Do

- Use Object ID standards
- Update metadata regularly
- Ensure each object in a collection has an Object ID

Don't

- Avoid using inconsistent or arbitrary naming.
- Avoid overlooking metadata updates or assign outdated data to the object
- Evade relying only on physical records

FURTHER RESOURCES

- Getty Object ID, 1999 https://www.getty.edu/publications/virtuallibrary/0892365722.html
- Object ID ICOM, https://icom.museum/en/resources/standards-guidelines/objectid/
- Yasaitis, K. E. (2005). Object ID: a model of global collaboration. *Museum Management and Curatorship*, *20*(1): 21–39. DOI: 10.1080/09647770500402001

***Figure**: Object ID from ICOM,*
https://icom.museum/en/resources/standards-guidelines/objectid/

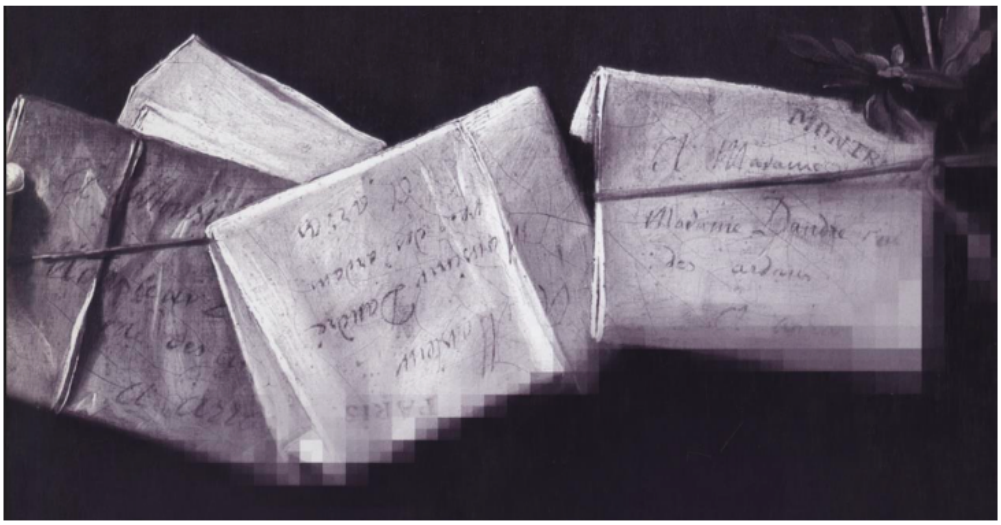
3.3.2 Museology and Heritage Vocabularies

DESCRIPTION

Controlled vocabularies are standardized sets of terms or classifications used to describe objects and cultural. Getty's AAT and TGN, as widely used vocabularies, provide consistent terms for describing cultural heritage objects. These vocabularies help standardize how we describe objects and make them easier to search, compare, and share. They are essential for ensuring consistency in metadata and improving interoperability between institutions.

IDEAL SCENARIO

All cultural assets are described by using standardized terms from recognized and relevant vocabularies. All records of objects rely on consistent terminology, which improves data consistency and enabling easy data searching and sharing for more efficient data access.



TIPS

Do

- Use controlled vocabularies (e.g., Getty AAT, TGN)
- Ensure object metadata conforms to the vocabularies
- Regularly review and update metadata regarding vocabularies

Don't

- Avoid using inconsistent or local terminology.
- Avoid skipping standardized and pre-existing vocabularies
- Avoid overlooking metadata linked to vocabularies

FURTHER RESOURCES

- Heritage Data, Vocabularies https://www.heritagedata.org/blog/vocabularies-provided/
- Getty Vocabularies, https://www.getty.edu/research/tools/vocabularies/
- Harpring, Patricia. (2010). *Introduction to Controlled Vocabularies. Terminology for Art, Architecture and Other Cultural Works*. Los Angeles: Getty Publications.
- EU Vocabularies, https://op.europa.eu/en/web/eu-vocabularies/controlled-vocabularies

***Figure**: Taken from cover page of Lanzi, Elisa. (1999). Vocabularies. Enhancing Access to Cultural Heritage Information. Los Angeles: Getty Publications.*

3.3.3 Museology, CIDOC and CMS

DESCRIPTION

CIDOC-CRM is an ontology and standard for cultural heritage documentation that ensures semantic consistency. It is a Conceptual Reference Model (CRM) developed by the International Committee for Documentation (CIDOC). When implemented in a Content Management System (CMS), it enables structured and meaningful data entry, storage, and sharing across institutions. Integrating CIDOC-CRM into CMS enhances interoperability, long-term preservation, and contextual understanding of cultural objects.

IDEAL SCENARIO

CMS platforms used for cultural heritage documentation often follow CIDOC-CRM principles. The system supports semantic relationships between entities and events, enabling rich and linked metadata that promotes reuse and data integration across museums and collections.

TIPS

Do

- Map metadata before CIDOC-CRM integration
- Ensure object metadata conforms to the vocabularies
- Use CMS platforms that support semantic data
- Regularly validate data to conform to CIDOC-CRM

Don't

- Avoid using unstructured metadata models
- Avoid relying on CMS that is not semantically compatible
- Avoid to neglect semantic mapping of data.

FURTHER RESOURCES

- CIDOC CRM, official website https://cidoc-crm.org/
- CIDOC CRM, ICOM special interest group, https://cidoc.mini.icom.museum/working-groups/crm-special-interest-group/
- CIDOC, CRM version 7.3.1; Bekiari C. et al. (2025). *Definition of the CIDOC Conceptual Reference Model.*

***Figure**: CIDOC-CRM from: https://cidoc-crm.org/*

3.4 Ethics & Data Protection

Data protection and ethical standards are essential when handling sensitive cultural heritage materials. This section covers best practices for ensuring data quality, privacy, compliance with GDPR, and the ethical use of ENIGMA tools in cultural heritage contexts. These practices remain essential for data compliance, protecting individuals' privacy, and securing the integrity of cultural data. By following these best practices, end-users can uphold both the legal and ethical responsibilities tied to their work, ensuring a sustainable and secure data environment.

Public Domain Image

3.4.1 Data Quality

DESCRIPTION

High data quality in cultural goods documentation is defined by image resolution, geometric fidelity, color accuracy, and file integrity. Ensuring high data quality and appropriate file size facilitates efficient storage, and reliable analysis by experts. Providing qualitative data contributes to reducing errors and creating reliable records.

IDEAL SCENARIO

All digital evidence (2D, 3D) should meet a minimum resolution standard (minimum 200 dpi for images) or include a simple text document (.txt) for metadata. The archival master file is saved in a minimally-compressed, lossless format (e.g., TIFF or RAW) to preserve all detail.

***Figure**: Example of Good data quality images (courtesy of KMKG, Scarab, E.02368)*

TIPS

Do

- Capture all digital evidence and allow for post-processing.
- Establish a clear naming convention and file structure for all assets.
- Compress files but also retain the original raw data.

Don't

- Don't rely on lossy formats (like low-quality JPEG).
- Be critical of object documentation that lacks a scale bar, or adequate resolution.
- Don't rely on large files as they may overload the system without offering extra data quality.

FURTHER RESOURCES

- UNESCO (2006) *Legal and Practical Measures Against Illicit Trafficking in Cultural Property – UNESCO Handbook* International Standards Section, Division of Cultural Heritage, Paris

3.4.2 Data Ethics and Privacy

DESCRIPTION

Best practices for AI, data ethics, and privacy prioritize responsible data management and algorithmic fairness. This involves implementing 'privacy-by-design' principles, ensuring data minimization, robust anonymization, and obtaining informed consent for data collection and use. Organizations must actively work to identify and mitigate biases within training datasets and algorithms to prevent discriminatory outcomes, as advocated by frameworks like the NIST AI Risk Management Framework. Furthermore, adherence to comprehensive data protection regulations such as GDPR is non-negotiable, alongside transparent data governance and strong accountability mechanisms for AI systems to safeguard individual rights and foster public trust.

IDEAL SCENARIO

All personally identifiable information (PII) of individuals (e.g., names, contact details) is consistently anonymized or removed (redacted) before data is shared or stored in the ENIGMA platform. This ensures privacy for all people involved and handling of data ethically.

Figure: *https://pixabay.com/photos/ai-ethics-ai-bias-reduction-8296760/*

TIPS

Do	Don't
- Consider the ethical implications regarding data security, bias and ensure legal compliance. - Follow GDPR for all data entries in ENIGMA. - Ensure transparency regarding the data's intended use.	- Don't treat objects inputs as publicly available and respect privacy. - Don't share raw evidence files that contain unredacted PII.

FURTHER RESOURCES

- IEEE Ethically Aligned Design (EAD): A comprehensive framework for autonomous and intelligent systems, developed through global consensus. https://standards.ieee.org/wp-content/uploads/import/documents/other/ead_v2.pdf
- NIST AI Risk Management Framework. https://nvlpubs.nist.gov/nistpubs/ai/NIST.AI.100-1.pdf
- Kate Crawford, *Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence* (2021)
- Michael Kearns & Aaron Roth, *The Ethical Algorithm: The Science of Socially Aware Algorithm Design* (2019)
- IBM AI Fairness 360: An open-source toolkit that helps detect and mitigate bias in machine learning models. https://research.ibm.com/blog/ai-fairness-360

3.4.3 Public Engagement and Data Reliability

DESCRIPTION

While crowdsourcing can provide a large volume of data to aid ENIGMA's aims, caution is needed regarding varying levels of accuracy and quality. This best practice outlines the necessity to verify data inputs stemming from public engagement and crowdsourcing, to filter out unreliable or inaccurate user-generated data.

IDEAL SCENARIO

Crowdsourced data enhances ENIGMA but requires a tiered validation system to verify the accuracy and reliability of data. Level 1 involves an automated check by LEAs for obvious errors (e.g., missing fields, impossible dates). Level 2 routes the data to a LEA for further investigation. Level 3 requires CH expert verification of the data to ensure data reliability.

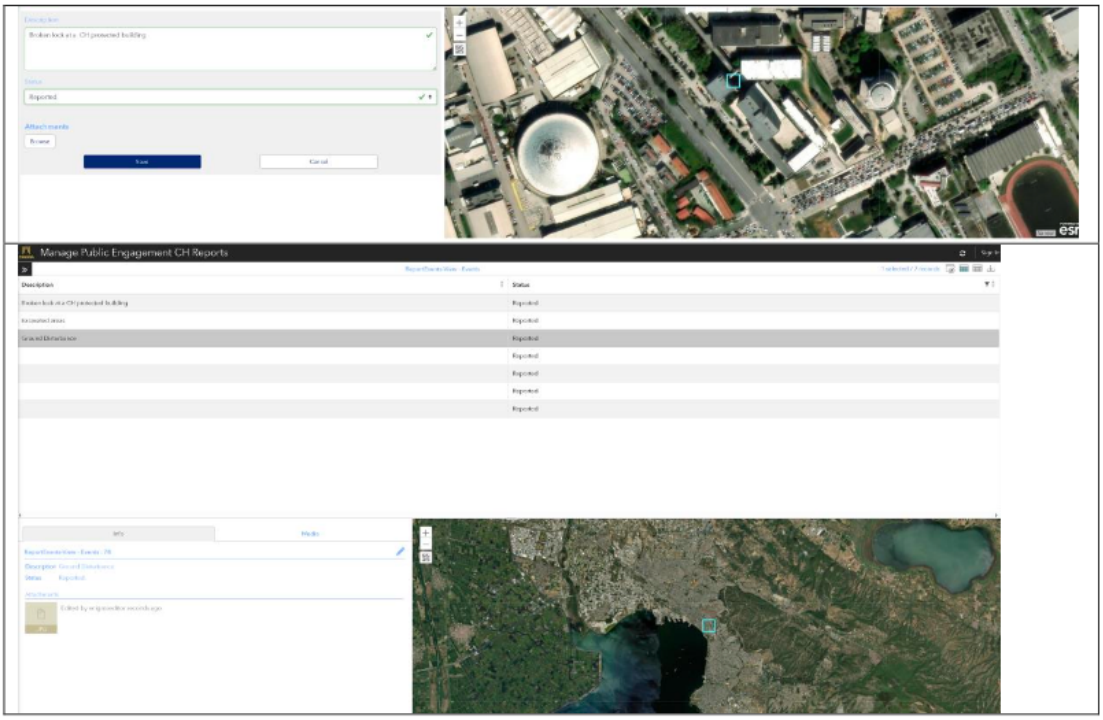


***Figure**: ENIGMA public engagement CH reports management module*

TIPS

Do

- Consider all crowdsources information as truthful inputs, even when wrong.
- Trust ENIGMA's tiered verification to amend wrong data inputs.
- Check and verify all crowdsourced data.

Don't

- Don't skip data quality checks due to the sheer volume of crowdsourcing may provide.
- Don't treat crowdsourced data as reliable, but treat it is well-intended highlights that require further investigation.

3.4.4 Data Licenses: Open Science and CCBY 4.0

DESCRIPTION

CC BY 4.0 is a Creative Commons license that allows data to be shared and reused with proper attribution to the creator. Developed by Creative Commons, it promotes open access, collaboration, and innovation, helping to increase the global visibility of cultural heritage data and disseminate accessible research outputs.

IDEAL SCENARIO

All public data is licensed under CC BY 4.0, enabling broad access and reuse with proper attribution. Publishing cultural heritage assets under this license aids open science and open access initiatives. The open data means cultural assets can reach a wider audience and maximize impact

TIPS

Do

- Apply CCBY 4.0 for public data
- Ensure proper attribution when data is reused based on CCBY 4.0
- Promote collaboration through open access
- Publish your own cultural assets under a CCBY 4.0

Don't

- Avoid using restrictive licenses when possible
- Avoid omitting attribution when sharing data
- Avoid infringing legal, privacy and ethical concerns regarding the license deed

FURTHER RESOURCES

- Creative Commons License, https://creativecommons.org/licenses/by/4.0/deed.en
- Interoperable Europe, CCBY 4.0 https://interoperable-europe.ec.europa.eu/licence/creative-commons-attribution-40-international-cc-40

***Figure**: Based on Creative Commons attribution,* https://creativecommons.org/licenses/by/4.0/deed.en

3.4.5 ENIGMA Technical and System Requirements

DESCRIPTION

A stable technical foundation is essential for delivering and accessing digital training content in cultural heritage projects, requiring certain technical and system requirements. The ENIGMA platform is built with modularity, accessibility, and scalability in mind. It integrates hierarchical training elements, role-based user experiences, and compatibility across devices to ensure a flexible and robust environment for various stakeholders.

IDEAL SCENARIO

All users access ENIGMA's content via supported desktop or mobile environments, with performance-appropriate devices. The system runs reliably, with clear documentation, role-specific access, technical fallback options (e.g., PDF manuals), and user-friendly interfaces. Platform admins manage user roles, monitor system activity, and maintain the platform via a well-documented system architecture and admin tools.

TIPS

Do

- Ensure your device meets minimum specifications
- Access training materials that your system allows (e.g., VR vs PDF)
- Report technical issues via ENIGMA support channels

Don't

- Avoid accessing ENIGMA's VR and interactive environment that don't meet recommended requirements
- Avoid using outdated browsers
- Avoid neglecting software updates

SYSTEM SPECIFICATIONS

ENIGMA recommended specifications: Windows 10+, Intel i5+, 8GB RAM supported on most modern browsers.

Figure: *https://fileroom.com/resources/blog/why-data-management-platforms-are-essential-for-digital-marketing. CCBY 4.0*

3.5 AI: Machine Learning and Large Language Models

Artificial intelligence (AI) and machine learning (ML) are transforming how current practices process, analyze, and interpret cultural heritage data. This section provides best practices for leveraging and applying AI and large language models (LLMs) in tasks like textual analysis, image generation as part of ENIGMA. By following these best practices, users can ensure that AI tools are applied ethically, with high accuracy and transparency. This section highlights how AI can be an asset in cultural heritage, while also fostering critical reflection on its use.

ENIGMA image co-created with AI

3.5.1 AI and Prompt Writing

DESCRIPTION

Writing effective prompts is crucial for getting reliable, relevant, and contextually accurate outputs from Generative AI tools (e.g., ENIGMA's 3D reconstruction tool). A well-structured prompt improves the reliability of the output for expert evaluation in the ENIGMA platform.

IDEAL SCENARIO

A LEA will use ENIGMA to generate a 3D object through AI through a prompt. The prompt includes the role (Generate a 3D object), context (Include all details described), data (textual description etc.). The LEA includes a description of the artefact and provides as many details as possible for the AI-based 3D reconstruction.

Figure 1 - Illustration of a 3D model generated from textual input, presented across six distinct viewing angles. Example of the object description can be accessed in this link. Multiple views video can be accessed here.

TIPS

Do

- Provide a full, detailed description of the artefact (shape, materials, colours, patterns, damages).
- Add contextual information, including historical period or cultural origin when known.
- Iterate: refine the prompt based on the AI's initial output.

Don't

- Avoid vague or ambiguous instructions (e.g., "make it better", "more complete").
- Don't stop after the first try, AI usually get better after a few tries.
- Don't use personal information.
- Don't describe more than one artefact in the same prompt.

FURTHER RESOURCES

- Effective Prompts for AI: The Essentials
- Getting started with prompts for text-based Generative AI tools
- How to Write Better Prompts for 3D model generation

3.5.2 AI and Critical Reflection

DESCRIPTION

Best practices for AI and critical reflection demand a skeptical approach to AI-generated content. Users must actively verify information for accuracy, completeness, and potential biases, recognizing AI's propensity for 'hallucinations' or outdated data. Critical reflection involves understanding the AI's limitations and the potential ethical implications of its output, advocating for robust human oversight at every stage. When incorporating AI, transparency is paramount: users should explicitly disclose its use and rigorously validate any references or data points it provides, adhering to established academic integrity guidelines that prioritize human judgment and source verification.

IDEAL SCENARIO

LEAs and CH Experts utilize ENIGMA, including the AI inputs which speeds up the process of determining an object's legal status. Yet, the users critically review and reflect on the AI results, including 3D reconstruction, similarity score). The users ask themselves, is this data reliable, is it comparable, does it match with the context? As such, the ENIGMA users perform a human-in-the-loop validation process, where human reflection and expertise prevents AI-based decision making and delete error of judgement in object authentication.

TIPS

Do

- Include human-based decision-making for reviewing AI-generated content.
- Rely on the AI and Ethics sections of ENIGMA in case of doubt.

Don't

- Don't blindly trust AI outputs but treat them as hypotheses to be verified with human judgement.
- Don't overlook the potential for AI to introduce or amplify existing cultural bias.

FURTHER RESOURCES

- Safiya Umoja Noble, *Algorithms of Oppression: How Search Engines Reinforce Racism* (2018)
- Shoshana Zuboff, *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power* (2019)
- AI Now Institute: https://ainowinstitute.org/

***Figure**: https://pixabay.com/illustrations/gdpr-privacy-europe-eu-authority-3518254/*

4. FEEDBACK AND IMPROVEMENT

4.1 Stakeholder engagement

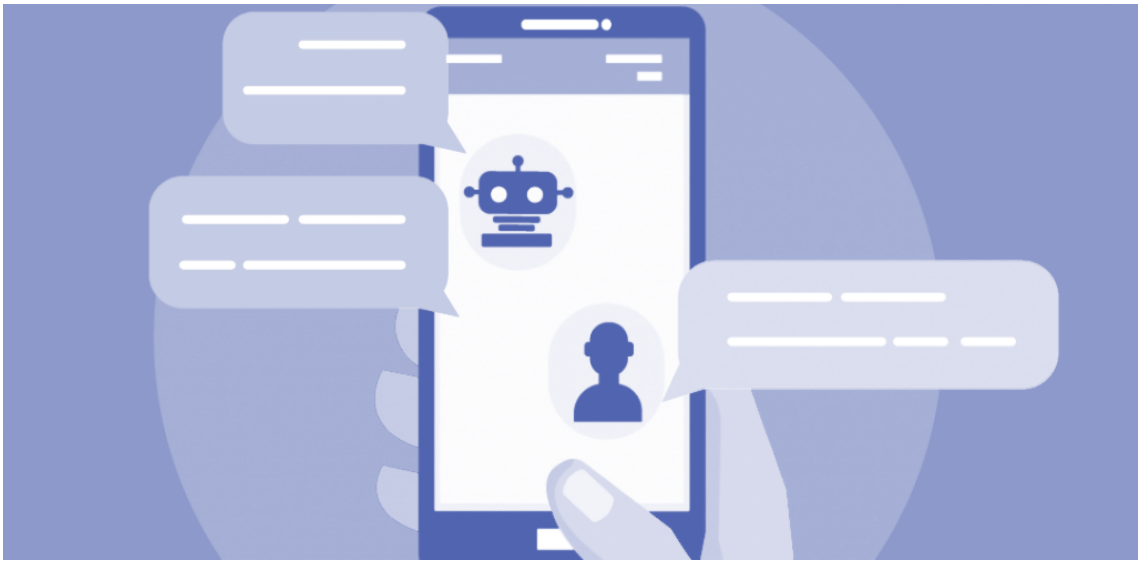
Best practices are not static — they evolve with new insights, changing technologies, and growing communities of users. ENIGMA embraces continuous improvement by actively involving its stakeholders, from law enforcement officers to heritage professionals, collecting field-based feedback, and maintaining open channels for dialogue and refinement. These forums not only refine technical tools but also surface ethical considerations and operational needs that influence best practice design. Participation in these spaces is a way for users to help co-create the system they depend on — and to ensure it evolves in line with the real-world challenges they face. Thus, contributing to these processes is not just encouraged, but considered part of using the ENIGMA platform responsibly.

Public Domain Image

4.2 ENIGMA Q&A / FAQ

To support day-to-day usability and training support for stakeholders and end users, ENIGMA maintains a Q&A and FAQ thread. These are continuously updated based on common user queries, field issues, and tool-specific challenges. FAQs are available for both technical usage and conceptual guidance — helping users apply best practices correctly and confidently. As a best practice, end users are encouraged to utilize the ENIGMA Q&A and FAQ so ENIGMA can grow with user demands and needs. This resource is part of ENIGMA's commitment to clarity and accessibility.

"The Q&A Thread reflects patterns in user experience and provides a space where feedback is directly transformed into helpful answers and updates."



Public Domain Image

4.3 ENIGMA Feedback loops

Feedback is not a one-off activity, but a best practice process integrated within the ENIGMA platform as a means for future enhancement of ENIGMA tools and technology. Each tool, training module, and best practice includes embedded mechanisms for submitting comments, reporting issues, and suggesting improvements. These feedback loops are monitored and assessed regularly, with input routed to developers, content authors, and practice coordinators. These ensure that feedback directly informs platform improvements.

By participating in this loop, users not only improve their own workflows but contribute to the quality and adaptability of the system as a whole. Whether it's a suggested edit to a best practice, a bug report in a tool, or an insight from a field deployment, every contribution helps refine the ENIGMA ecosystem. Sharing what works, what doesn't, or what's missing is a responsible use of the platform — turning personal experience into collective progress.

"In ENIGMA, giving feedback isn't extra work — it's part of doing things right."