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ENIGMA

Endorsing safeguarding, protection, and
provenance management of cultural heritage

3D Reconstruction Tool Manual

User Guide of LEA Officers and Experts

ENIGMA Project

Project title	Endorsing safeguarding, protection, and provenance management of cultural heritage
Project acronym	ENIGMA
Date	27/01/2025

Manual name	3D Reconstruction Tool User Guide_v0.1
Tool name	3D Reconstruction Tool
Beneficiary	Members of the Consortium

Abbreviations

Term	Explanation
CGs	Cultural Goods
CH	Cultural Heritage
DO	Demonstration, Dissemination & Exploitation Objectives
EC	European Commission
PC	Project Coordinator
TG	Target Group
WP	Work Package

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The 3D Generation application is designed to assist customs officers and cultural heritage (CH) experts in analyzing and reconstructing fragmented or damaged CH objects. The platform provides three primary functionalities:

1. 2D Assembly of Objects with Fragmented Parts
2. 2D Damage Detection and Reconstruction of Partly Damaged Objects
3. 3D Model Generation from 2D Images

This manual explains how stakeholders, such as customs officers and archaeologists, can interact with the 3D Generation application when they encounter possible CH objects of interest, such as at airports during baggage check.

1.1 USE CASES

- **Use Case: Customs Officers at Airports**

Capturing Images: Customs officers take 2D photographs of the CH object during baggage checks. The objects can be: a) fragmented, in which case images of individual fragments are required; b) assembled but damaged, a single image capturing the entire object is sufficient.

Uploading Images to the Platform: The custom officer uploads the images to the ENIGMA platform.

Processing with ENIGMA: Depending on the state of the CH object, the 3D Generation application performs different steps: a) Assemble fragments, the application employs artificial intelligence algorithms to assemble fragmented parts into a coherent 3D estimation; b) Detect and reconstruct damage, the applications identifies damage in 2D images and applies automated corrections to reconstruct the object; and c) Generate the final 3D model: the application creates a 3D model from the processed 2D images.

Results Display: The generated 3D model is displayed on-screen for review by the customs officers and CH experts.

- **Image Capture Guidelines**

To ensure accurate reconstruction and processing, the following guidelines must be followed:

Case 1 - Fragments of objects with one visible face (e.g., frescoes): Take clear, high-resolution (i.e., at least 1920x1080 pixels) pictures of each fragment's front face. Ensure the camera is positioned directly in front of the object to avoid distortion. Use adequate lighting to avoid shadows or glare. A flash can be used if it *does not* create reflective spots. Place the fragment against a neutral, non-distracting background (e.g., white or black) to enhance contrast. Save the images as JPEG or PNG (*Figure 1*).

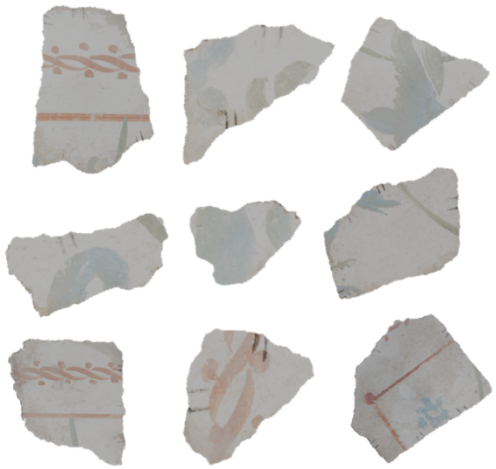

Figure 1: Fragments of a frescoes

Case 2 – Fragments of objects with Multiple faces (e.g., vases or bowls): Capture clear, high-resolution (i.e., at least 1920x1080 pixels) images of both the outside and inside of each fragment. Begin by photographing one side of the fragments (e.g., the outside), ensuring the camera is positioned directly in front of the surface to avoid distortion. Once all fragments have been photographed from this side, turn each fragment over and capture images of the other side (e.g., the inside). Use adequate lighting to eliminate shadows or glare; a flash can be used if it does not create reflective spots. Place the fragment against a neutral, non-distracting background (e.g., white or black) to enhance contrast. Save the images in a common, high-quality format, such as JPEG or PNG (*Figure 2*).

Figure 2: Fragments of a vase. On the top of the image, it is possible to see the outside of the fragments. On the bottom of the image, it is possible to see the inside of the fragment.

Case 3 – Assembled but damaged objects: Take a single, high-resolution (i.e., at least 1920x1080 pixels) image that clearly shows the entire object, including all visible damaged areas. Position the camera directly in front of the object to avoid distortion. Use adequate lighting to highlight the damage without creating shadows or glare; a flash can be used if it does not cause reflective spots. Place the object against a neutral, non-distracting background (e.g., white or black) to ensure the damage is visible and stands out. Save the image as JPEG or PNG. See *Figure 3* as an example.

Figure 3: Assembled object with visible damage.

1.2 RESULTS DISPLAY GUIDELINES

The display interface allows stakeholders to interact with the 3D model in different manners: a) Rotate and zoom into the 3D model for detailed inspection; b) Compare the reconstructed model with reference images from the database; and c) Download the 3D model for further analysis or documentation. An example of the 3D model is depicted in *Figures 4 and 5*.

Figure 4: An example of the reconstructed 3D model with multiple faces. In the ENIGMA interface, the user can interact with the object.

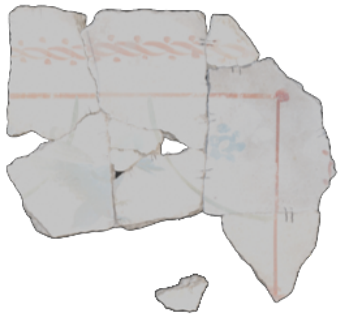

Figure 5: An example of the reconstructed 3D model with a single face. In the ENIGMA interface, the user can interact with the object.

1.3 TEST SCENARIOS

Test Scenario 1

Fragmented Vase Reconstruction: The objective of this scenario is to validate the system's ability to accurately assemble and generate a 3D model from fragmented objects with multiple faces.
Steps: 1) from the test data provided, choose the fragments from a ceramic vase with both the pictures from the outside and inside surfaces; 2) upload the chosen data to the ENIGMA platform. To accomplish that, first input the CG details. Then, in the "Upload documents and Photos" option, add the selected data from Step 1; 3) the system processes the fragments and display the reconstructed 3D model; 4) review the output, verify that all fragments are assembled correctly into the 3D representation.

Test Scenario 2

Damage Detection and Correction: The objective of this scenario is to ensure the system accurately detects and reconstructs damages in assembled CH objects. 1) from the test data provided, choose an assembled ceramic bowl with visible missing parts; 2) upload the chosen data to the ENIGMA platform. To accomplish that, first input the CG details. Then in the "Upload documents and Photos" option, add the selected data from Step 1; 3) The system processes the partially damaged object and displays a reconstructed 2D object with corrected damages and the 3D model of the reconstructed object; 4) review the output, verify that the missing parts in the 2D image are corrected and the 3D model incorporates the reconstructed features.

Test Data

Fragmented Frescoes, Vases, and Bowls: This set of data contains a set of high-resolution images of frescoes, vases, and bowls fragments. For vases and bowls, this includes both outside and inside views. In total, this set will comprise 15 fragmented objects.

Damaged Vases, Bowls, Bust of Statue, Tablet, Stele, and Arrowhead: This set of data contains images of partially damaged vases, bowls, bust of statue, tablet, stele, and arrowhead. In total, this set will comprise 15 partially damaged objects with visible missing parts.

1.4 INSTRUCTIONS FOR INSTRUCTOR

Preparation: Ensure all test data is available and accessible for all the participants.

Training Execution: Demonstrate each action step-by-step, a) show how to capture images following the "Image Capture Guidelines"; b) guide the uploading process of the fragmented and damaged objects to the platform; c) display the final output and explain its significance. Finally, allow participants to practice each test scenario using the provided test datasets.

Assessment: Provide the checklist for trainees to ensure correct execution of each step. Observe and provide real-time feedback during the training. Evaluate the final output and the series of steps taken.

1.5 CHECKLIST FOR TRAINEES

General Preparation:
- ☐ Verify access to the ENIGMA platform and ensure trainee login credentials are available.
- ☐ Confirm availability of test datasets (e.g., fragmented and partially damaged).
- ☐ Ensure the trainee have the equipment to take pictures according to the requirements in the "Image Capture Guideline".

Upload Images:
- ☐ Log in to the ENIGMA platform.
- ☐ Navigate to the "Upload documents and Photos" option.
- ☐ Upload the images to the designated section.

Processing:
- ☐ Confirm that the fragments are accounted for in the image preview.
- ☐ Confirm that damaged areas can be seen in the image preview.

Output Verification:
- ☐ In case of partially damaged objects, Inspect the reconstructed 2D image to confirm all damage has been addressed.
- ☐ Generate the 3D model and verify how the estimation fits with the appearance of a certain object.

Post-Exercise:
- ☐ Complete both test scenarios.
- ☐ Provide feedback on platform usability and any challenges faced.
- ☐ Submit screenshots, 3D models, and notes to the instruction for evaluation.

1.6 ENIGMA PLATFORM STEP-BY-STEP

LEA Officers:

1. Open the ENIGMA platform and navigate to the Provenance Tool - LEA Screen.
2. Click on the "Add a new CG" button on the left-side menu to initiate the process of adding a new cultural good.
3. After feeling the fields demonstrated in *Figure 6*, click the "Next" button to proceed to the image upload stage.

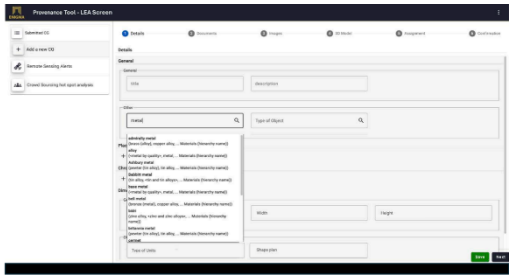

Figure 6: Add a new CG screen.

4. Now in the "Upload documents and photos" step, *Figure 7*, locate the upload section on the right-hand side of the screen. Then, click the "Upload" button to select the pictures of the object.

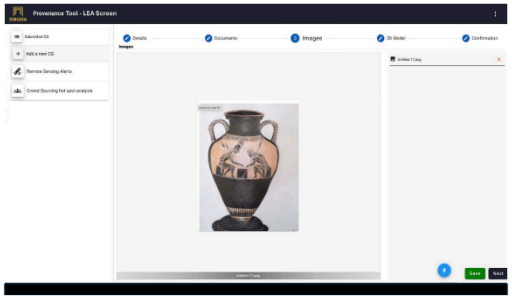

Figure 7: Upload pictures screen.

5. For fragmented objects, if they have two faces, upload images of both the outside and inside of each fragment following the provided capture guidelines. For partially damaged objects, upload a single image showing the complete object, including all visible damaged areas.
6. As each image is uploaded, it will appear in the preview panel on the right. Ensure the images are: clear, high-resolution (at least 1920x1080 pixels), properly oriented, and free of shadows.
7. Once all required images are uploaded and verified, click the "Save" button to store the object data and images. The, click "Next" to proceed to the next steps, such as automatically generating a 3D model or assigning tasks.

Archaeologists/Experts

1. Open the ENIGMA platform and navigate to the "Provenance Tool – Archaeologists / Experts" screen.
2. Click on "Assigned Jobs" in the left-side menu to view a list of CGs assigned by LEA officers, as shown in *Figure 8*.

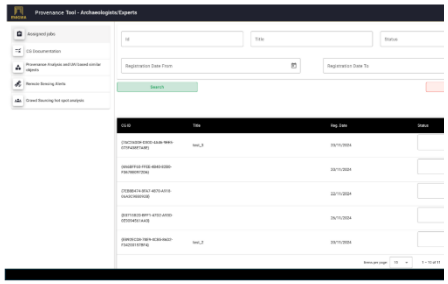

Figure 8: Assigned jobs expert screen.

3. Review the list of assigned items, including the CG ID, Title, Registration Date, and Status.
4. Select an item from the list by clicking the corresponding row to proceed to the evaluation and enrichment process.
5. After selecting an item, the system will display the detailed view in the Details tab, as shown in *Figure 9*.

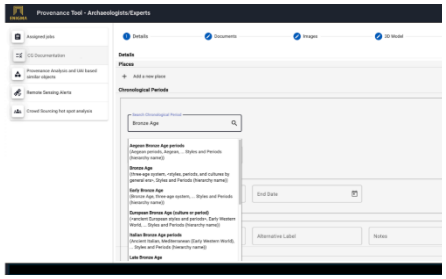

Figure 9: Job details screen.

6. Open the 3D Model tab to review the reconstructed model. If the reconstruction is successful, evaluate the accuracy of the model in comparison to the uploaded images and known attributes. If the reconstruction fails, proceed with the evaluation based on available attributes and data (e.g., material type, dimensions, chronological period).
7. When the 3D reconstruction process fails: a) cross-check the provided attributes (e.g., material, dimensions, chronological period) against known historical and cultural databases; b) use the available images to perform a manual assessment of the object's condition, damage, and possible provenance; c) document any findings of hypotheses.
8. After completing the evaluation and enrichment process, click "Save" to store the updated data. Then, click "Next" to proceed to the final confirmation step, ensuring all required fields are complete. Lastly, submit the enriched CG record for further review or finalization in the ENIGMA platform.