

THE DATASET OF PAINTINGS FROM THE POMPEII ARCHIVE: A TASK OF THE RePAIR PROJECT

*M.C. Napolitano, S. Giudice, E. Gravina, G. Scarpati, A. Zambrano,
G. Zuchtriegel, S. Aslan, M. Khoroshiltseva, L. Palmieri, M. Pelillo, S. Vascon,
O. Ben-Shahar, Y. Ohayon, O. Shahar, A. Traviglia*

ABSTRACT

Il progetto RePAIR intende sviluppare un sistema robotico intelligente in grado di elaborare, abbinare e assemblare, in modo autonomo, reperti frammentati. Il contributo espone uno degli obiettivi del progetto – a cura del Parco Archeologico di Pompei – ovvero la realizzazione del dataset funzionale al sistema robotico, composto da fotografie ad alta risoluzione di pareti dipinte pompeiane e dalla descrizione degli elementi decorativi riconoscibili, adoperando uno strumento web open source.

PAROLE CHIAVE: pittura romana, ricostruzione, Pompei, intelligenza artificiale, ingegneria elettronica

KEYWORDS: Roman Paintings, Reconstruction, Pompeii, Artificial Intelligence, Electronic Engineering

The RePAIR project¹ aims to create an innovative technology to significantly reduce the laborious and frustrating task of physically reconstructing broken artworks. Reconstruction of small artefacts is typically done by experienced operators, possibly with the assistance of dedicated software but when the number of fragments is large (say, in the order of thousands) manual or computer-assisted restoration is simply hopeless. As a result, a significant portion of our global cultural heritage remains inaccessible to scholars and the general public. By leveraging advancements in robotics, computer vision, and artificial intelligence, the project's vision is to revolutionise the field of archaeology by effectively addressing the challenges of reconstruction on an unprecedented scale. This will enable the resurrection of ancient artworks and masterpieces that would otherwise forever remain in fragments. Specifically, the project's aim is to develop an intelligent robotic system that will autonomously process, match and physically assemble large fractured artefacts in a fraction of the time it takes humans to do (*fig. 1*). The level of ambition of the RePAIR project poses several challenges that cannot be satisfactorily addressed with off-the-shelf technologies, and hence brand-new solutions will be developed to push the boundaries of research in the fields of robotics and computer vision (*fig. 2*).

The RePAIR project seeks to recompose the thousand fragments of the ceiling frescoes found in the Casa dei Pittori al lavoro (IX 12 10), part of the *insula* of the Casti Amanti² on the Via dell'Abbondanza in Pompeii. At the time of the eruption in AD 79, restructuring works were in progress inside the buildings, maybe to repair the damage of the AD 62 earthquake, as evidenced by archaeological remains, including the redecoration in progress in an *oecus* of the house. There, the archaeologists found the preparatory drawings on the walls that were made before the colour was applied to the

¹ The project has received funding from the Horizon 2020 research and innovation program of the European Union, under Grant Agreement no. 964854. Alongside the Parco Archeologico di Pompei, the partners of the RePAIR project are: The Ca' Foscari Università di Venezia (co-ordinating body), the Ben-Gurion University of the Negev of Israel, the IIT – Istituto Italiano di Tecnologia, the Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento of Portugal, the Rheinische Friedrich Wilhelms Universität of Bonn in Germany and the Ministry of Culture. Finally, on the project: TSESMELIS *et alii* 2024.

² VARONE 2005, pp. 297-306 (with previous bibliography).



Fig. 1 – The robotic arm moves the wall painting fragments of the Casa dei Pittori a lavoro (Pompeii; photo credit: RePAIR Project).

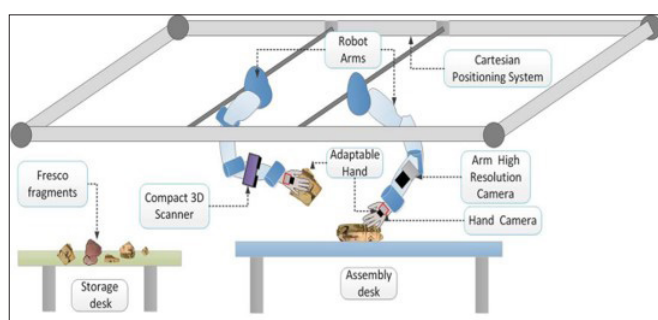


Fig. 2 – The scheme of the robotic intelligence (photo credit: Università Ca' Foscari – Venezia).

of fragments of different sizes, to initially give an overall image of the lost decoration, and then guide the physical reassembly of one or more of the decorative schemes³.

As part of the archaeological research, the fragments are subjected to minimal conservation processes aimed at stabilising the original constituent layers, preventing the loss of mortar, ensuring adhesion and cohesion between the plaster layers, and preventing the so-called “spolvero” (dusting), i.e. the disintegration and loss of the painted surface⁴.

The consolidation processes are to be considered preliminary to a more organic restoration intervention, which will have to include the actual recomposition of the fragments, or at least part of them, guided by the results of the research work for the purposes of a future relocation *in situ* or display in a museum.

The task of equipping artificial intelligence with a functional dataset that allows the recognition of iconographies, within the objective of recomposition of fragments of wall painting⁵, is carri-

fresco (wall painting), mortars, cups containing pigments, amphorae containing the lime from which to produce the plasters, and compasses. This work was interrupted by the catastrophic eruption.

The building was damaged again in the modern era, when it was shattered by the bombing of World War II, which heavily damaged many areas of the ancient city. The *insula* has undergone and is currently undergoing archaeological excavations and restoration but has only been partially exposed.

The fragments of frescoes from the Casa dei Pittori al lavoro, currently kept in the storerooms of the Casina Rustica within the Parco Archeologico di Pompei (PAP), have been the subject of study since their recovery. Over the years they have been subdivided by material and context, grouped in numbered boxes or placed on numbered shelves, to ensure their visibility and availability.

In the RePAIR project, artificial intelligence and an open-source web-based tool is being used to piece together the jigsaw puzzle, in this case comprised of thousands

³ It is not possible, in this paper, to trace a detailed history of the studies on the recomposition of frescoes in the field of archaeology. Nevertheless, it is necessary to mention the importance attached to fragmentary paintings since the establishment of the Centre d'Etude des Peintures Murales Romaines by A. Barbet, C. Allag and F. Monier in 1984. For a recent summary on the subject: CORALINI 2024, pp. 1156-1159.

⁴ Specifically, the first process consists of the cleaning of the plaster surface to remove deposits that can be detached with relative ease. This step is carried out delicately without using liquids, bearing in mind that some pigments or areas of the fresco may have different degrees of carbonation and, consequently, be of varying fragility. This first step is followed by a gentle cleaning of the surface with water mixed with a mild biocide, which also serves to prevent any biological attacks. Lastly, the pre-consolidation of the mortar, necessary to re-establish the cohesion of the constituent material is performed through imbibition with nanoacrylic resins in an aqueous solution in varying percentages and for varying waiting times, so as to allow the consolidating agent to penetrate easily into the plaster. In addition, where necessary, consolidation processes are performed on the painted surface by applying a low-residue fixative with a brush in order to prevent the loss of pigments without leaving residues or altering the original appearance and quality of the painting.

⁵ Thickness of fractured surfaces will be assessed directly from the scanned point clouds, and colour characteristics of the mortar layers will be processed via colour histograms; those aims are another specific task of the project.

ed out using high-resolution orthophotos relating to pictorial walls from Pompeii. The objective of the work is not only the images, but also the description of the preserved and recognizable decorative elements present within the group of 400 photographs of Pompeian paintings.

The first phase of the work (*fig. 3*) is the selection of wall paintings through the study of bibliographical sources. Then the images of the chosen paintings are located within the digital photographic archive of the PAP. The selected images are then divided into groups following the convention adopted by August Mau in 1882; a typology, still generally in use that categorises Pompeian wall painting into four styles based on different iconographic characteristics, compositional schemes, and relating to four chronological periods between the second century BC and AD 79⁶.

This subdivision is followed by the first description of the paintings. In this first inventory, the list of iconographic motifs forms the labels that define each recognisable iconographic element on the image. These terms have been chosen on the basis of the form or ground of appeal. The nomenclature used is an open, modifiable and constantly expandable vocabulary⁷.

To perform these tasks, the Computer Vision Annotation Tool (CVAT) is used, which is an open-source web-based tool designed for annotating digital images and videos. CVAT is particularly useful for its user-friendly interface, collaborative features, and ability to handle large datasets. It allows the user to focus on selected parts of the fresco, zoom in and out, mark motifs interactively with a bounding box, and then select one of the designated labels associated with this box⁸ (*fig. 4*).

Despite the robust features of CVAT, the classification of frescoes and the identification of motifs were challenging tasks since the quality of frescoes varied significantly, with some suffering from contrasting light conditions, obstructions, and/or faded paint.

So, each decorative element is defined, within the CVAT, by the specific terminology chosen (Glossary), which composes, together with the images, the dataset to be used by the artificial intelligence.

The RePAIR Project is a groundbreaking endeavour that underscores the importance of integrating advanced technologies in archaeology. By seamlessly combining digitisation, robotics, and artificial intelligence, this project showcases their vast potential in enhancing archaeological research and restoration efforts.

The digitisation of thousands of fresco fragments represents a fundamental step that lays the groundwork for subsequent research activities. This accomplishment has led to the creation of an

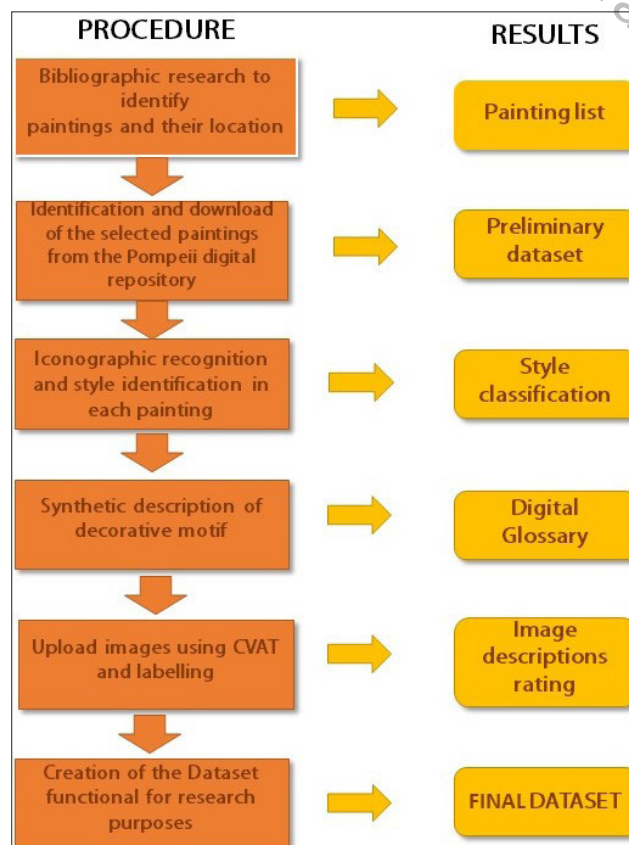


Fig. 3 – The flowchart of the methodology used and described in this preliminary paper (photo credit: Parco Archeologico di Pompei).

⁶ This subdivision is used only to group the images in the dataset and the related notes on the iconography; therefore, it does not possess any chronological definition or phases that take into account any ancient restoration of the painted walls.

⁷ In addition to technical terminology, in some cases a simplification of the nomenclature has been opted for, avoiding greater detail, which are not useful to the identification of the “form” and therefore of its recognition by artificial intelligence. For the development of the dataset-specific glossary, the TECT project’s glossary will be used as a reference (TECT 1 2015).

⁸ All annotations were saved in the interactive tool and are available to download and use with one of several working formats like CVAT or COCO.

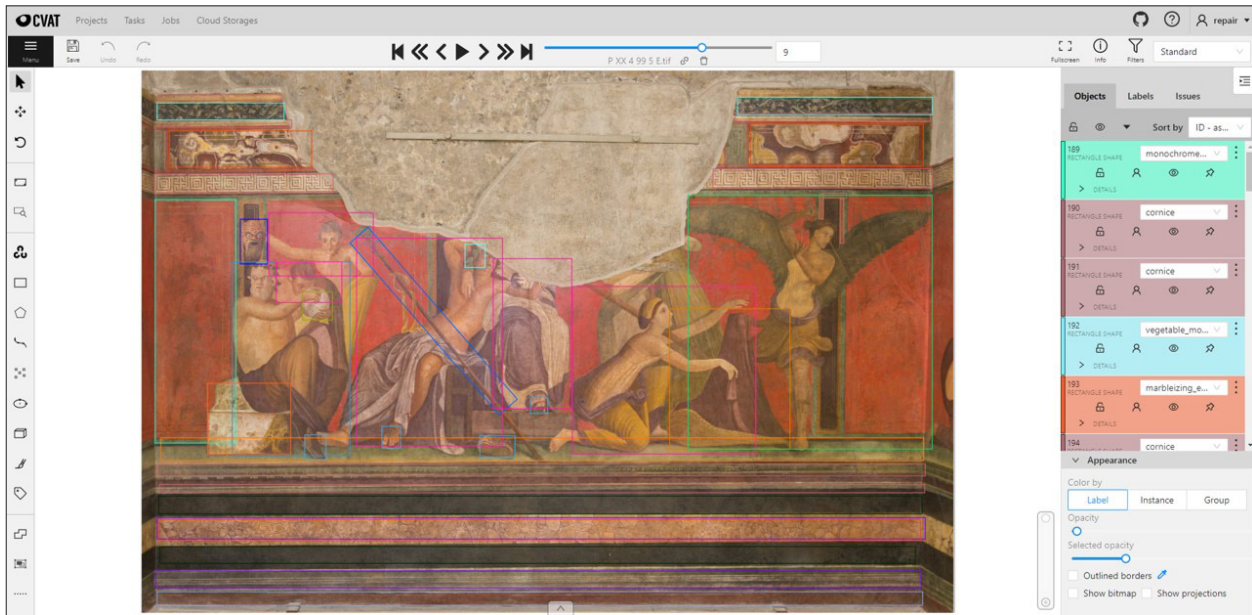


Fig. 4 – The Computer Vision Annotation Tool, the open-source web-based tool used to create the dataset (photo credit: Ben Gurion University of the Negev - Parco Archeologico di Pompei).

extensive dataset documenting the identified and extracted iconographic images concealed within the fragments, providing valuable insights for future investigations. Additionally, a comprehensive glossary is being developed, enriching our understanding of fresco-related concepts and terminology. The dataset's versatility and adaptability are key aspects, allowing it to be replicated and customized for diverse scientific research pursuits. This outcome establishes a robust basis for future research activity that harness the power of artificial intelligence.

These achievements open up new horizons in exploring and understanding our cultural heritage, ushering in a new era of archaeological investigation fueled by cutting-edge technologies. By leveraging these advancements, we are poised to deepen our knowledge and appreciation of the past, paving the way for innovative approaches to preserving and interpreting our shared history.

Maria Cristina Napolitano
Parco Archeologico di Pompei
mariacristinanapolitano2@gmail.com

Elena Gravina
Parco Archeologico di Pompei
elena.gravina@cultura.gov.it

Alessandra Zambrano
Parco Archeologico di Pompei
alessandra.zambrano@cultura.gov.it

S. Giudice, G. Scarpati, G. Zuchtriegel
Parco Archeologico di Pompei

S. Aslan, M. Khoroshiltseva,
L. Palmieri, M. Pelillo, S. Vascon
Ca' Foscari - Università di Venezia

O. Ben-Shahar, Y. Ohayon, O. Shahar
Ben Gurion - University of the Negev

A. Traviglia
Istituto Italiano di Tecnologia

BIBLIOGRAPHY

CORALINI A. 2024, *Pareti dipinte, dal restauratore al pittore. Materialità e filologia dei cantieri*, in *Pareti dipinte. Dallo scavo alla valorizzazione*, a cura di A. Coralini, P. Giulierini, V. Sampaolo, F. Sirano, Roma, pp. 1155-1209.

- TECT 1* 2015 = SALVADORI M., SCAGLIARINI D., CORALINI A., con DIDONÈ A., HELG R., MALGIERI A., SALVO G., *TECT 1. Un progetto per la conoscenza della pittura parietale romana nell'Italia settentrionale*, Antenor Quaderni 34, Padova.
- VARONE A. 2005, *L'insula pompeiana dei Casti Amanti (IX 12): dallo scavo alla fruizione*, in *Domus romane: dallo scavo alla valorizzazione*, Atti del convegno (Brescia aprile 2003), a cura di F. Morandini, F. Rossi, Milano, pp. 297-306.
- TSESMELIS *et alii* 2024 = TSESMELIS T., PALMIERI L., KHOROSHILTSEVA M., ISLAM A., ELKIN G., SHAHAR O.I., SCARPELLINI G., FIORINI S., OHAYON Y., ALALI N., ASLAN S., MORERIO P., VASCON S., GRAVINA E., NAPOLITANO M.C., SCARPATI G., ZUCHTRIEGEL G., SPÜHLER A., FUCHS M.E., JAMES S., BEN-SHAHAR O., PELILLO M., DEL BUE A., *Re-assembling the past: The RePAIR dataset and benchmark for real world 2D and 3D puzzle solving*, in *Neural Information Processing Systems Datasets and Benchmarks Track*, Vancouver.

