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Use of archaeological archives: 3D visualization of old two-dimensional drawings

Keywords: Cultural heritage, Augmented reality archaeology, 3D visualization.

Summary

The two-dimensional plans of older archeological excavations describe unique historical phases, giving a wealth of information about them. These plans, implemented by hand, are supplemented by photographs and diary-descriptions of the excavations. Today, archival material is being digitized and provides a unique source of knowledge about both history and science of archeology over time.

As part of the Smart Eye research project, the old two-dimensional plans (horizontal and vertical sections) of the archeological trenches of the Toumba and Thermi excavations in Thessaloniki (Greece) were first digitized in order to be integrated into an Augmented Reality (AR) application which will provide information to future users about the archaeological activity that has taken place in these areas in the past. Then, the three-dimensional models of archeological excavations or even wider areas in which archaeological researches have been carried out, were created and texture was applied to these models. Various methodologies and software programs were tested to finally select the most suitable one for introducing textured models into the Augmented Reality application.

In this regard, legacy excavation documentation data can be better used, presented to a wider audience, not necessarily scientific, or even compared to other contemporary data obtained with modern technologies of collecting, processing and displaying 3D information (e.g., laser scanning, UAV and close-range photogrammetry).

Introduction

Nowadays archaeological research includes a great number of digital data obtained during excavation. This data, together with archival material (drawings, maps, images, texts, manuscripts, books, diaries etc.), is considered a basic tool for interpreting the events that took place and contributed to the formation of an archaeological site. For example, the 3D models used to document excavation sites allow researchers to navigate virtual spaces where excavation activity can be reconstructed. The creation of these 3D environments aims not only at dissemination and education but also at historical and architectural analysis (Galasso F. *et al*, 2021). It is important to note that archaeological visualization is a documentary as well as an interpretative method, a way of understanding and not just a representation of material remains. In this sense, archaeological visualization can also serve as a methodology for bridging theory and practice of the archaeological knowledge production (Opgenhaffen L., 2021).

Before the digital era, archaeologists documented objects, structures, and sites using traditional techniques and methods, for example, using 2D representations of reality in pencil on paper and using local reference systems. This documentation process involved carefully selecting the sections and placing the elevation measurements. From the beginning, the construction details and the scale were chosen to represent in two dimensions objects, structures, and sites. As a rule, an archaeological drawing was a handmade drawing representing 2D sections, profiles or projections on selected planes of 3D objects and sites. The content of the drawing was not strictly standardized, relied on expert knowledge, and it

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could contain sketches of different details (Agre G., Hristov V., 2013). These drawings, as accurate and precise as they were, conveyed an interpretation of reality.

On the other hand, the latest 3D recording techniques (e.g. laser scanning, UAV and close-range photogrammetry) offer excellent data sets, which can be reviewed whenever necessary and processed, even if the framework of the archeological excavation no longer exists (a reality that constitutes the rule and not the exception in the case of archaeological field work). Moreover, a digital record does not replace the need to study and understand the recorded objects, structures, and sites, and a digital 3D model does not replace the archeological documentation and the importance of thinking spatially (Kinzel M., 2022).

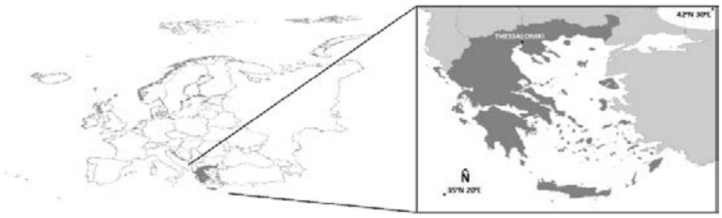
In any case, «detailed engagement» with 3D recording technologies requires the conceptual embrace of spatial thinking. This requires re-evaluating the concept of space and its representations in archaeology and, in particular, of the way in which 3D geometries move beyond traditional 2D representations to provide a framework for new 3D digital products that represent the digital recording of an archaeological excavation (Nobles G. R., Roosevelt Ch. H., 2021). Moreover, the combination of archival drawings and recorded descriptive information and the ability to work on a basic level with several measurement systems at the same time, can be of great help in reconstructing objects, structures and sites in a full three-dimensional way (Beex W., 1995).

In this context, the Smart Eye research project, carried out by the Aristotle University of Thessaloniki (Greece), aims to reconstruct in 3D the archeological trenches of the excavation projects conducted at two archaeological sites in the wider area of the city of Thessaloniki, that is Thessaloniki Toumba and Thermi, using digitized legacy hand-drawn two-dimensional drawings (plans and sections). Once the three-dimensional models of archeological excavations or even wider areas in which archaeological investigations have been carried out, are created, they are given texture. The textured 3D models are then integrated into an Augmented Reality (AR) application which will provide information to future users about the archaeological activity that has taken place in these areas in the past. Various methodologies and software programs have been tested to finally select the most suitable one for introducing textured models into the Augmented Reality application.

The Toumba and Thermi Archaeological Excavations in Thessaloniki

The Thessaloniki Toumba Excavation (Figure 1) is a research program of the School of History and Archaeology, at Aristotle University of Thessaloniki (AUTh), Greece. The excavation project has brought to light significant findings and have contributed significantly to the progress of archaeological research (investigation of the various aspects of the prehistoric habitation in the area, of the social, political and economic structures, and of their transformation within a long-standing prehistoric community etc.) (Andreou *et al.* 2022; Andreou 2010) The project has also provided undergraduate and postgraduate students with extensive training in excavation methods (Stamnas A. *et al*, 2021). Furthermore, through the collaboration with other departments of the AUTh, such as the Department of Cadastre, Photogrammetry and Cartography, School of Rural and Surveying Engineering, it has been made possible to use a great number of up-to-date documentation methods, practices and techniques (e.g., the use of 3D laser scanning, terrestrial and airborne photogrammetry etc).

In the wider area of the contemporary settlement of Thermi (Figure 1) extensive research has been carried out by the Ephorate of Antiquities of Thessaloniki Region bringing to light important findings dating from the Neolithic to the Bronze Age, and to the Iron Age, the Archaic and the Classical-Hellenistic periods. The domestic, funerary and other archaeological remains unearthed (Skarlatidou Eu. *et al*, 2011; Pappa et al, 2018; Pappa et al, 2019) reveal the history of the area over millenia of habitation and use of space.

I) 

II) 

III) 

Figure 1: (I) Thessaloniki, located in Northern Greece, central Macedonia (Source: Google Earth), (II) Thessaloniki Toumba Excavation as seen from above (Source: Thessaloniki Toumba Excavation archive) and (III) Thermi Excavation (Source: https://www.archaiologia.gr/ blog/2013/09/09/νέες-ανασκαφικές-έρευνες-στη-νεολιθι-2/).

Archival drawings of the archaeological excavations

In both archeological sites, systematic excavations were carried out for years bringing to light successive construction phases, remains of foundation walls, vessels, tombs, skeletons etc. All of these were thoroughly measured and recorded by the archaeological teams of the Aristotle University of Thessaloniki and the Ephorate of Antiquities of Thessaloniki Region. For the purposes of the present research project (SmartEye), the two-dimensional drawings (floor plans, sections, guide maps) of the findings of these excavations were located, digitized and the corresponding two-dimensional digital geometric data were created in AutoCAD© software (Figure 2, 3). In these drawings, stones, mudbricks, human and animal skeletons, vessels, and ground lines were designed as different layers. These digital drawings formed the basis for the creation of the three-dimensional representations of the excavations of Toumba and Thermi (Figure 4).

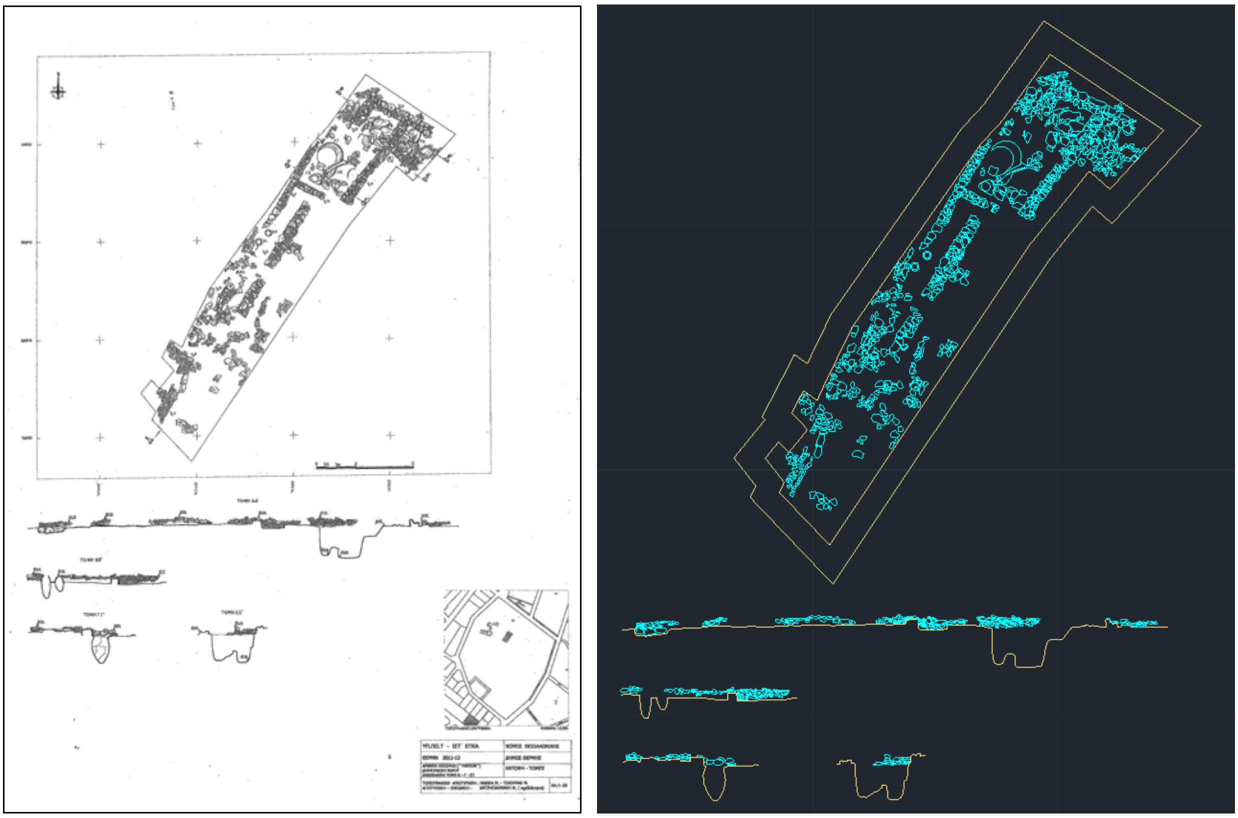


Figure 2: Top view, cross sections and guide map of the building remains in the section B-G-E-F, in the center of the plateau of the "Trapeza" (Bank) of Thermi Excavation (Source: Ephorate of Antiquities of Thessaloniki Region) and the corresponding digital geometric data processed in AutoCAD© software.

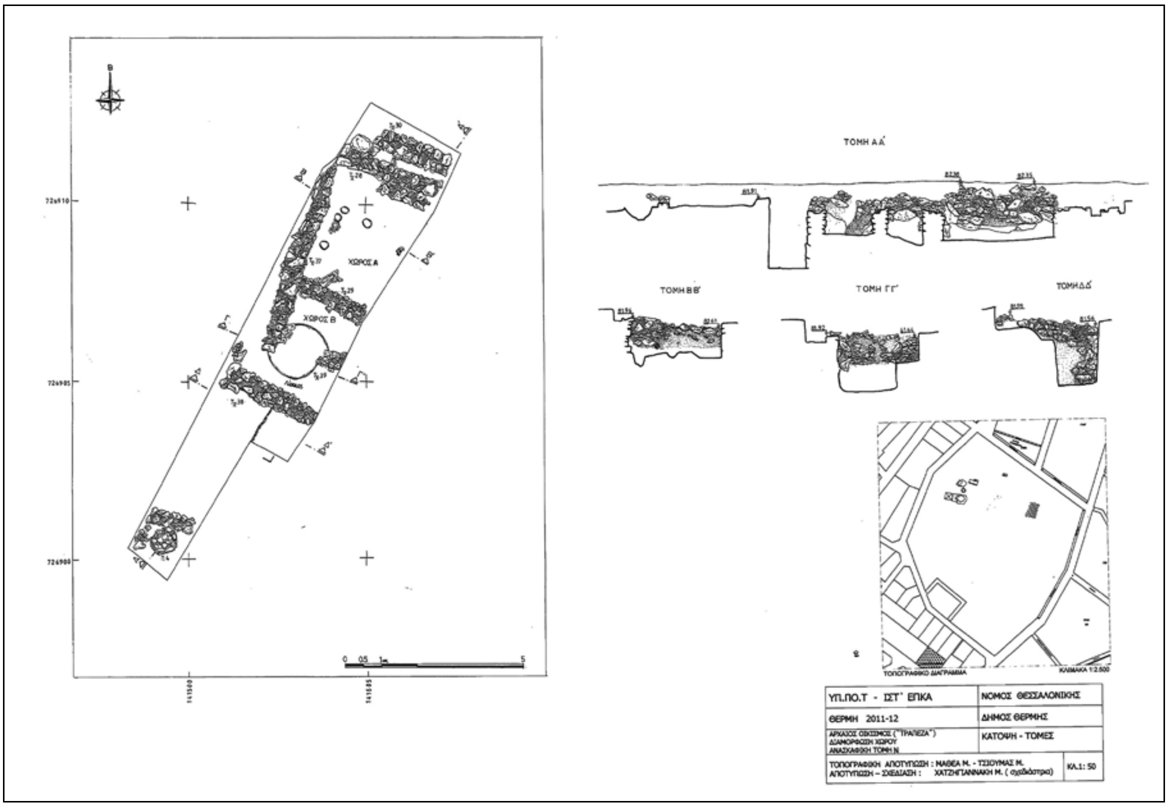


Figure 3: Top view, cross sections and guide map of the building remains in the section N of Thermi Excavation (Source: Ephorate of Antiquities of Thessaloniki Region).

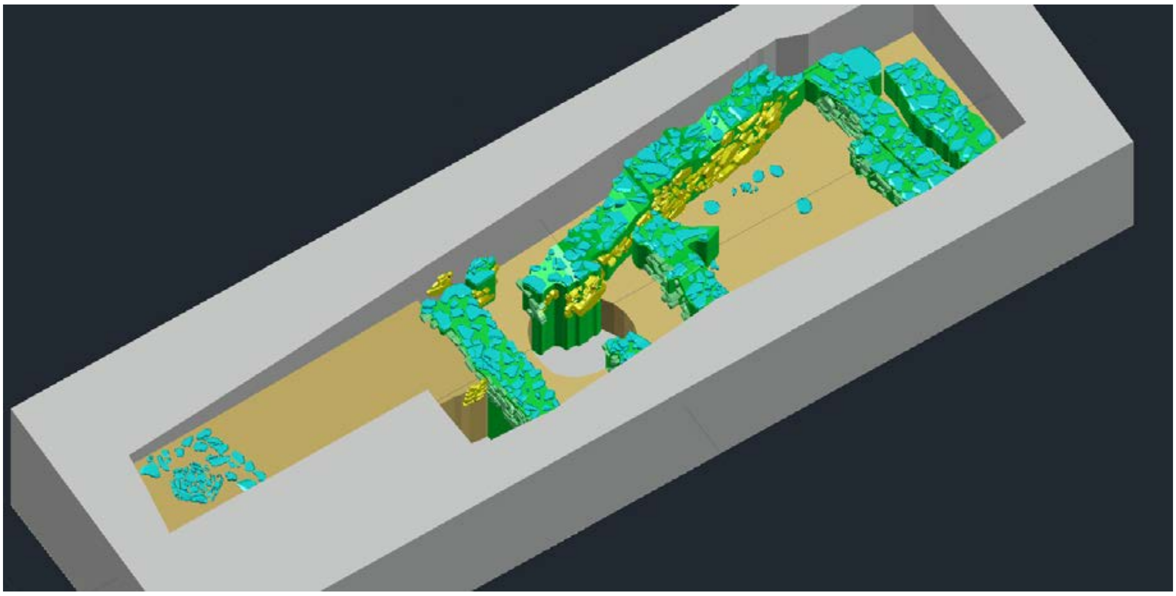


Figure 4: Isometric projection of the building remains in the section N of Thermi Excavation.

The three-dimensional models of archeological excavations

The creation of the three-dimensional models with the texture of the archeological trenches of the Toumba and Thermi excavations in Thessaloniki was made from the available 2-dimensional digital geometric data was tested on the following softwares: (I) Autodesk Maya©, (II) Autocad CIVIL 3D Metric©, (III) Autodesk Revit© and (IV) Autodesk 3DS Max©. The software that was finally chosen was 3DS Max, as it provides the best optical result (solid geometry and photorealistic 3D graphics) and is compatible with the Unity platform on which the augmented reality application was developed.

(I) Creation of three-dimensional models in Autodesk Maya©

From the available 2D digital geometric data processed in AutoCAD© software, 3D textured models were created in Autodesk Maya© software. For this purpose, raster images were applied repeatedly over the entire surface of the 3D solid objects (Figure 5). These images were selected and applied through the software library in the Hypershade window (Figure 6). First, parts of the images of the archaeological trenches were selected in Photoshop and 3000pixelsx3000pixels patterns were created for each object. These parts of the images were then inserted and modeled in the UV Editor window separately for each 3D solid object created.

Figure 5: Application of raster images in order to add texture to 3D solid objects in Autodesk Maya© software.

The basic steps followed to add a surface texture to 3D solid objects (stones, soil, walls, ceramics, etc.) using the Hypershade window were as follows: (I) creation of a new material, (II) selection of the color, (III) selection of the corresponding image file, (IV) assignment of the image to the selected 3D solid object and (V) adjustment of the image individually on each surface of the solid object. The 3D model was exported in *.fbx format so that there is the possibility of viewing the 3D model in the 3D Viewer application. Unfortunately, parts of the surfaces (materials and textures) of these 3D models remain in-active in the viewing window of the Unity software (Figure 7).

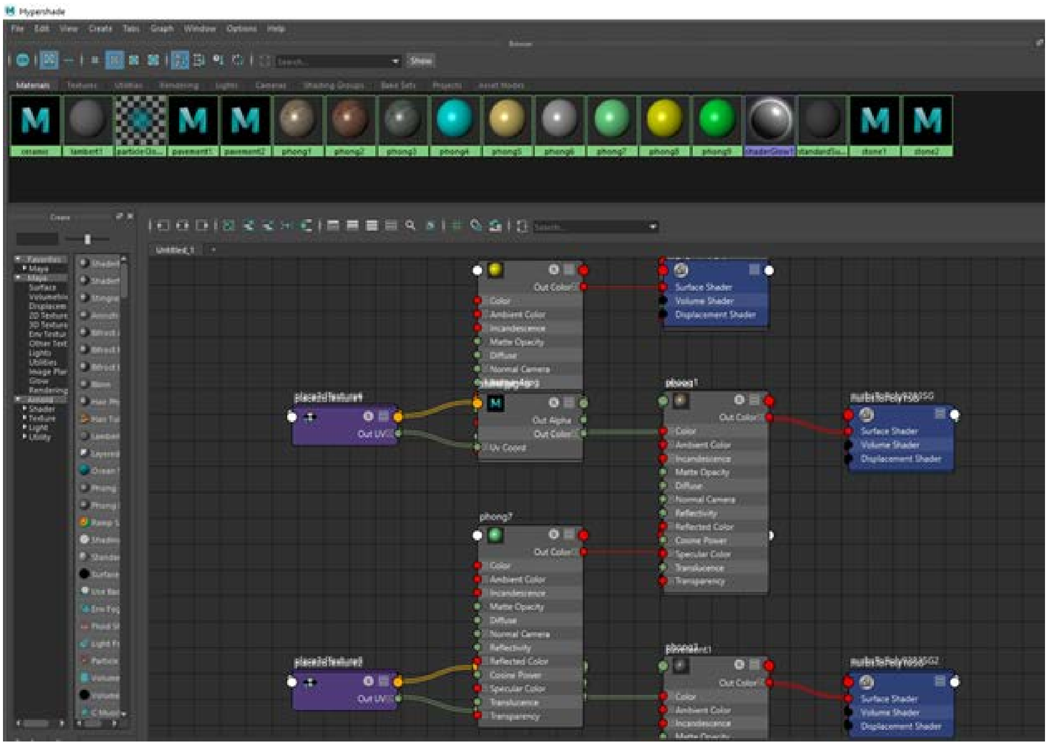


Figure 6: Procedure of applying raster images to add texture to 3D solid objects in Autodesk Maya© software (Hyper-shade window).

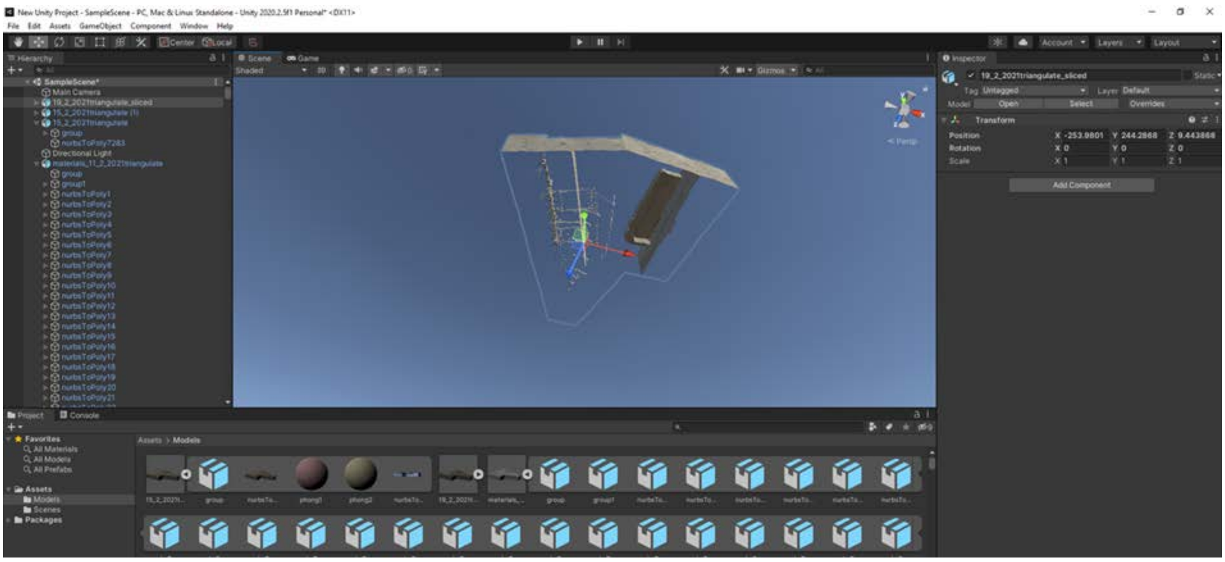


Figure 7: View of a 3D model (from Autodesk Maya©) with texture in the Unity software.

(II) Creation of three-dimensional models in Autocad CIVIL 3D Metric©

The original geometric 2D drawings were also organized in Autocad CIVIL 3D Metric© in individual types in order to distinguish between the different types of entities that compose it (e.g., ground points, wall stones, skeletons, vessels, etc.). For the representation of the 3D surface of the ground, the creation of a digital model in the form of a triangle file (*.tin) was chosen. Then, the ground surface was created according to the initially available elevation information of each archaeological trench (Figure 8).

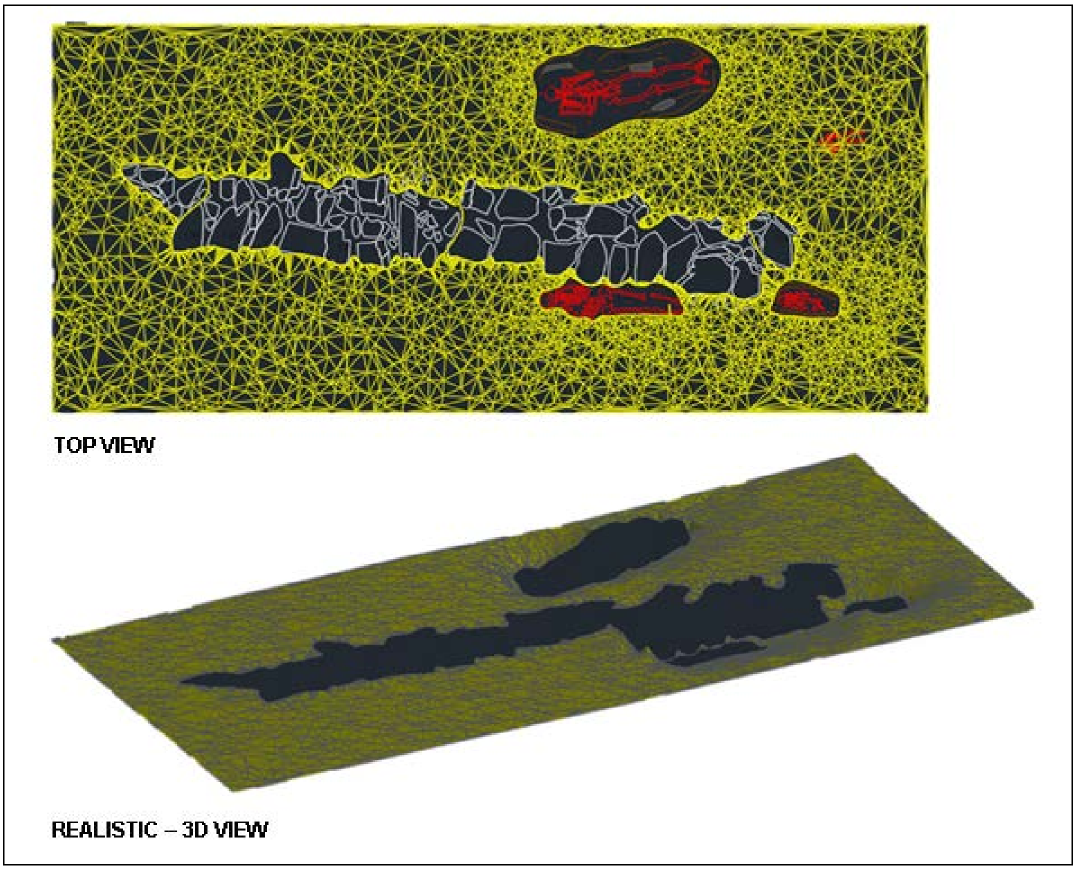


Figure 8: 3D representations of the ground surface of a trench in Autodesk CIVIL 3D Metric© software.

Manual point generation was performed taking into account the elevation differences between the ground and the other entities of the archaeological trench (e.g., elevation difference between ground and archaeological excavation walls), and textual descriptions from the archaeological excavation diaries. A series of surface treatment tools were then used, starting with the generation of the available altitude information using different mathematical densification models (the Natural neighbor interpolation model, the Kriging method). Subsequent visualization techniques (Render) and application of different materials were then applied (Figure 9). Similar surface editing procedures were used on other entities such as wall stones which practically interfere with the original 3D solids by applying individual distortion filters. (Figure 10).

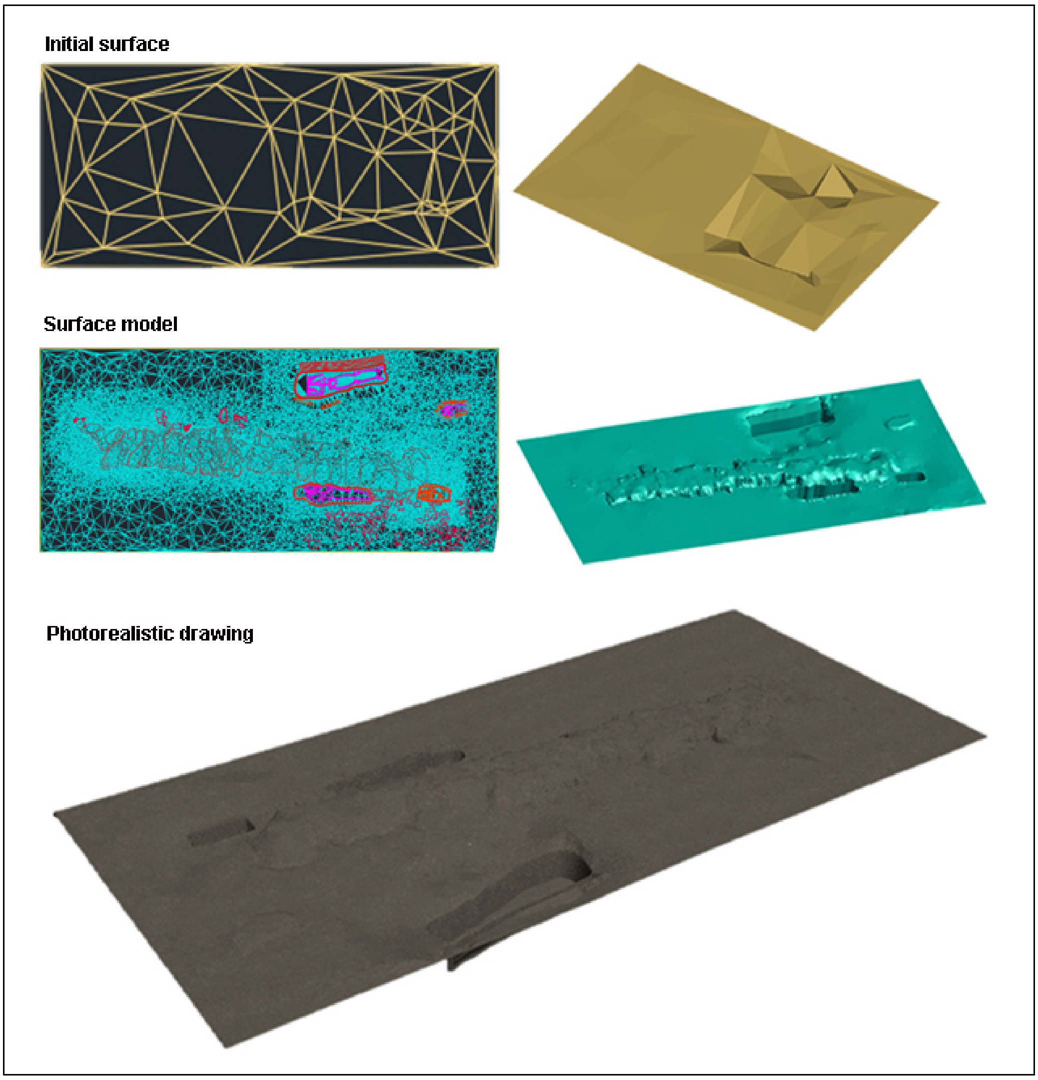


Figure 9: Representation of the ground model using the initially available geometry of the archaeological excavation in Autodesk CIVIL 3D Metric© software.

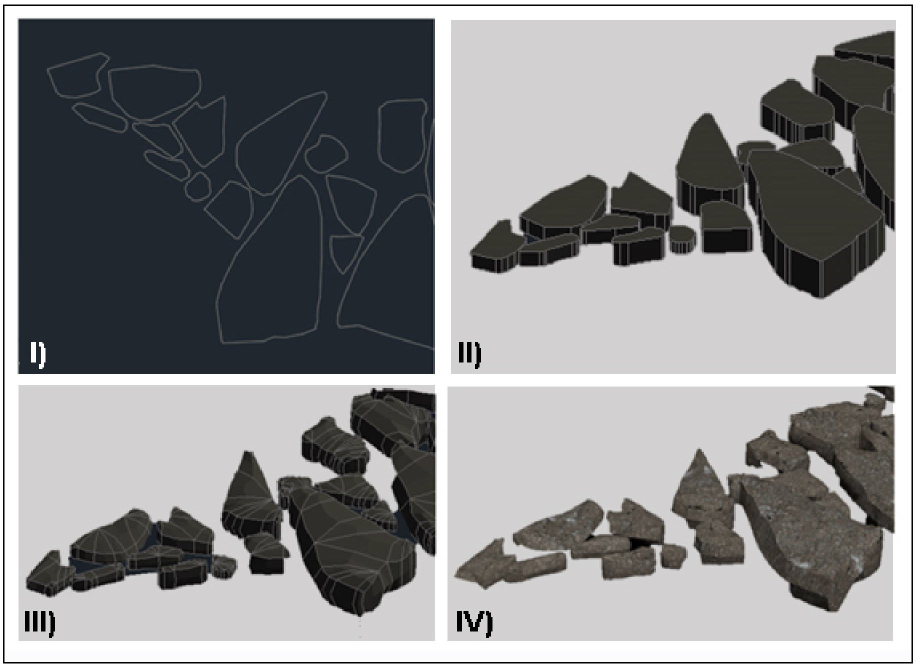


Figure 10: Process of creating and editing 3D models of wall stones in Autodesk CIVIL 3D Metric© software, starting from the original 2D geometric pattern (I) and using the solid processing / molding tools (II) extruding the surface, (III) molding 3D objects, (IV) texturing.

(III) Creation of three-dimensional models in Autodesk Revit©

Autodesk Revit© software allows the creation of a ground surface through points the position and height of which are defined using various tools (e.g., Toposurface, In place Mass). These tools have significant limitations that make it difficult to create a ground surface with steep slopes and gradations (Figure 11). Respectively, for the creation of stones the editing features offered by the software are not satisfactory (Figure 12). The result of the editing procedure is considered not realistic (either because simple deformations increased the size of the file, without providing in return an acceptable result, or because the procedure itself is exceedingly time-consuming).

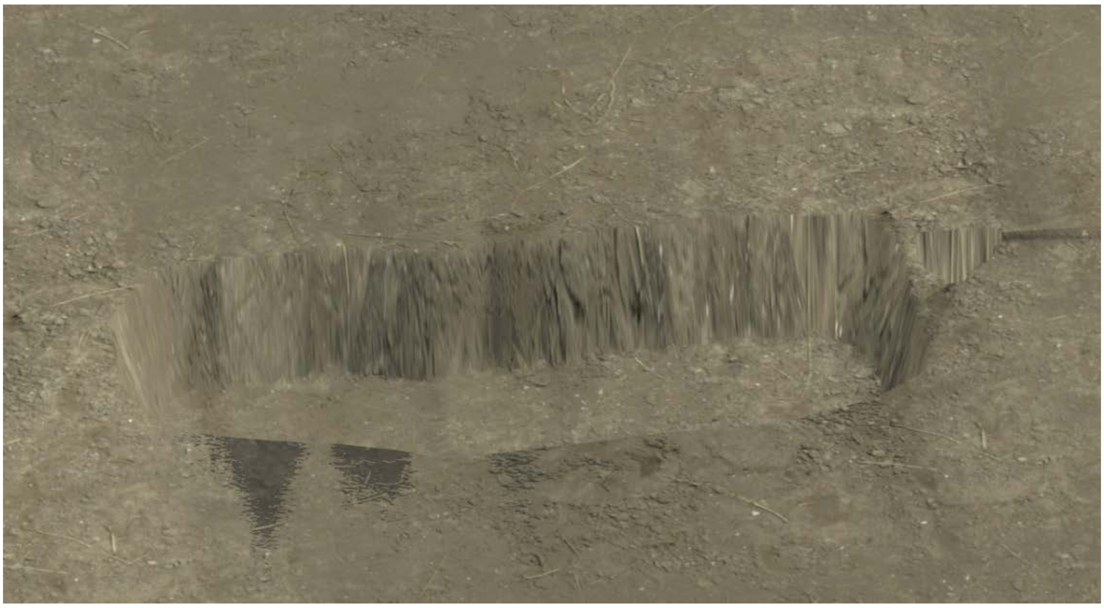


Figure 11: 3D representation of the ground surface of a trench in Autodesk Revit© software.

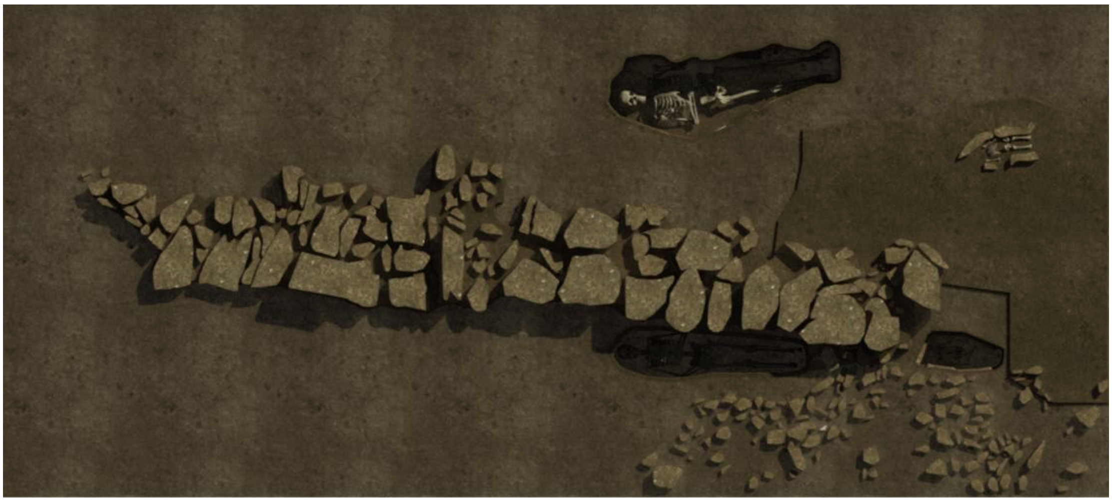


Figure 12: 3D representation of stones and the ground surface of a trench in Autodesk Revit© software.

(IV) Creation of three-dimensional models in Autodesk 3DS Max©

The procedure followed in Autodesk 3ds Max© for the creation of 3D objects (e.g., ground surface, wall stones, skeletons, vessels, etc.) was executed through polygons that offer more detail and precision. In addition, the software allows the creation of the materials and the textures necessary for the realistic illustration of these 3D objects (Figure 15, 16, 17).

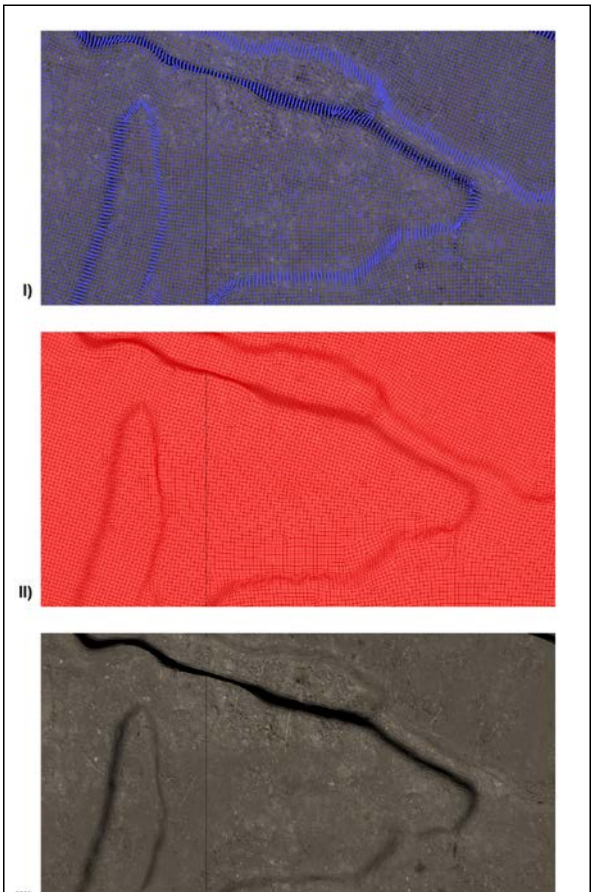


Figure 13: 10: Process of creating the ground surface of a trench in Autodesk 3DS Max©: (I) creating points and moving selected points to the desired height, (II) smoothing the surface of the ground and (III) texturing.

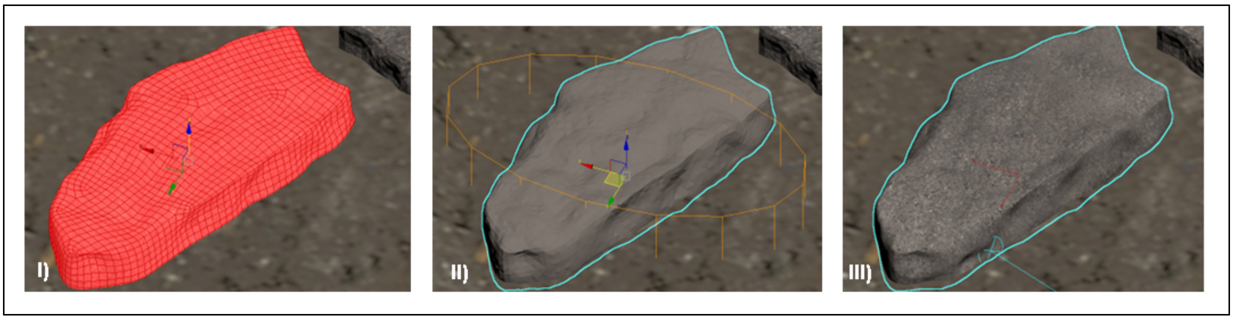


Figure 14: Process of editing wall stones in Autodesk 3DS Max© software: (I) creating the 3D object, (II) sculpting the surface, (III) texturing.

The process of creating the ground surface of a trench in Autodesk 3DS Max© comprises of 3 stages: (I) creating points and moving selected points to the desired height and (II) smoothing the surface of the ground and (III) texturing (Figure 13). The process of editing wall stones comprises of 3 stages: (I) creating the 3D object, (II) sculpting the surface, (III) texturing (Figure 14). Creating 3D objects in Autodesk 3DS Max© proved to be the most suitable of all the methodologies and software programs tested for introducing textured models (Figure 15, 16, 17) into the Augmented Reality application.

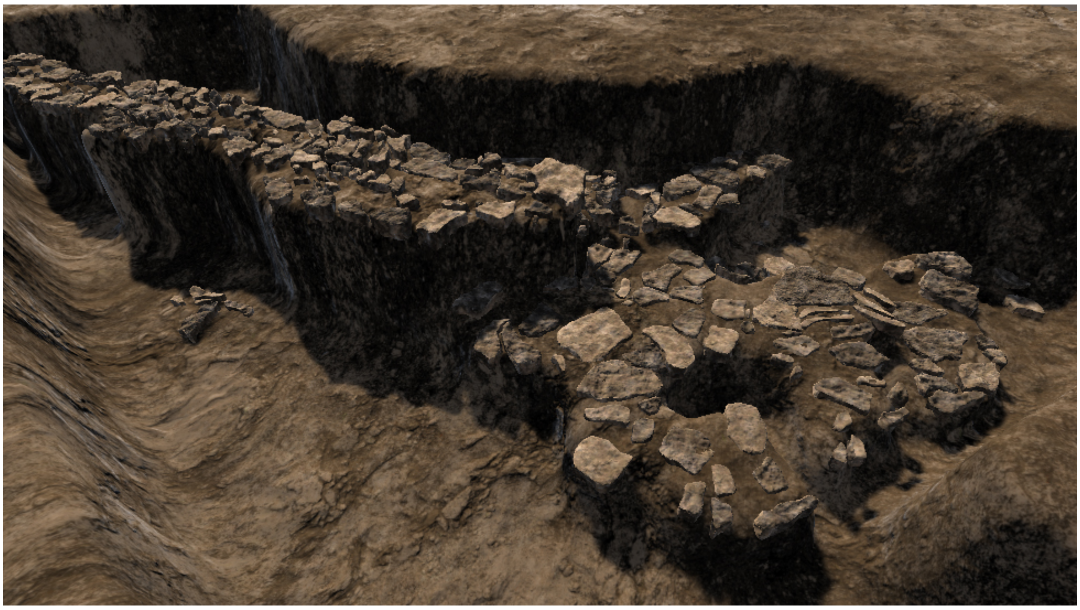


Figure 15: 3D representation of stones and the ground surface of a trench in Autodesk 3DS Max©.

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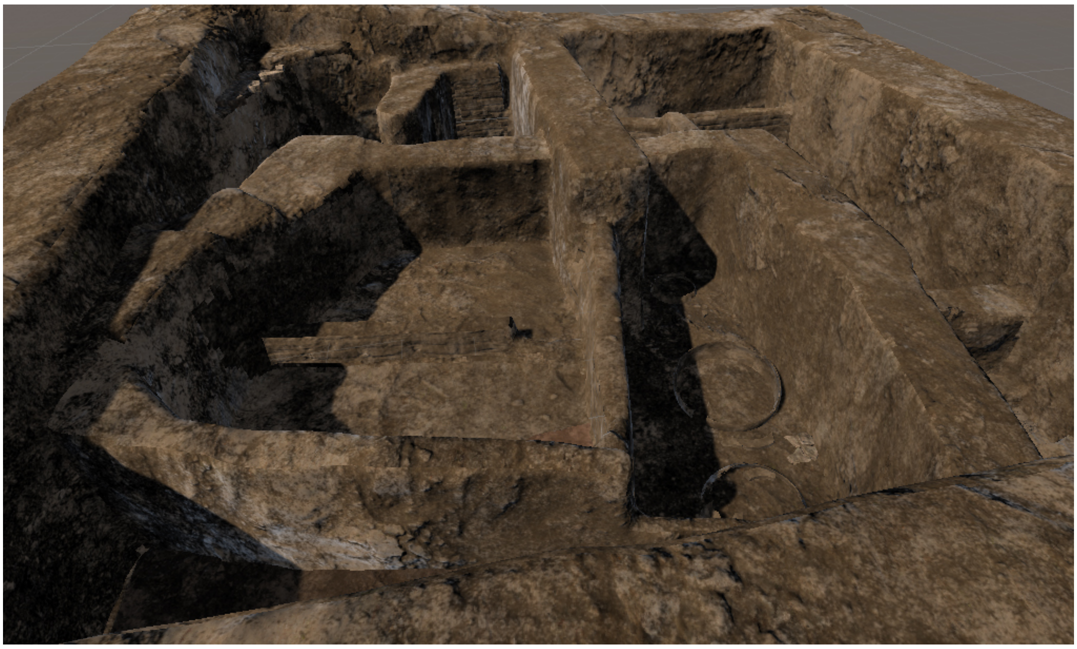

Figure 16: 3D representation of stones, vessels and the ground surface of a trench in Autodesk 3DS Max©.

Figure 17: 3D representation of stones, a human skeleton and the ground surface of a trench in Autodesk 3DS Max©.

The Augmented Reality application

The three-dimensional models of the archeological excavations of Toumba and Thermi were integrated in the Augmented Reality application. This application allows the viewing and the augmented reality tour of the excavation sites that are now covered with soil, as well as the connection with important archeological findings and information (e.g., products derived from laser scanning, UAV and close-range photogrammetry) about them (Figure 17, 18).

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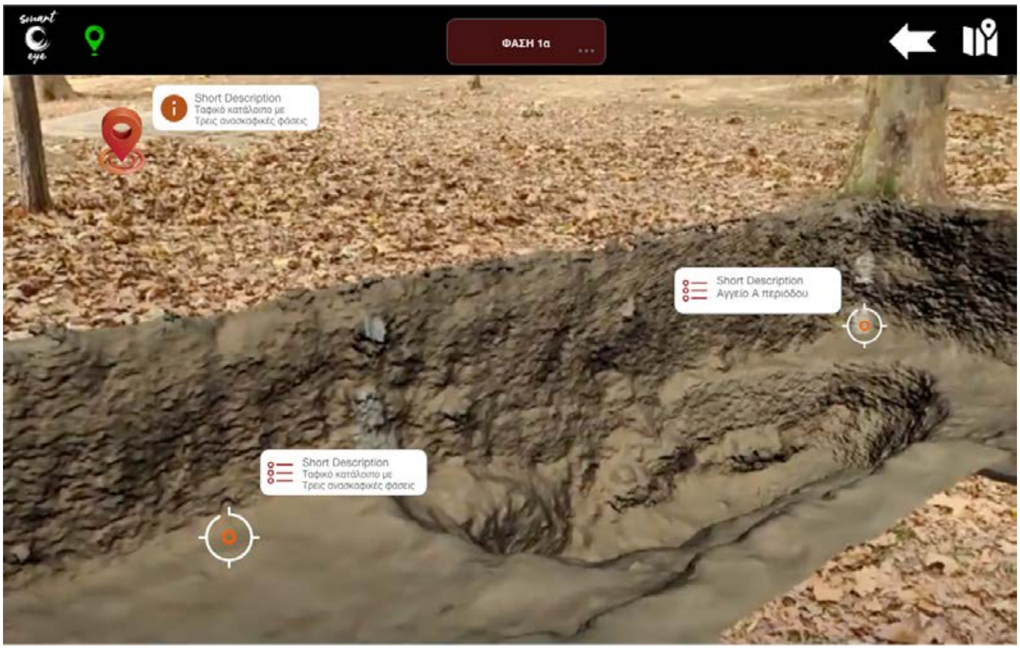

Figure 17: The layout of the Augment Reality application.

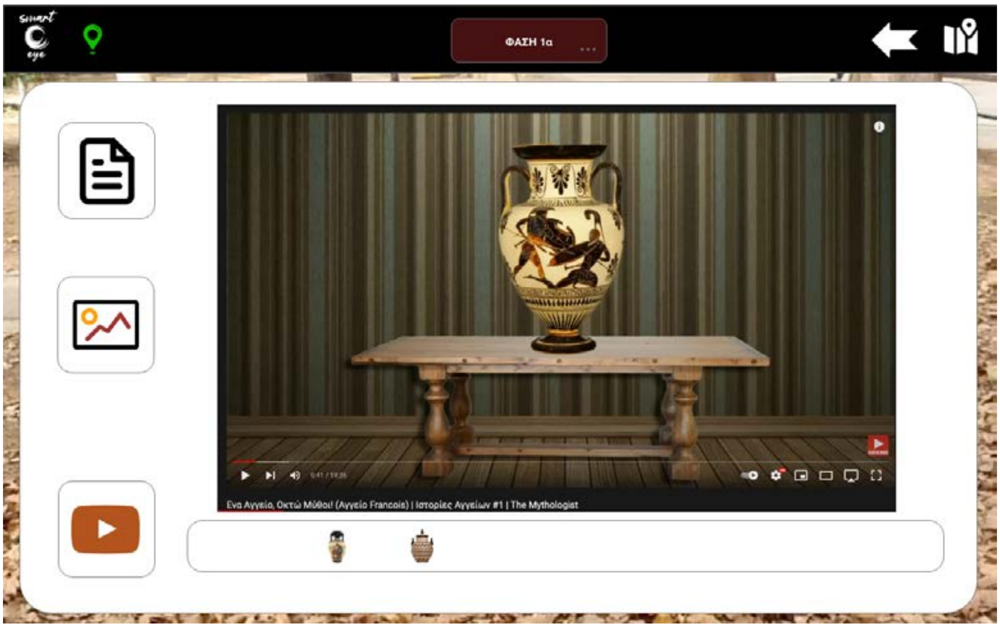

Figure 18: The layout of the Augment Reality application.

Conclusion

New and emerging technologies such as digitization, automation and the current 3D visualizations have significantly improved archaeological knowledge-making. Innovative methods and practices produce completely new ideas and fresh perspectives. The best software for the transformation of the legacy hand-drawn archaeological drawings into digital 3D models with measuring accuracy and the best possible photorealistic effect proved to be Autodesk 3DS Max©. Moreover, the use of Augmented Reality, in which the three-dimensional models of archaeological sites and findings are integrated, allows the understanding, the interpretation and the reconstruction of multiple narratives of the past. Finally, different types of users, from scientists to common visitors, are provided with the opportunity to access detailed information and different types of content depending on their types of knowledge and interest.

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