Fieldwork 3D interpretation

Integrating established methods and emerging technologies in a medieval context

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Abstract: Fieldwork interpretation of archaeological data can be at the present time a challenging task involving several established methods. Combining traditional techniques with computing tools in the archaeological field creates opportunities to model historical space and time, providing a possibility for "real-time" interpretation of archaeological excavation data. In the present project, extensive use was made of laser scanner data and Computer Vision techniques combined with traditional 2D data, allowing visualization and interpretation of ancient contexts, thus making evaluations of building features in workshops and stores possible. Computer Vision and laser scanner data, processed with Agisoft PhotoScan and MeshLab were used to evaluate and analyze, in a non-intrusive manner, medieval buildings. Applying filters to meshes so as to inspect small features, real artifacts shapes, measurements, cross sections, it has been possible to compare the resulting images with traditional drawings, getting additional information and "real-time" interpretation. From a researcher's point of view, the possibility of an early visualization of different hypotheses allows deeper comprehension of an archaeological context. This project is aimed at analyzing the remains and reinterpreting the function of medieval buildings in an Italian excavation, both during field work and afterwards. The challenging aspect is to use and reutilize existing 2D data and drawings, matching them with new acquisitions, trying to see under a new light areas which were investigated many years before.

Keywords: Medieval Archaeology, Fieldwork interpretation, Computer Vision, Laser scanning, MeshLab.

Introduction

Fieldwork interpretation of archaeological data can be, at the present time, a challenging operation involving several established methods. Combining traditional techniques with software tools in the archaeological field creates opportunities to model historical space and time, providing a possibility to interpret archaeological excavation data in "real time". Digital technologies proved to be an essential tool for such a task. 3D modeling helps represent and analyze complexities of the real world, understanding its issues or predicting how certain aspects may pan out. Models become evolving entities, which can be seamlessly integrated into an evolving research, such as an excavation. The purpose of a 3D model is not to show an accurate picture of the past -an impossible task- but rather to offer a reasonable visualization of it, helping scholars developing hypotheses, as well as "normal" observers trying to figure out how scenarios could have looked like.

The combined use of Laser Scanners, Computer Vision techniques (producing three dimensional models from photographs, allowing to acquire, at a lower cost, excavation data and to produce three-dimensional documentation in the field) and 3D modeling, allowed representing space and time as a variety of possibilities. We were able to draw hypotheses about shapes and uses of buildings and to assess their functions according to space, materials, construction techniques, recording their appearance at the moment of acquisition.

The challenge of bringing houses in Cencelle back to life started from the use of excavation data and paper documentation. Then, models were obtained acquiring measurements of the remaining buildings, finally generating philological 3D models overlapping the existing ones, to validate their confidence. All those tasks were performed in the view of a future in which 3D technologies can be natively integrated into the excavation.

The comprehension process carries on along with the excavation and it is enriched acquiring new data: during the implementation of resulting models, new questions originate along with new possibilities related to how buildings were structured and designed for. Understanding how rooms were used, how space was organized, which activities took place and where, remains an open question.

Usage of digitization tools helps preserving artifacts, structures, burials which would otherwise face the inexorable process of deterioration, leading them to an immediate dissolution after being brought back to light. As a consequence the models “freeze” buildings as they were in the Commune Age.

Leopoli-Cencelle

According to the “Liber Pontificalis” of the Roman Church, Pope Leo IV (847-855) founded the city at a distance of 12 miles from the roman “Centumcellae” (today Civitavecchia) to put citizens in a safe place, due to attacks carried out by Saracens[1] (fig. 1).

Byzantine military treatises, including the transmission of techniques regarding classical architecture, like those from Vitruvius, became the basis for the design of the new city, conceived by the papacy and commissioned to a soldier. The site, on a hilltop, is not far from the river Mignone (fig. 2) which runs to the west and from the Rio Melledra enclosing it from West to North ensuring, not only water at a short distance, but also sand used to construct buildings.

Leopoli-Cencelle, from the name of Pope Leo IV who founded it, stands out from top of a trachyte hill. Although extensively renovated in the Commune period, it allows to catch a glimpse to remains belonging to its first phase of life. Documents indicated it as Civitas Centumcellensis, Castrum Centumcellense, Cencelle/Cincelle in 600 and today Centocelle: it is situated on a hill at an altitude of about 160 metres Above Mean Sea Level. Cencelle was provided with city walls having four gates and seven towers, a built-up area hosting also several workshops, a main square where public buildings and the Church faced each other, and a cemetery which grew close to the church, since some areas of the city were deserted during the XIV Century.

[1] (DUSCHESNE L. 1955)

Fig. 1 – Leopoli-Cencelle, view from South-West (Copyright: Maria Doriana De Padova)

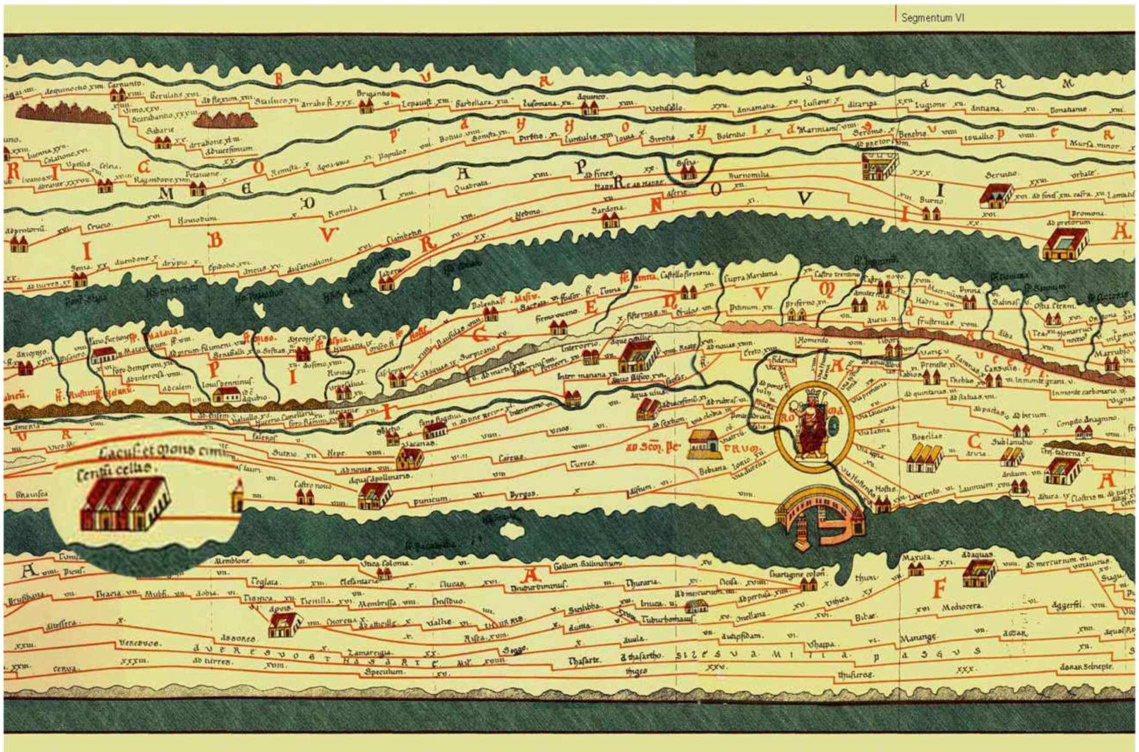

Fig. 2 – Ancient Centumcellae represented on the Tabula Peutingeriana. (Copyright www.tabulapeutingeriana.de)

Cencelle is today an exceptional model and unique in many of its features, both in terms of structures and stratigraphy (the lower layers found in houses are more recent). The city allows also the inspection of criteria and procedures used when founding a city during the Carolingian period (fig. 3).

Fig. 3 – Leopoli-Cencelle, aerial view. (Copyright: Chair of Medieval Archaeology, Sapienza Università di Roma)

For the present project we chose neighborhoods where life was flowing, hidden in the privacy of a home or in several workshops in the South-Eastern area of the medieval city.

The project

> *"Unlike traditional 2D technology, 3D reconstruction of deposits allows the archaeologist to develop more complex understandings and analyses of the deposits and artefacts they excavate. Digging is a destructive technique: how can we reanalyze and interpret what we excavate? How to simulate an archaeological excavation with all the stratigraphy? And if we simulate virtually an excavation, how can different archaeologists collaborate in the same virtual space from different locations while sharing the same archaeological data? The digital recording does not per se solve all these issues if not supported by a robust methodological workflow".* (FORTE ET AL. 2012)

On the excavation it is fundamental to be able to analyze layers already destroyed or specific items such as bones or artifacts in their original position. Digital tools used in the field give a possibility of acquiring artifacts still *in situ*, as for example numerous graves by the church in Cencelle.

The present project results from a challenge started in 2010 as a PhD at Bologna University, under the direction of the chair of medieval Archaeology at Sapienza Università di Roma and concluded thanks to the generous support and state of the art tools provided by Lund University, Sweden.

A FARO Focus3D laser scanner looked like the most appropriate instrument to acquire walls and houses measurements from inside and a camera (fig. 4) was used for small objects, "real time" documentation of graves and to acquire pictures for Computer Vision post-processing.

The research team was able to get "real time" data from their daily work, documenting layer by layer the excavation process thanks to Computer Vision technologies able to reconstruct the destroyed stratigraphy when the campaign ended. A RTK differential GPS receiver was also used for accurate positioning of the excavation perimeter and the positions of the graves. Data obtained were processed with PhotoScan[2] at the end of each day of work so as to obtain three-dimensional stratigraphic data, which would otherwise change irretrievably on a daily basis (fig. 4).

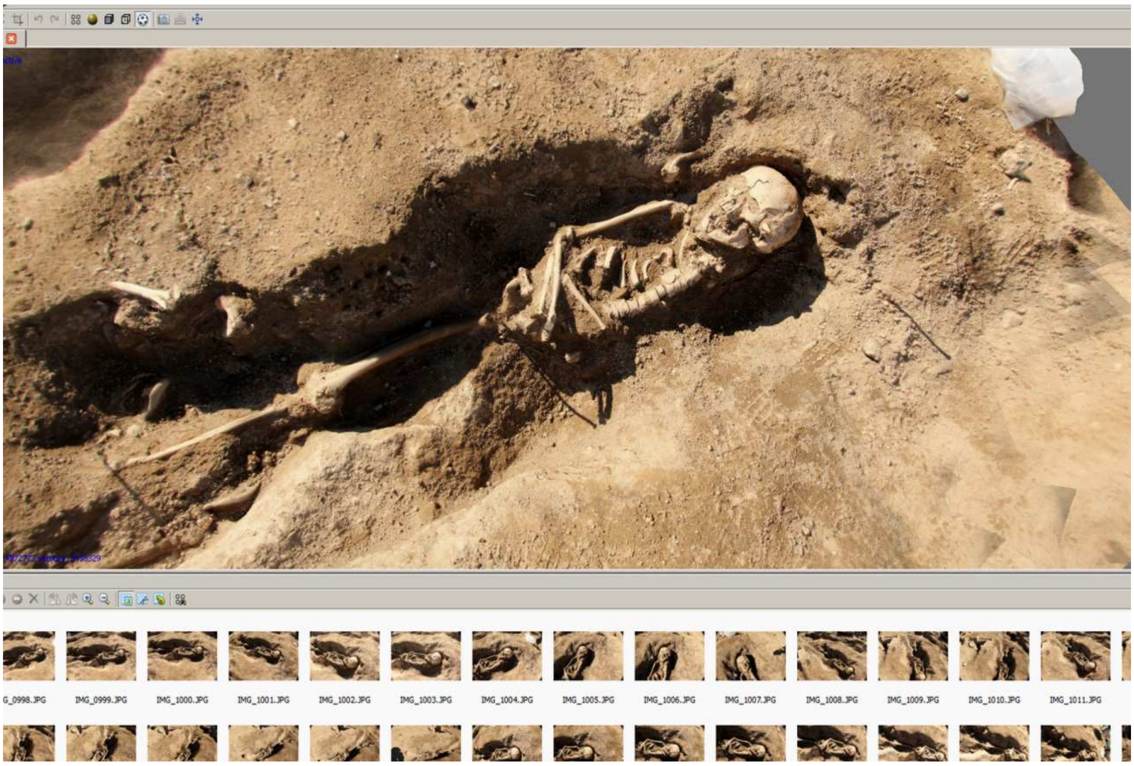

Fig. 4 – The graves acquired in Computer Vision processed in MeshLab. (Copyright: Maria Doriana De Padova)

Finally, georeferenced scalable models were obtained, and then aligned with MeshLab[3], giving an idea of layers, their location and of how the excavation was evolving. The use of such an affordable, easy-to-use, effective and offline software tool quickly produced excellent results, proving itself an excellent fit with the needs of researchers carrying out an excavation. Availability of complete 3D models usable during the survey, not only does provide added value, but also a formidable means to share results and details no longer available, such as skeletons, graves or, for example, signs and drawings engraved on the plaster in the crypt (fig. 5).

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[2] http://www.agisoft.ru/products/PhotoScan/

[3] "*MeshLab is an open source, portable, and extensible system for the processing and editing of unstructured 3D triangular meshes. The system is aimed to help the processing of the typical not-so-small unstructured models arising in 3D scanning, providing a set of tools for editing, cleaning, healing, inspecting, rendering and converting this kind of meshes*". (http://MeshLab.sourceforge.net/)

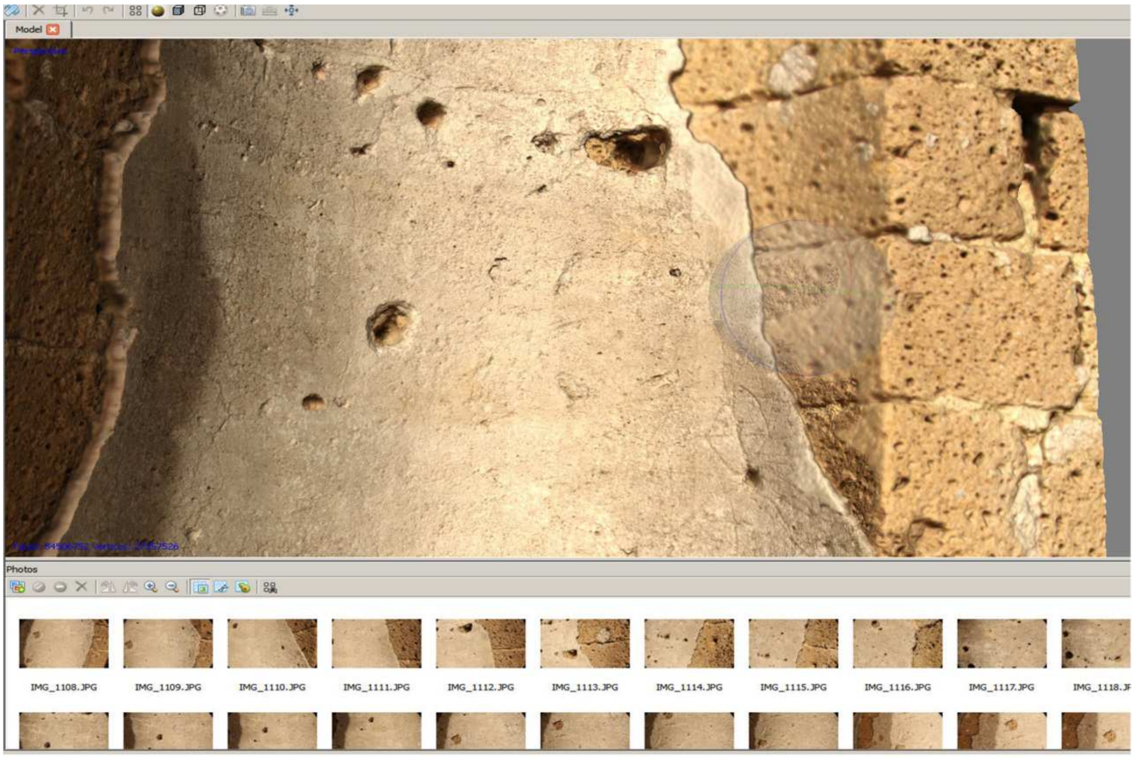

Fig. 5 – Signs engraved on the plaster in the crypt, processed in PhotoScan. (Copyright: Maria Doriana De Padova)

At the same time such tools are useful to draw new conclusions and to develop strategies on methods of excavation and documentation to acquire.

What is shown here is only the preliminary result of a trial, leading to the idea of organizing in the near future a workflow producing and disseminating 3D real time documentation.

Comprehension from 3D

An issue often occurring in fieldwork is dealing directly with those people who excavated years before, to better understand older data: 3D tools, integrated with traditional drawings, can increase the value of paper documentation, adding information probably lost by now. 3D models obtained with laser scanners for example can freeze a building as it was when found (fig. 6).

An experiment was carried out using 3D data matched with 2D and previous paper documentation. MeshLab allows to augment information provided by standard documentation with simple tools which, applied to a section, can give more effective results. A three-dimensional model obtained with Computer Vision was imported into MeshLab and scaled (fig. 7), then cut, applying several filters to the cross-section obtained in order to get different kinds of information (fig 9).

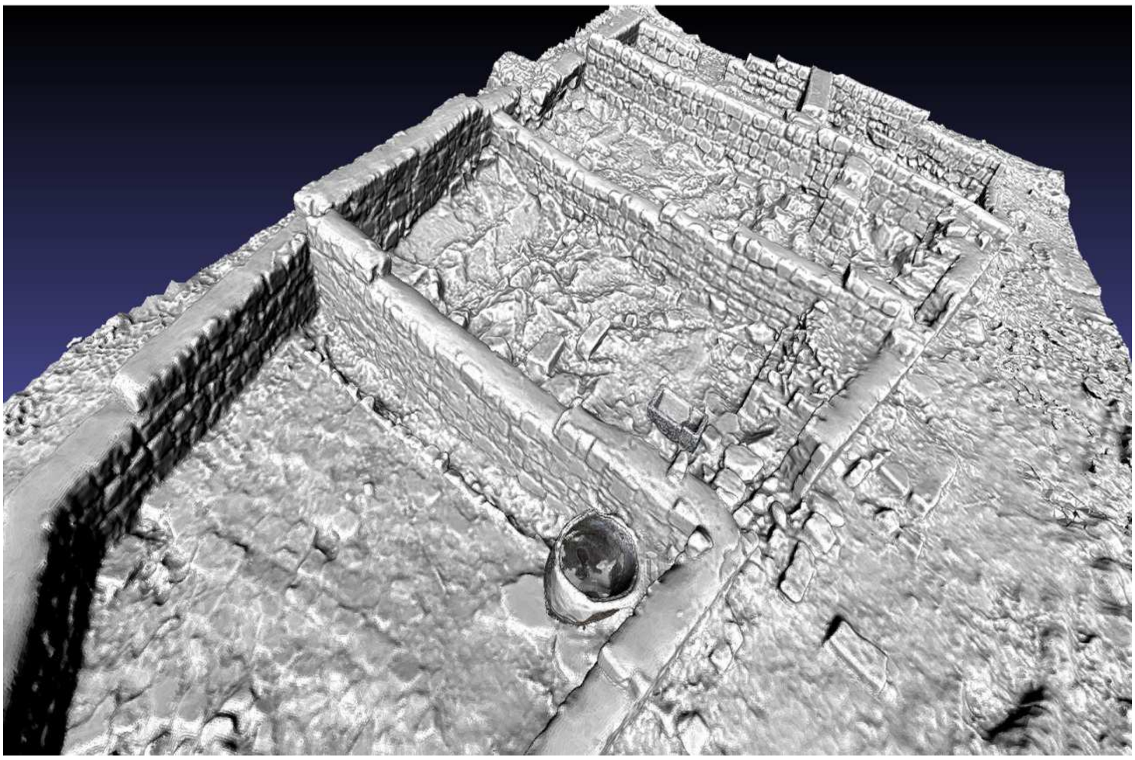

Fig. 6 – 3D Model of a block obtained using Laser scanning. (Copyright: Maria Doriana De Padova)

Fig. 7 – 3D Model of a room obtained using Computer Vision. (Copyright: Maria Doriana De Padova)

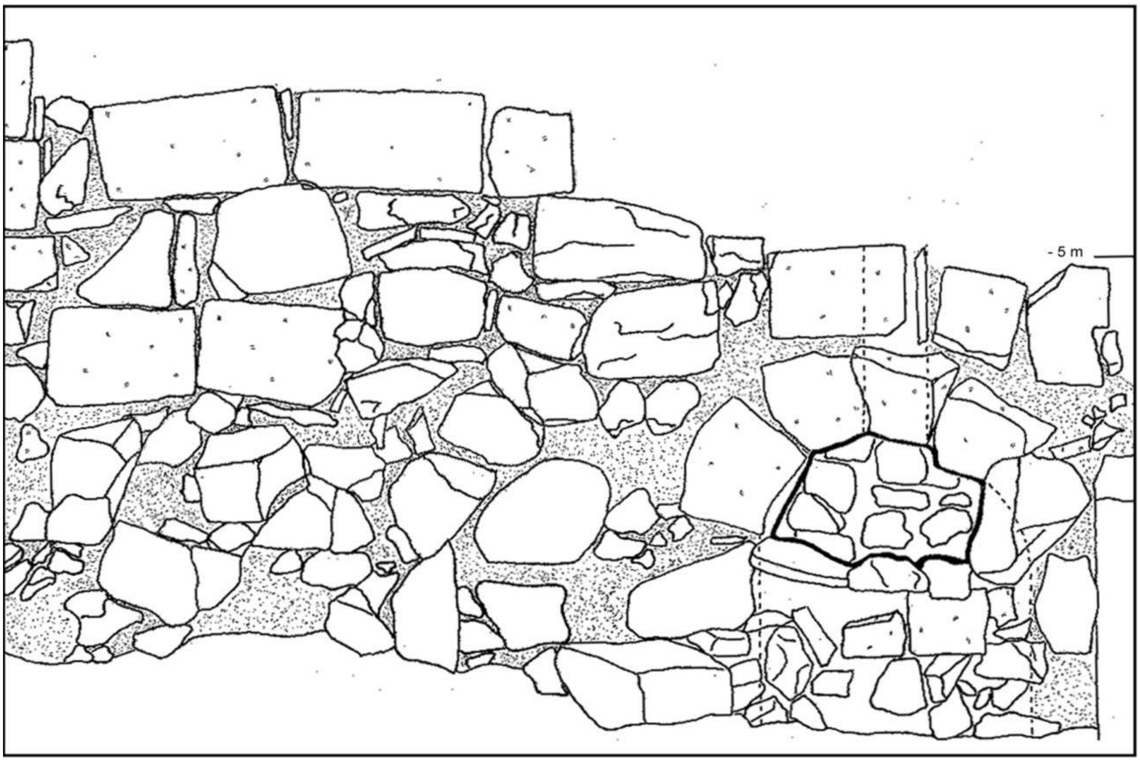

Fig. 8 –Cross-section of a room: traditional drawings. (Copyright: Chair of Medieval Archaeology University “La Sapienza, Rome)

Fig. 9 –Cross-section of a room: comparison between traditional drawings and 3D with filters applyed. (Copyright: Maria Doriana De Padova)

Comparing traditional documentation (fig. 8) with 3D cross sections (fig. 9), applying filters with MeshLab, it is possible to get different levels of information. A traditional drawing clearly shows constructing techniques, materials, wall conditions and shape. A 3D cross-section with different filters applied, amplifies the amount of information displaying features such as its state of conservation, its thickness, the real position of stone blocks, as objective data, unrelated to interpretation or artistic skills of archaeologists who documented that area. Not to mention endless possibilities to visualize immediately site features usually documented in 2D, such as differently-shaped objects found at the same height (fig. 10).

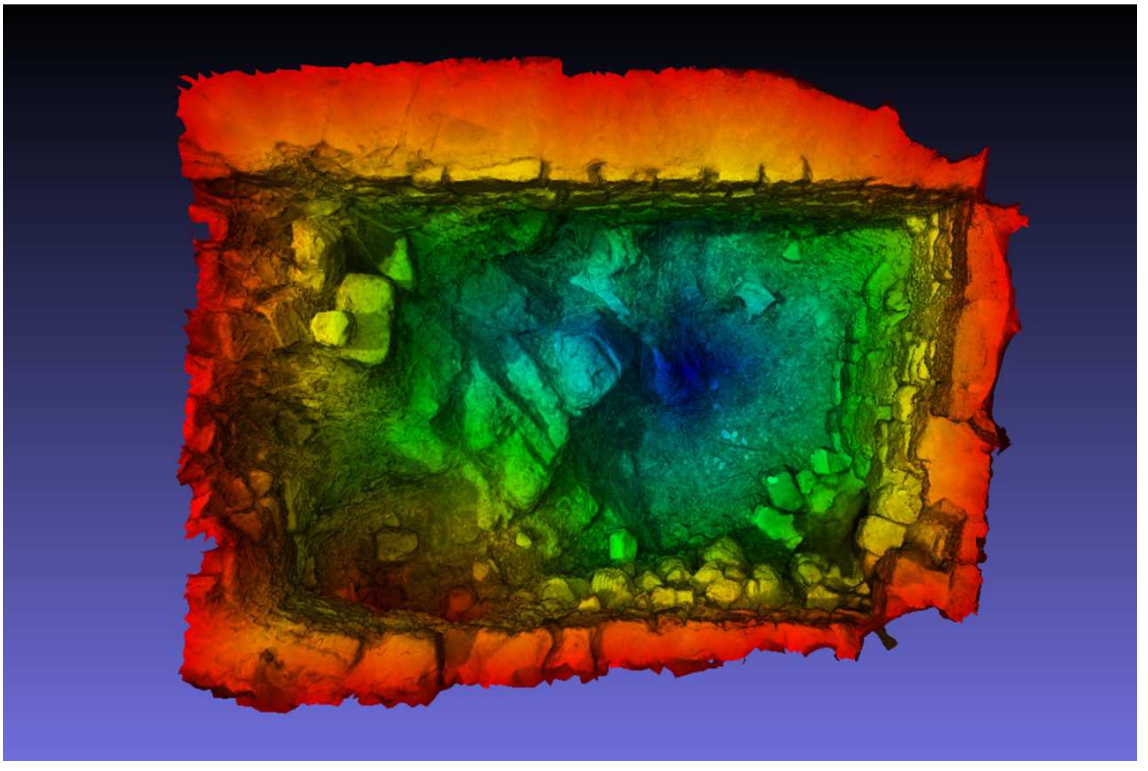

Fig. 10 –The filter “Color by border distance” applied to a mesh in MeshLab. (Copyright: Maria Doriana De Padova)

This combination of different software tools gives further opportunities to insert furniture items found in the excavation into 3D-modeled environments. At Cencelle, many stone basins were found; investigation of their purpose is an interesting case-study which is currently ongoing. Such items were acquired with a digital camera and post-processed with PhotoScan (fig. 11) and MeshLab, then scaled to their real measurements. With the aim of validating several hypotheses about their position in workshops, they were positioned in the rooms thus generated, so that their occupied space, function, possibility of being used more effectively elsewhere in the house could all be evaluated.

As a texture for objects, the mesh color was left intentionally, so that the “real” object could stand out in the virtual environment. Finally, furniture, basins and objects, exported into MeshLab, can be visualized, combined, switched on and off, depending on several different interpretations.

One more aspect originated joining traditional documentation and 3D models to evaluate the effectiveness of hand drawings. Of course drawings themselves can be useful, at the same time, as a meaningful basis to extrude 3D models.

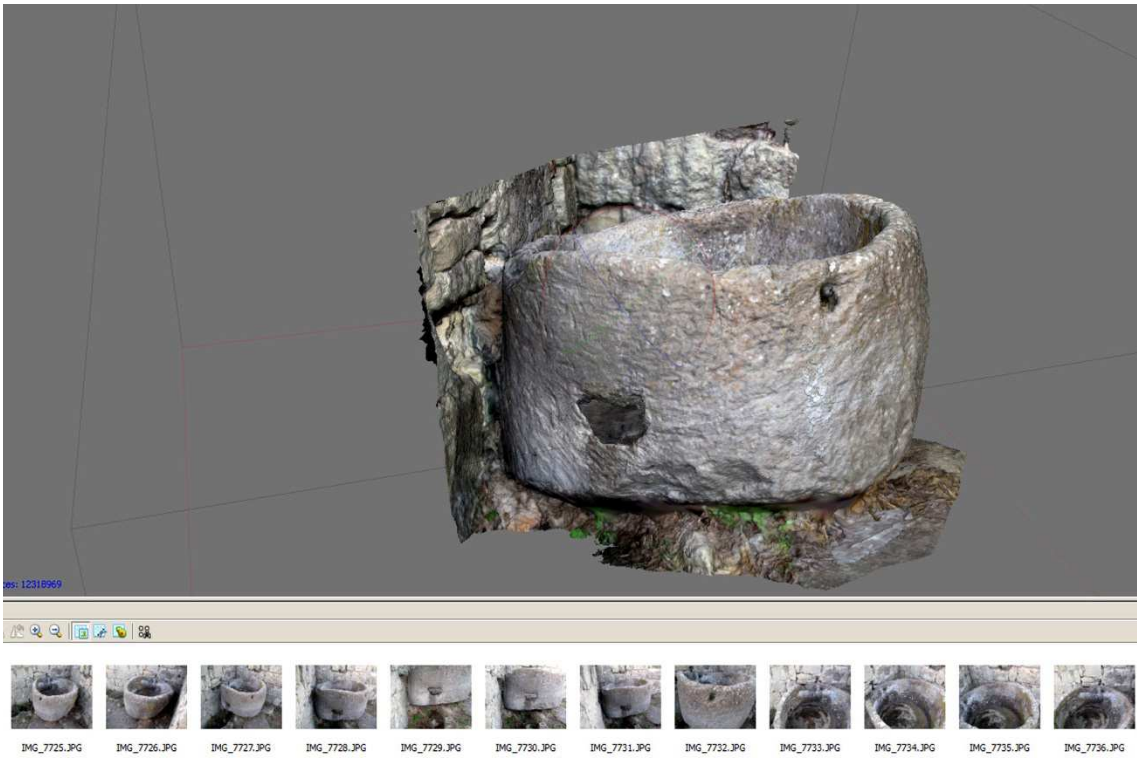

Fig. 11 –3D mesh of a stone basin found in the excavation post-processed in PhotoScan. (Copyright: Maria Doriana De Padova)

For a short pipeline, as another case in point, using Blender the block excavation plan was used as texture for a plane so that it could act as a reference point both to extrude models and to align meshes (fig. 12).

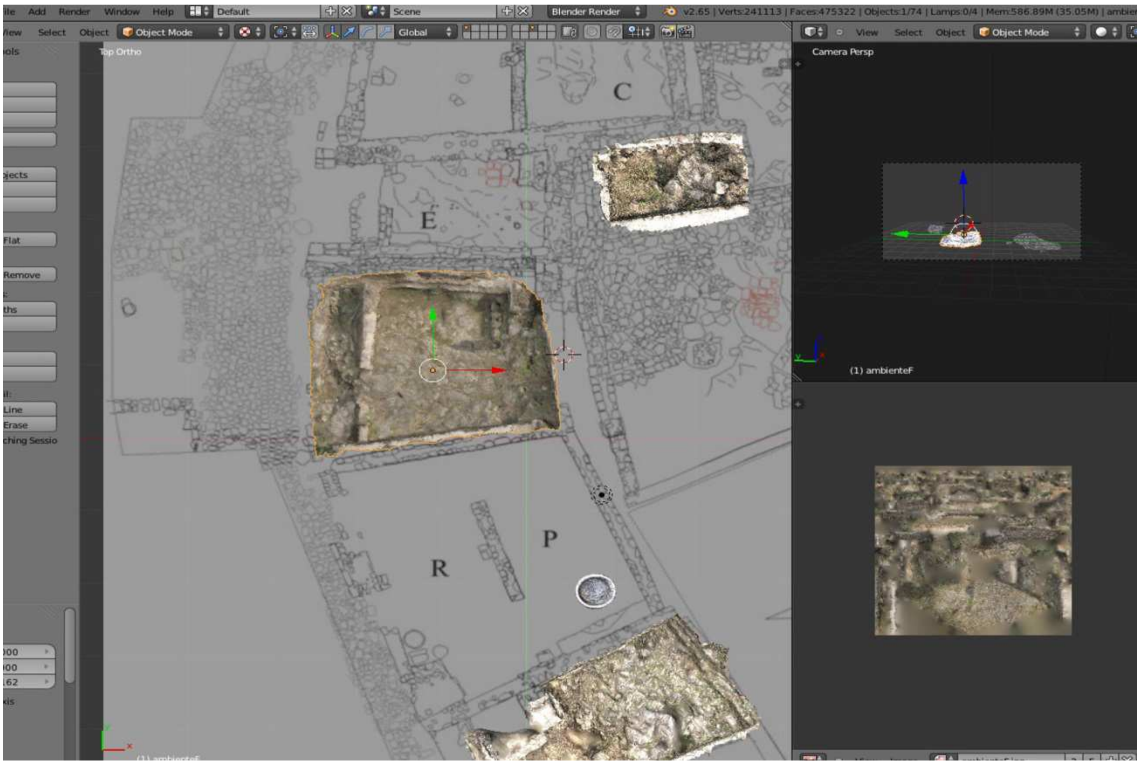

Fig. 12 – 3D mesh of the houses left post-processed in PhotoScan and aligned the the plan into Blender. (Copyright: Maria Doriana De Padova)

Polygonal meshes processed with PhotoScan were then imported into Blender, aligned to the plan and used as a starting point for modeling work. Starting from acquisitions, several models were created with Blender, each of them providing a different interpretation for the purpose of the same building, integrating existing data acquired using 3D scans and PhotoScan with reconstruction hypotheses. Just to provide an example, 3D acquisitions allowed re-interpreting many rooms with a cobblestone floor, originally thought to be covered or outdoor areas due to excavations of more rooms led by different people at different times. Thanks to 3D acquisitions led at the same time, we were able to interpret all the areas covered in cobblestones as open areas because of similarities between many buildings. Such a re-interpretation provided a new starting point to reshape buildings in a 3D reconstruction.

Blender, a powerful 3D modeling program was chosen for the last step. Such a software tool was selected due to its flexibility and availability, being an "open source" development helped reducing costs.

For the last step related to interpretation, still ongoing, we chose to adopt textures just where tracks of the brickwork were left. In some cases reconstructed buildings were left as a transparent structure, to allow a modular approach and the possibility to inspect details such as staircases, dividing walls, doorways inside the building.

The usage of such a technique was, in some ways, an experiment aiming at augmenting virtuality with reality, where the former can give extra value to archaeological interpretation, while the latter represents a solid base to start and formulate guesses and theories.

Conclusions

Models are an invaluable means to explain, with an effective visual language, connections between a site and its interpretation, being able to disseminate the whole process of archaeological investigation.

Use of 3D joined to traditional documentation can lead to useful and effective results such as: accurate measurements of ancient human spaces, new interpretations of consolidated data, different hypotheses of buildings and their functions, in field reconstruction of stratigraphy as it was originally drawn out, adding time as a 4th dimension, modeling space and time as room of possibilities.

A three dimensional representation, especially of an excavation, should never be static, but in constant change, such as knowledge is during the field survey, never certain:

> *"temporary states in a process of coming to know"* (BAKER ET AL. 2012).

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