QGIS, pyarchinit and blender: Surveying and Management of Archaeological data with Open Source Solutions

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The goal of this article is to provide several practical procedures for working within the GIS environment in the archaeological sector, with specific reference to the excavation site, through open source methodologies and software such as Qgis and PyArchinit. It will also demonstrate how to use the data derived from the survey, processed and managed through Qgis and PyArchinit for enhancement projects such as 3d modeling and 3d mapping through Blender software.
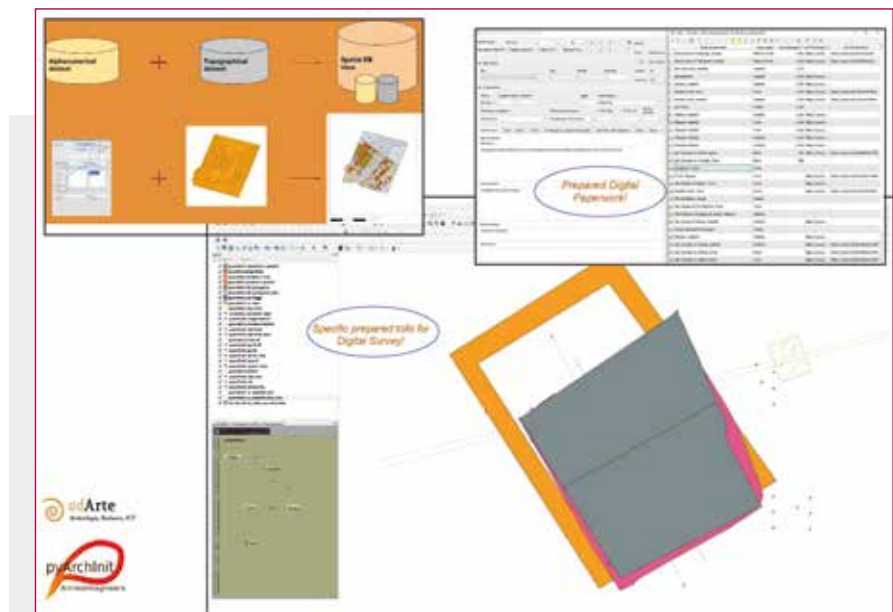
Fig. 1 - PyArchinit Logo. Image by Mandolesi 2006.

The term georeferencing means to place one or more objects on a topographic map (paper or digital), which are represented as geometries (point, line, polygon, polyline etc.). It attributes a precise geographical position to an object by assigning X, Y or X, Y, Z coordinates according to a geographic reference system that can be chosen conforming to the needs of the user[1].
However, today, thanks to the huge developments in numerical cartography, it makes no sense to continue georeferencing objects on paper given the great advantages of digital cartography, in particular the vectorial one, compared to the paper one; the many benefits include:

1. Digital maps in comparison to paper, are not affected by weather, wear, or deformation;
2. Digital maps are easier to manage, to compare, to share, and do not take up space;

3. The vectorization of the elements that make up a digital map and also of any georeferenced object allows the user to associate any alphanumeric information to them that can be queried.

At the same time, it facilitates comparison and interaction with data of different natures and origins, as well as the possibility of processing spatial analyzes.
All this presupposes the use of the GIS software. As only GIS software has the following characteristics:

1. They allow for the geographical positioning and the geometric representation of the entities that make up the project that is being worked on;

2. They are structured in order to be able to manage and maintain all the information concerning the mutual spatial relationships between the different elements, such as connection, adjacency and overlap, defining the topology of the elements of the platform;

3. They make it possible to assign attributes to individual data, guaranteeing management through mutual relations, quite similar to that allowed by normal databases.

In this way it is possible to query every element in the system, which will return the alphanumeric information associated with it (Peuquet 1988).

Based on the attributes of the vectors that make up the platform, it is also possible to carry out geoprocessing analyzes that will further implement the knowledge about the specific "territorial system" being investigated[2].

Georeferencing and vectorization of cultural heritage in a GIS environment is of fundamental importance, whether they are used for an entire archaeological site, a single monument, or simple stratigraphic units. In addition to the benefits already listed, in this way it is possible to link the all information collected for each cultural asset to satisfy multiple requests:

1.Specific research aims;

2.Preservation, enhancement, and touristic enjoyment aims.

For this second point it is useful to remember that GIS is the software used by the different public and private authorities. It is important to make sure that all those who work around the cultural heritage sector can produce types of data suitable to be managed through GIS software.

Conformity with territorial planning standards, would make interdisciplinary exchange easier and, at the same time, save time for processing projects.

This aspect is even more pronounced when it comes specifically to archaeological excavation projects.

Archaeological projects usually involve a massive production of topographical and alphanumeric data (e.g. survey, paperwork, namely the all the various documentation sheets that are used during an archaeological evaluation)[3].

It would be unthinkable in the future to carry on to provide such data in paper formats, for both huge benefits of the digital vectorial documentations compared to the traditional paper format.

At some point, it will become harder to continue to store them within the warehouses of the governmental bodies charged with the preservation and enhancement of cultural heritage, since it is likely that they will not have the necessary space[4]. For example in Italy, the new regulations issued by the Ministry of Cultural Heritage and Tourism - Direzione Generale Archeologia, Belle Arti e Paesaggio, with specific reference to the circolare n. 30 of 30/2019, concerning "Archaeological excavations and research permissions" - D. Lgs. 22.01.2004, n. 42, Artt. 88-89, set out that the archaeological survey related to archaeological excavations and investigations must be provided in vectorial format SR WGS84 (EPSG4326).

In light of this need to adopt an approach based on the use of GIS software for the survey and documentation of cultural heritage, in 2005 the *PyArchinit* (Python for Archeology Project) was created with the aim of creating a python plugin for the open source *Qgis* software, aimed at managing data from archaeological contexts on the GIS platform (Figure 1).

The main aim was to create an application that can be used by archaeologists but, at the same time, perfectly compatible with the formats and territory management systems used by public administrations (e.g. Piani Regolatori Generali - PRG in Italy). Our initial goals for the software were:

1.Simple and immediate use;

2.Development with open source software;

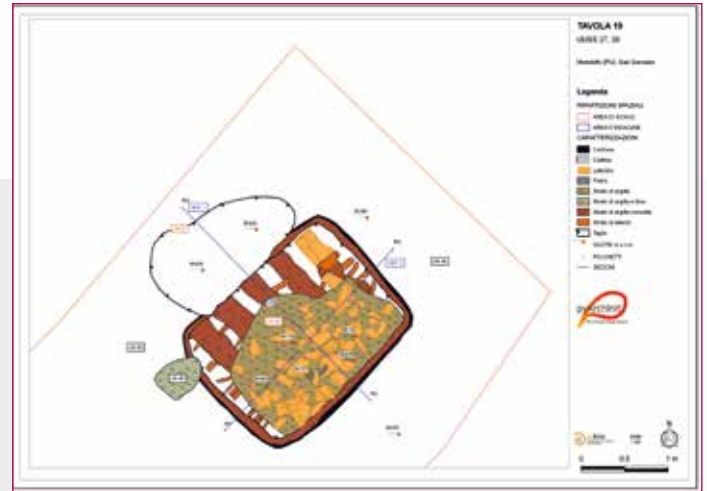Fig. 2 - The pattern in the upper part illustrates how PyArchinit is structured. In fact, the plugin uses a Geodatabase (Postgresql or Spatialite) to store all the data collected during an archaeological project. These data can be alphanumeric (tables) and vectorial (Digital Survey) which, into PyArchinit, are merged with each other through the "views" system. This system allows you to automatically interconnect many and different types of data with each other. PyArchinit provides comfortable graphical interfaces already prepared for both alphanumeric and vectorial data. Image by Mandolesi 2006

3.Supply specific tools for archaeological survey and paperwork.

This last aspect is what makes *PyArchinit* the first GIS in the world specifically for archeology.

It uses the *Qgis* interface as a graphic work environment, and is shaped by years of practical experience by its developers gained in the field by its developers, for the creation of the tools necessary for the production and management of archaeological data in the GIS environment.

The goal of this article is to provide several practical procedures for working within the GIS environment in the archaeological sector, with specific reference to the excavation site, through open source methodologies and software such as *Qgis* and *PyArchinit*. It will also demonstrate how to use the data derived from the survey, processed and managed through *Qgis* and *PyArchinit* for enhancement projects such as 3d modeling and 3d mapping through *Blender* software (R.M).

Fig. 3 - Example of Excavation Plan Template worked out with PyArchinit. Image by Mandolesi 2019.

ARCHAEOLOGICAL SURVEY AND DATA MANAGEMENT WITH QGIS AND PYARCHINIT

The PyArchinit Plugin
GIS technologies, such as the open source software *Qgis*, are an extremely useful solution for the production and management of excavation data. All the documentation developed during an excavation, such as stratigraphics units, excavation levels, and other kinds of contexts, can be digitised through this software, and in particular through the plugin *PyArchinit*.
PyArchinit has been created by archaeologists, and it caters to specific archeology needs. It provides dedicated tools that allow archaeologists to upload and check all the digital survey information taken and all the alphanumeric documentation (paperwork) produced during an archaeological project (Figure 2).

PyArchinit consists of:
1. A database in which to store and to manage the numerous amounts of data processed during an excavation or any other archaeological investigation (e.g. watching briefs, evaluations trenches, field survey) (Figure 2);
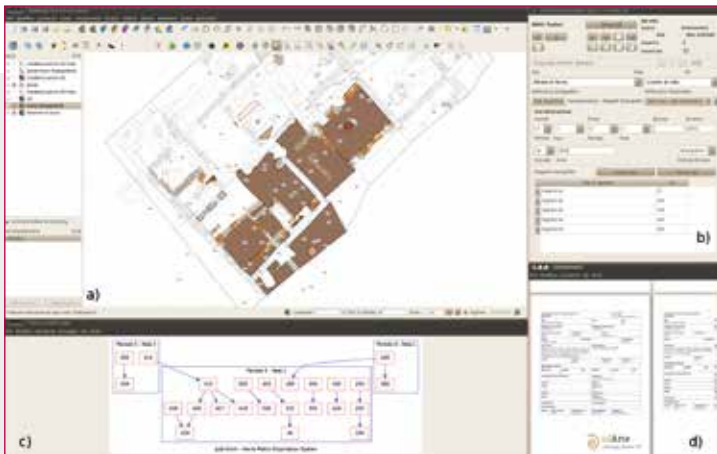

Fig. 5 - Example of integrated use of PyArchinit tools: a) visualization on canvas of a phasing plan digitized; b) Alphanumeric information related to the archaeologica features digitized; c) Automatic export of the Matrix; d) Automatic .pdf export of the archaeological paperwork. Image by Mandolesi L. 2015.
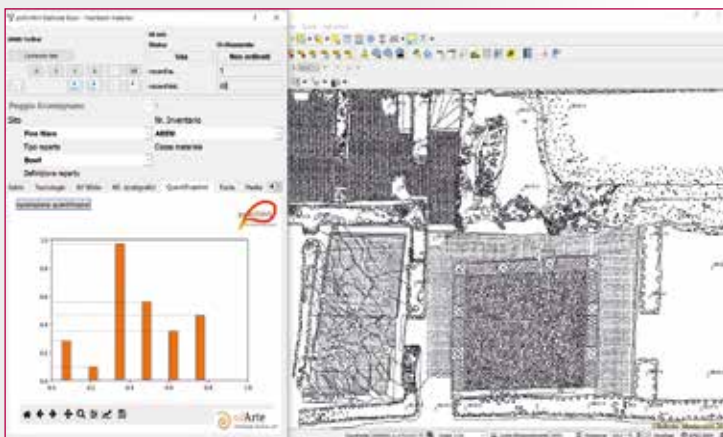

Fig. 6 - Example of PyArchinit Quantification Tools: after filling the data of the materials table provided by the Plugin, PyArchinit allows you to set which data you want to quantify and to process histograms of the set quantification. Image by Montagnetti R. 2019.
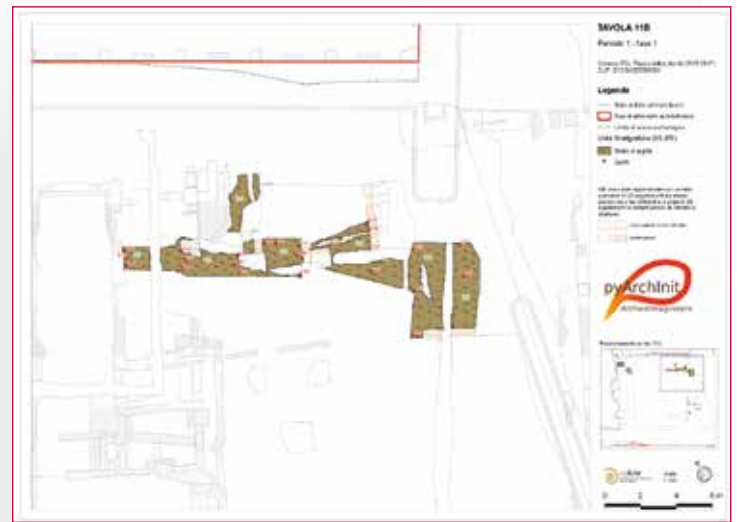

Fig. 4 - Example of Phasing Plan Template worked out with PyArchinit. Image by Mandolesi L. 2019.

2. Different tools prepared by the plugin that automate many of the operations that take place during the processing of archaeological data such as: excavation plans; phasing plans; harris Matrix reconstruction; inventory and quantification of the different kinds of archaeological materials found.

3. It automatically creates overviews or virtual tables, in which to merge data from various tables, providing a bridge between alphanumeric and cartographic data. This drastically speeds up the analysis and geoprocessing operations, and facilitates the interpretation of the processed data;

4. It allows more than one operator at time to access the database, making it easily possible to modify and share the work with other colleagues. This is of particular importance especially with international projects, in which different universities and specialists from various countries collaborate together;

5. Finally, these functions allow the user control over the data integrity and validity of the output,
while cutting down significantly on working time (Figures 3,4,5,6,7)[5].

The Archaeologica Survey on site
On site, with regard to the survey of various archaeological features, it is possible to use two different systems: one manual, conducted with the traditional techniques such as triangulation or "*coltellazio*" (the technique of taking orthogonal measurements through two metric tapes); and the digital one, using instead computer vision techniques based on the algorithms of *Structure from Motion* (sfm).
In both cases, the procedure consists in referring to some GCPs (Ground Control Point), located across the interested area of investigation and previously geolocalized with the GPS[6]. GCPs can be used both for manual survey by triangulation and for photogrammetry depending on the type of survey being used.
For the manual survey of various archaeological features, as a first step, we need to compose a "Beginning Excavation Plan" on a 1:20 scale.
This is made using the "Map Editor" tool of *Qgis* after geore-

ferencing the area of excavation using the "georeferencer plugin" provided by the same software. The following step consists of adding the GCP locations and a grid 2 seconds of grade wide suitable to enclose an area of 2 m2 to the "Beginning Excavation Plan".

Both the GCPs and the vertices of the grid are represented with a cross shaped symbol and they form the topographical markers of the plan[7]. Each vertex of the grid and GCPs must be labeled with its geographic coordinates in order to carry out the task.

The purpose of this procedure is to obtain a georeferenced map, to print it on a plexiglass base and to take it to the site (Figure 8). At this point, archaeologists can simply take a permatrace (drawing paper) sheet, place it over the "Beginning Excavation Plan" on the corresponding area where there is a feature that must be drawn and trace from it at least four topographical markers together with the corresponding coordinates of longitude and latitude. After this operation, the permatrace is transferred to a drawing board to let the manual survey by triangulation.

Subsequently the survey of the various identified contexts, the next step will be to carry on georeferencing every scanned permatrace into *Qgis*. The centre of each topographical marker on the drawing must correspond to the points to be selected on the screen necessary for georeferencing. Select the center of each marker with the tool "Add point" and manually enter the corresponding X and Y coordinates in the appropriate boxes, just start the transformation to georeference each individual file.

Once each context has been georeferenced, it can be digitized directly into the GIS environment with the *PyArchinit* tools (Figure 9) (Montagnetti, Rosati 2019).

However, very often, it is preferable to use the photogrammetric survey especially when dealing with very important, detail rich archaeological features. In fact, thanks to the use of photogrammetric software (SFM software), by taking photos of the features identified from multiple angles it is possible to reproduce a three-dimensional model of the feature or artefact (Figure 10)[8].
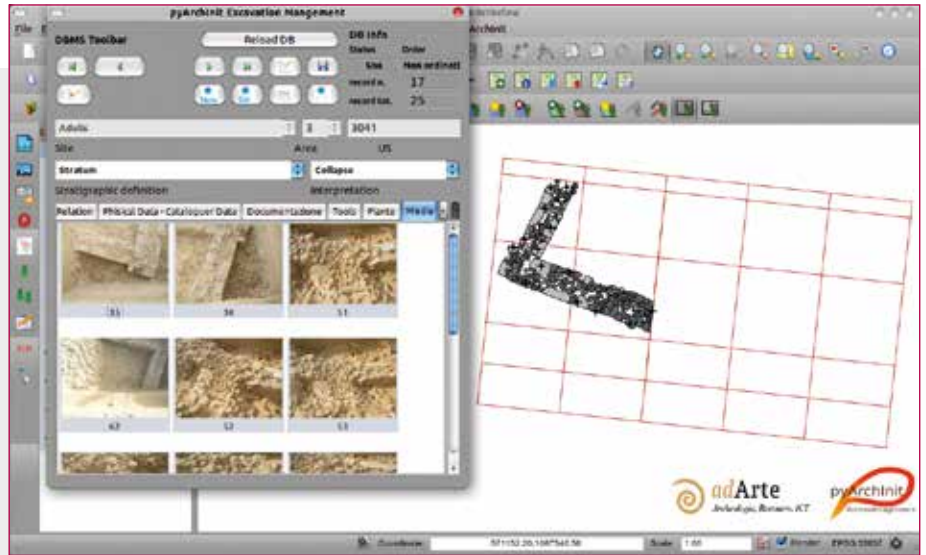

Fig. 7 - PyArchinit Excavation Management: example of managing and connecting archaeological feature photos to their digital survey. Image by Mandolesi L. 2006.
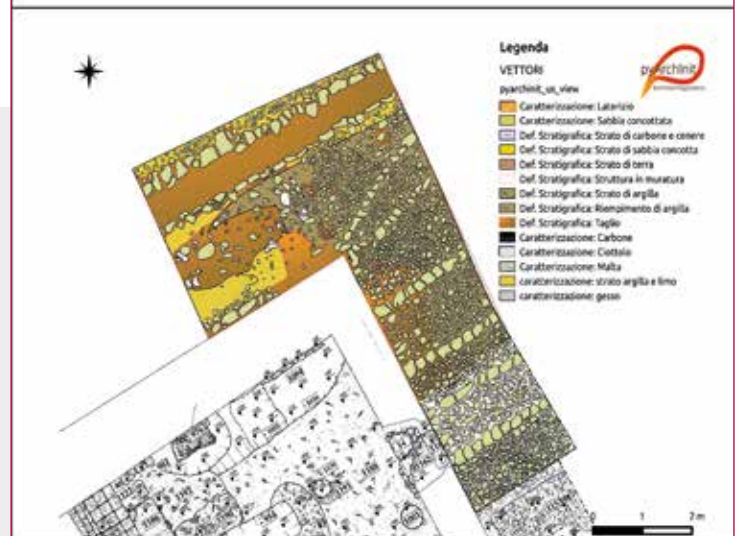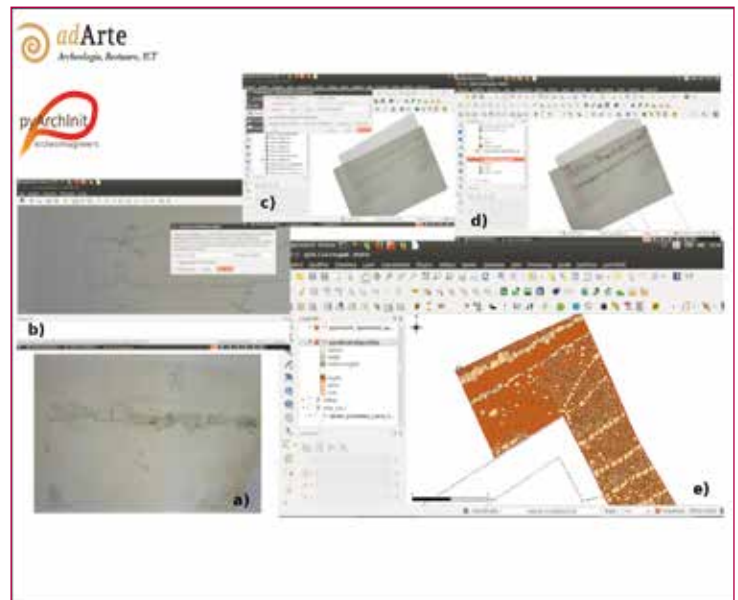

Fig. 9 - Example of georeferencing of scanned drawing permatraces. a) Original scanned drawing sheet; b) Georeferencing into Qgis; c) Overlay of several georeferenced drawing sheets into Qgis; d) Vectorialization with PyArchinit provided tools; e) Characterization of the digital survey with PyArchinit following the stratigraphic SU order. Image by Montagnetti R. 2019.

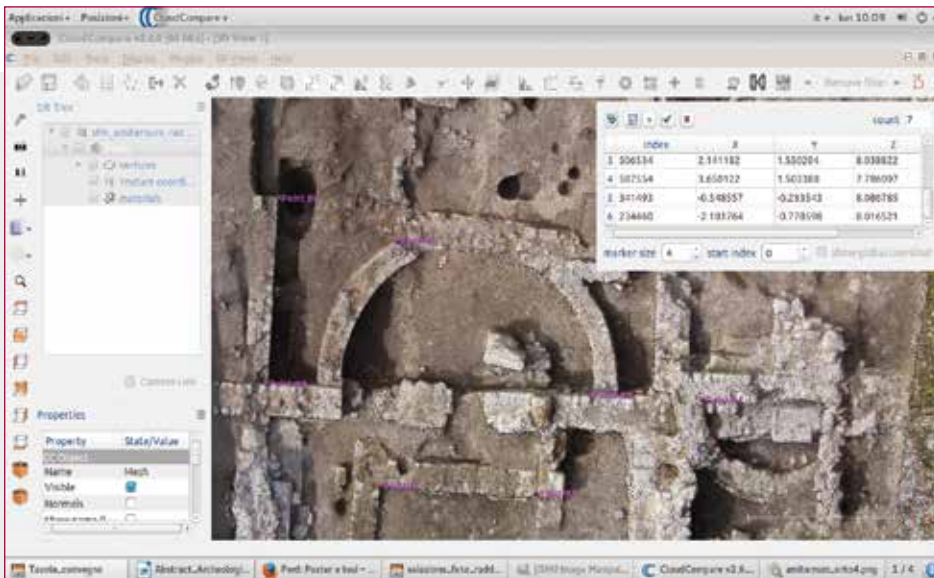Fig. 8 - Example of "Beginning Excavation Plan". Image by Montagnetti R. 2019.

Fig. 10 - Example of 3D Model (dense cloud) georeferencing with CloudCompare. Image by Montagnetti 2015.

At this point it is possible to continue georeferencing the scanned section drawing, by matching the four ends of the sheet with the vertices created through the *Qgis* "enable grid" function, using the TPS transformation with a "cubic" method[15]. After this procedure it is finally possible to vectorize the drawings inside *Qgis* with the special vectors made available by the *PyArchinit* plugin (Figure 13).

PyArchinit for Andorid devices: Qfield
To better support excavation operations, all the collected data can be transferred onto a tablet in order to manage and further update info directly on site through the use of *Qfield*, an Android app that can be downloaded from Google Play.
Qfield allows the user to display and manage, on an Android tablet or smartphone, a GIS project created with *Qgis*, maintaining all the themes, the tags, styles and data set in the *Qgis* software of a PC.

This application, though it seems to have a very simple interface, is rich in useful functions such as tools for digitization, edit geometry and attributes, query for attributes, GPS support as well as the ability to insert and customize basic maps, add photos, use of the device's camera, and much more. The benefits of using this system are remarkable; in particular it allows the implementation of the on-site data collection(constantly updating the system and creating an up-to-date overview of the site) and eliminates the time consuming work of digitizing the registers and the paper sheets[16]. In this way, being able to transfer our *Qgis* project to a tablet, *PyArchinit* database included (Figure 14), we can directly record the all excavation paperwork in *Qfield* and then synchronize the *Qfield* database with the *Qgis* desktop project (master) stored in the laptop at the end of each day of excavation.

The use of *Qfield* in the field greatly simplifies the work of directors and supervisors in planning the excavations, allowing them to easily instruct the archaeologists directly in the field. It will allow them to give field workers directions regarding what they will have to dig, supporting their explanation with the visual aid of the tablet, coupled with the information related to what has already been investigated and entered into the database of the project.

The advantages of using *Qfield* are considerable during the excavation phase, as well as simplifying the work of archaeologists in drafting their paperwork. They can continuously refer to the tablet to obtain the necessary information to insert into their archaeological documentation, such as the section or plan numbers of the contexts that have been excavated for example. Above all they will have much more information available to provide an interpretation for what they have excavated and recorded (R.M).

FROM *PYARCHINIT* TO 3D MODELING WITH BLENDER
The management of archaeological data with *Qgis* and *PyArchinit* allows the user to create thematic maps through specific queries based on the data entered in the Database.

Later on it will be possible to extract orthophotos of the various archaeological features from the 3d model[9] and digitally draw them directly into *Qgis* with the *PyArchinit* tools as we have already seen for the manual survey (Figure 11). This implies that orthophotos used for digital survey must be georeferenced. The georeferencing of these images can be done in two ways:

1. Through the Georeferencer GDAL Plugin of *Qgis*; in the same way seen previously regarding
the georeferencing of permatece sheets;

2. Through the Georeferencing of the 3D model of the features identified with a photogrammetry
software (Figure 10)[10].

In both cases the georeferencing is based on the GCPs positioned on the ground on the investigation area, with geographical coordinates taken with the GPS[11]. This system saves a considerable amount of time and manpower and, at the same time, the survey will be much more accurate[12]. Through this methodology, at the end of the excavation season, it is also possible to realize the "Final Excavation Plan".

The procedures described above can also be adopted for section or profile drawings , albeit with slightly different expedients. However in this case, unlike plans, it is suggested to use the traditional system for drawing sections on site with measuring tape and graph paper sheets of standard dimensions 0.40m x 0.27m[13]. Once the drawings of the sections are done, these sheets are scanned and imported into *Qgis* and vectorialized with the *PyArchinit* tools. Clicking on the *Qgis* tool "enable grid", it will be possible to set the values of the X and Y of the grid, depending on the scale.

For example, if a 1:20 scale has been used for the drawing of the section, knowing that the size of the paper is 0.40 m x 0.27 m, the grid will have a value X = 8 m (0.40 x 20) and a value Y = 5.4 m (0.27 x 20)[14]. The result of this operation is the creation of a grid in which each cell has dimensions of 8 m x 5.4 m (Figure 12).
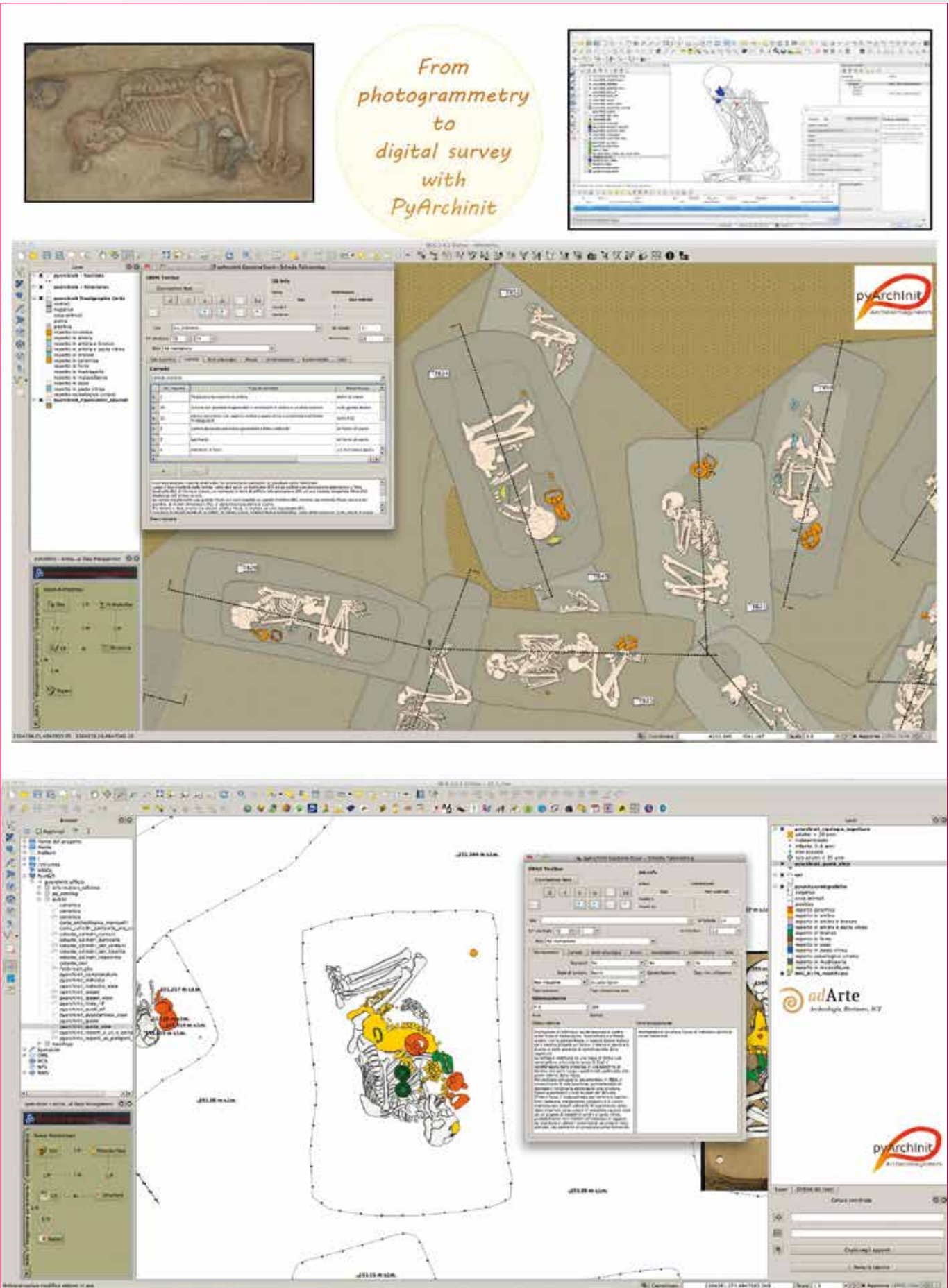
Fig. 11 - Example of digital survey of orthophotos obtained from photogrammetric processes using PyArchinit tools. Image by Montagnetti R., Mandolesi L. 2019.
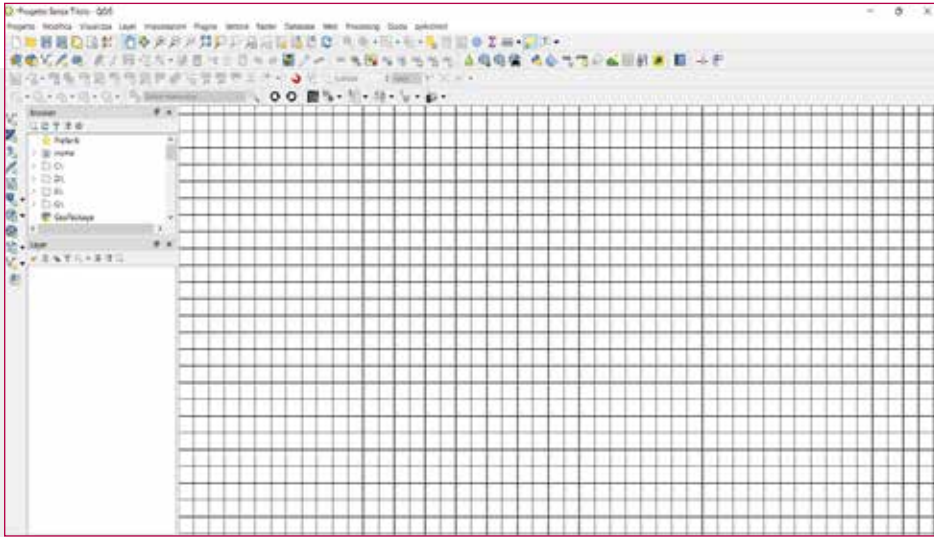
Fig. 12 - Example of Qgis Grid for section drawings. Image by Montagnetti R. 2019.

to both import data into the shapefiles format and maintain the georeferencing of the data (Figure 15).

During the uploading it is possible to use some simple precautions to divide geometries into smaller parts in order to obtain meshes in *Blender*, such as individual themes that groupable in dedicated collections. Also, it is important to remember that the geometries of a layer within *Blender* can be placed at a certain altitude if the elevation attribute is present within the table linked to the shapefile.

Once two-dimensional geometries are obtained in *Blender*, it is possible to model, scale and georeference other asset models in three dimensions. At the same time, it is possible to create virtual reconstructions based on the thematic divisions of shapefiles. This means loading all the power of a geodatabase into a photorealistic rendering tool such as *Blender* in just a few

More specifically, after setting the queries needed, through the "view" method, the selected alphanumeric data and their respective vectors are merged together returning a custom thematic map. Such thematic maps can be phase plans, time period plans or simple Context/SU plan or sections and many others (Figure 5).

Using *PyArchinit*, all these operations are automated. The user only has to fill in the data in the database, at that point, through an easy graphical interface and the special tools provided by the plugin, a variety of maps are easily produced.

Once the thematic map has been created, it can be exported in a shapefile format with the required EPSG ID. The data can then be uploaded to Blender using the *BlenderGIS addons[17]*. The GDAL libraries used by *BlenderGIS* allow users

steps. In addition to the three-dimensional reconstructions of an archaeological site, it is possible to perform other tasks and functions:

1. To implement asset models of generic ancient structures which can be emanated as particles from the individual geometries distributed over the territory in order to recreate the historical
Landscape (Figure 16);

2. To model the historical landscape from contours[18] and the DEM on which to place landscape elements coeval to the era intended to be represented (Figure 17);

3. To take pictures and video of the former landscape, feature, or artefact, which is useful for informative and/or popular purposes;
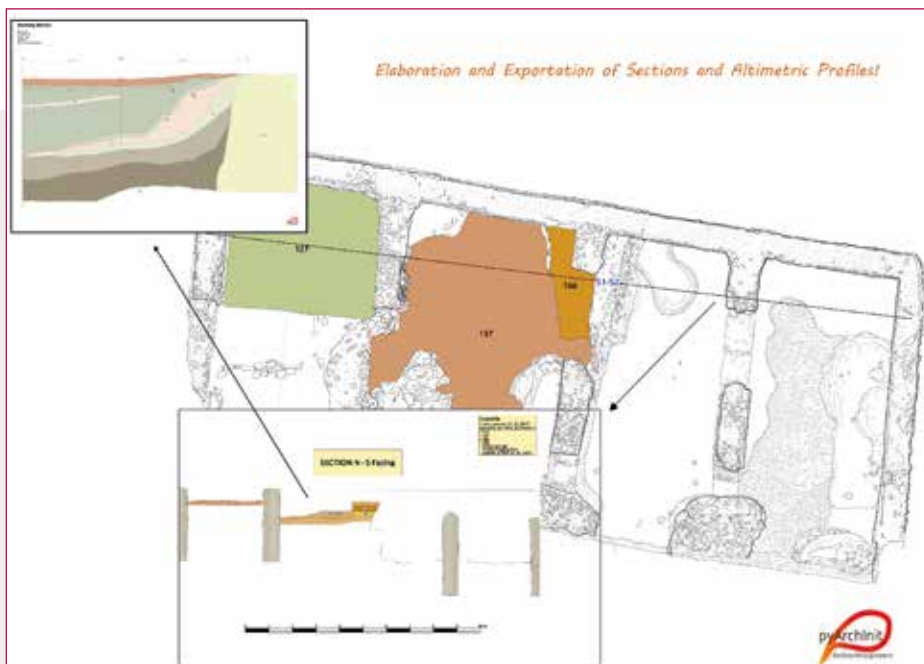
4. To create 3d simulations;

5. To create "virtual reality" paths in order to be able to observe the reconstructions from inside the
3D model through the "Oculus technologies" and to be able to personally verify the quality of the reconstruction (Figure 18).

Once a 3D model has been created, the work can be divided into two paths:

1. To connect the scene with other *Blender*'s files in order to obtain a new georeferenced scene with
multiple asset models;
2. To export the 3D modeling into a 2D model in the shapefile format, from which it will be possible to reintegrate the model back into the *Qgis* platform to be checked and sent back again to *Blender*GIS with new information.
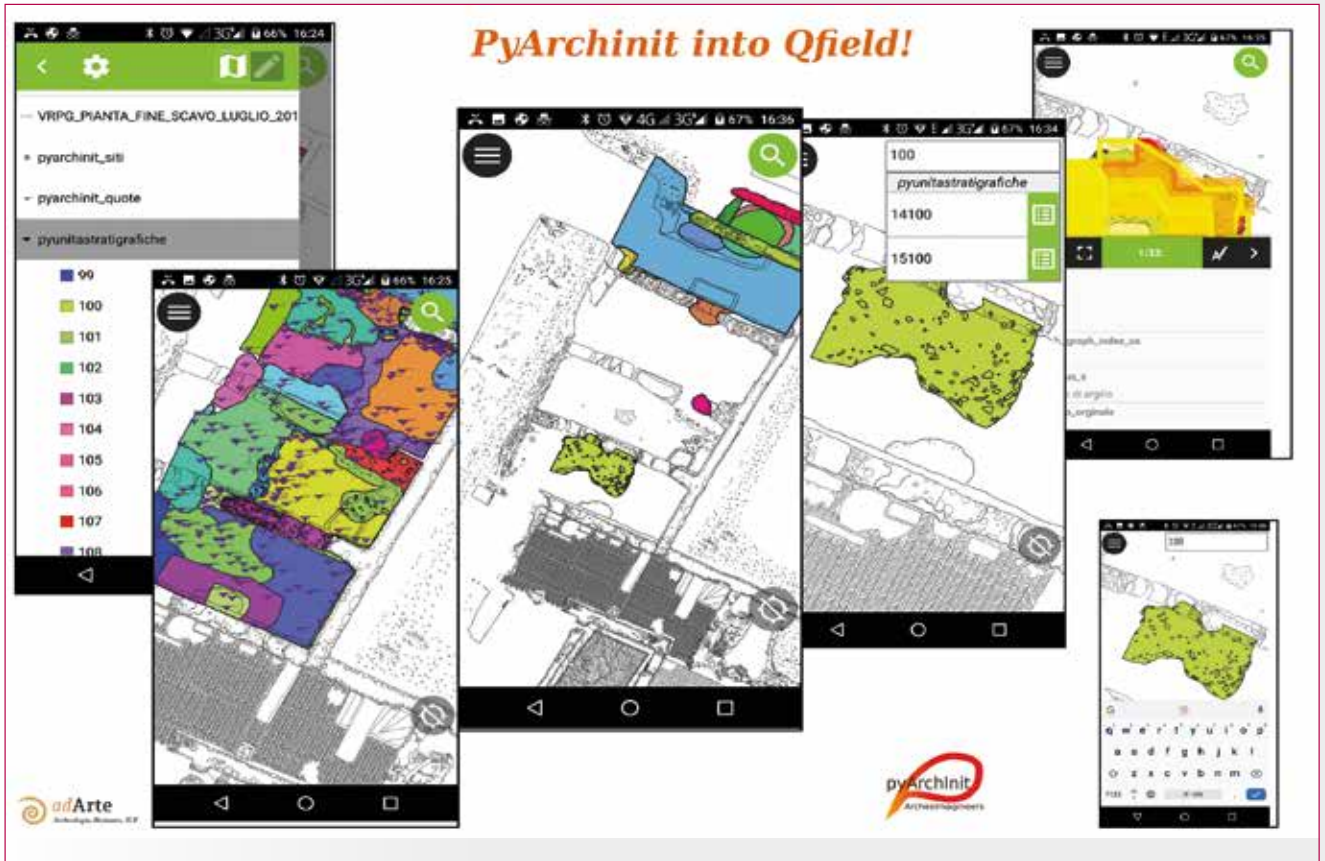

Fig. 13 - Example of digitalization of sections with PyArchinit tools and their exportations. Image by Montagnetti R. 2019.

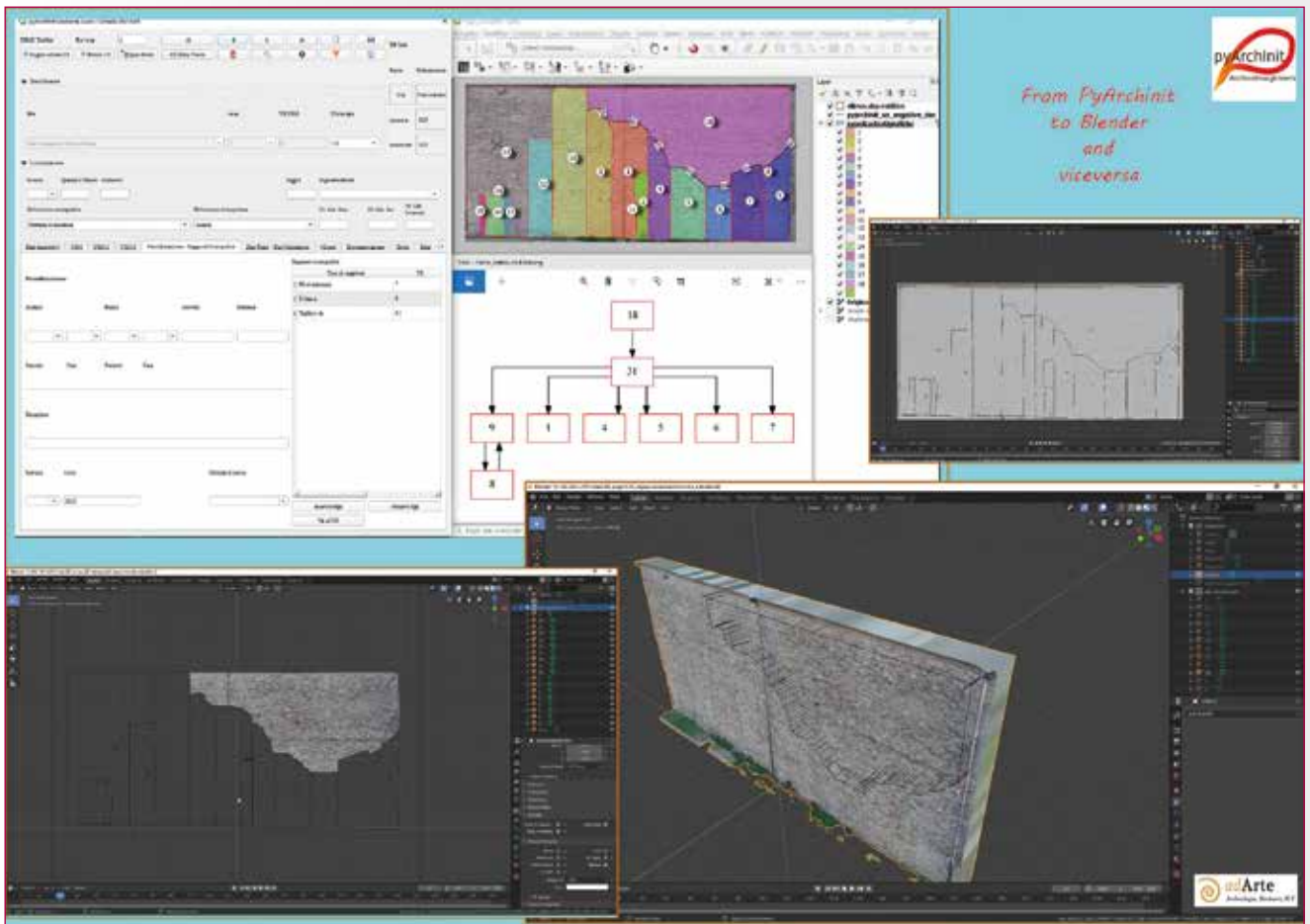**Fig. 14 - Example of PyArchinit into Qfield. Image by Montagnetti R. 2019.**

Fig. 15 - Example of exportation of a digital section drawing (Matrix included) from PyArchinit to Blender. Image by Montagnetti R., Mandolesi L. 2019.
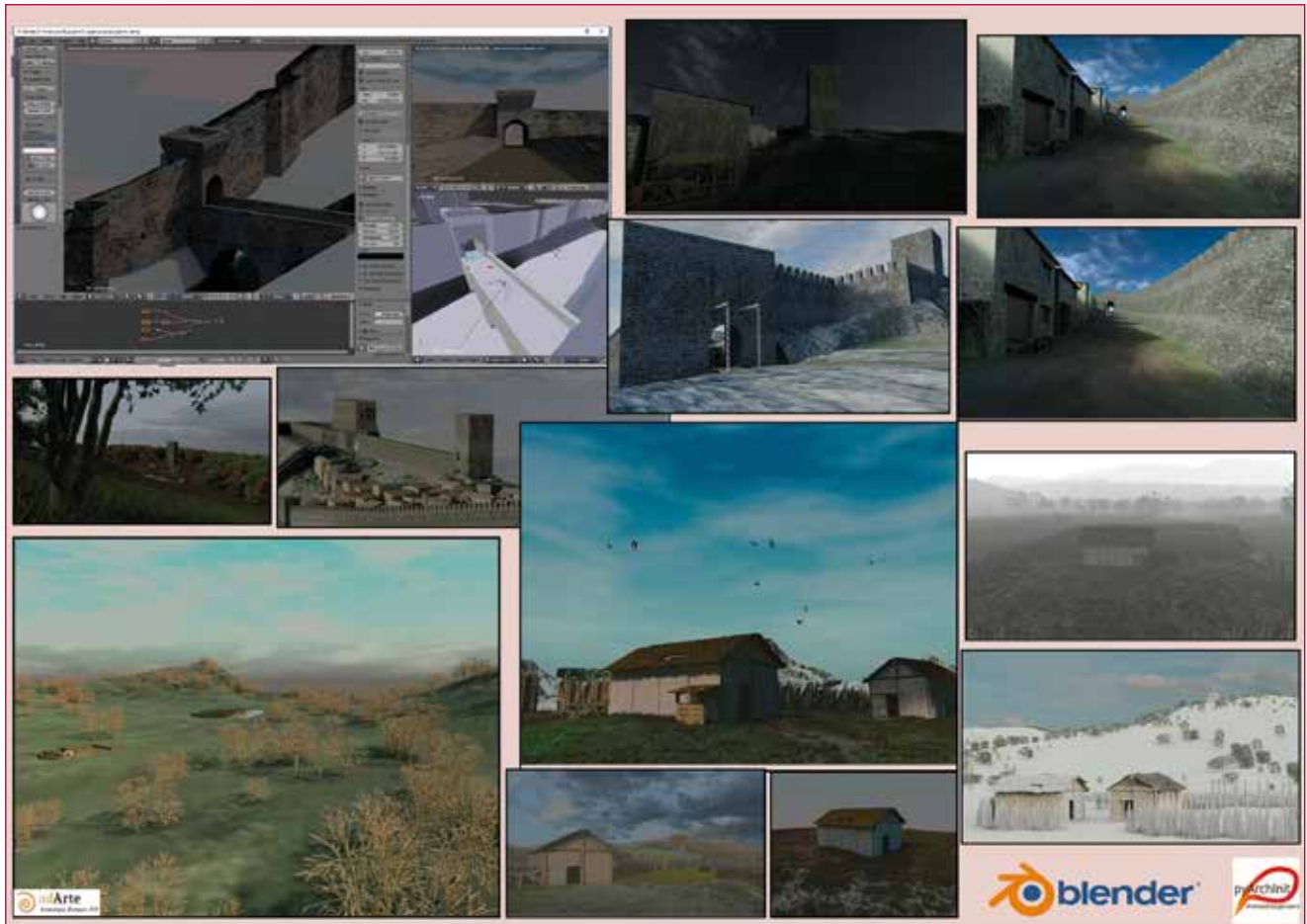
Fig. 16 - Examples of reconstructions of ancient landscapes and settlements with Blender. Image by Mandolesi L. 2019

The aim for the future will be to connect *Blender*'s asset models directly to the *PyArchinit* geodatabase and to the augmented reality and virtual reality goggles (L.M).

CONCLUSIONS
Digital archaeology and data management through GIS systems is now a well-established reality, and is now making an entrance into the archaeological sector. Beyond the benefits already mentioned, these systems speed up operations which are fundamental and mandatory for those working in the archaeological field:

1. To have a continuous overview of the investigation area;

2. To update the data and be able to query it, facilitating the data validation process (Figure 19);
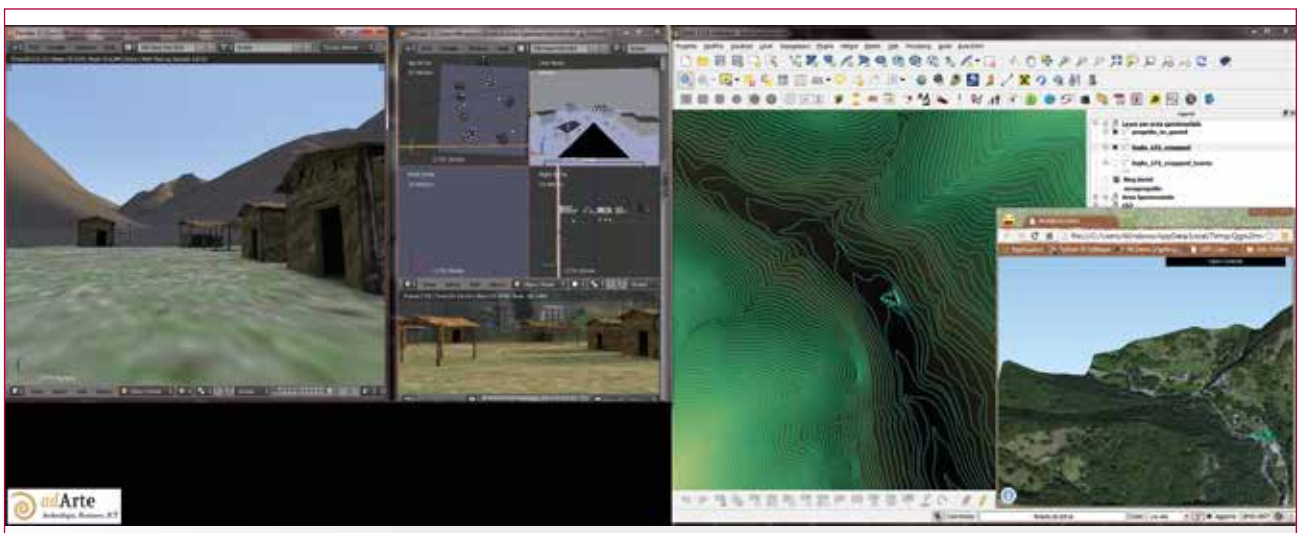
3. For cross-referencing data.

Fig. 17 - Example of reconstruction of an historical landscape with Blender based on its contours and DEM. Image by Mandolesi L. 2019.

GIS systems make these operations immediate, but above all, guarantees the centralized management of all the documentation produced. This avoiding dispersing data into hundreds of files creating a tedious, prolonged process retrieve information[19].

Added to this is the possibility of further increasing the data available about the area being investigated thanks to the use of geoprocessing[20] and spatial analysis tools made available by GIS software.

All of this, therefore, has an advantageous effect on the final interpretation of the collected data, which is the real motive behind any archaeological research or assesment.

The use of such methodologies will simplify the next steps of archaeological intervention namely, the spreading of the

Fig. 18 - Example of "virtual reality" with "Oculus technologies" after created 3d animation models into Blender. Image by Mandolesi L. 2019.

Fig. 19 - Examples of interactive queries and cross-referencing data with PyArchinit tools. Image by Montagnetti R. 2019.
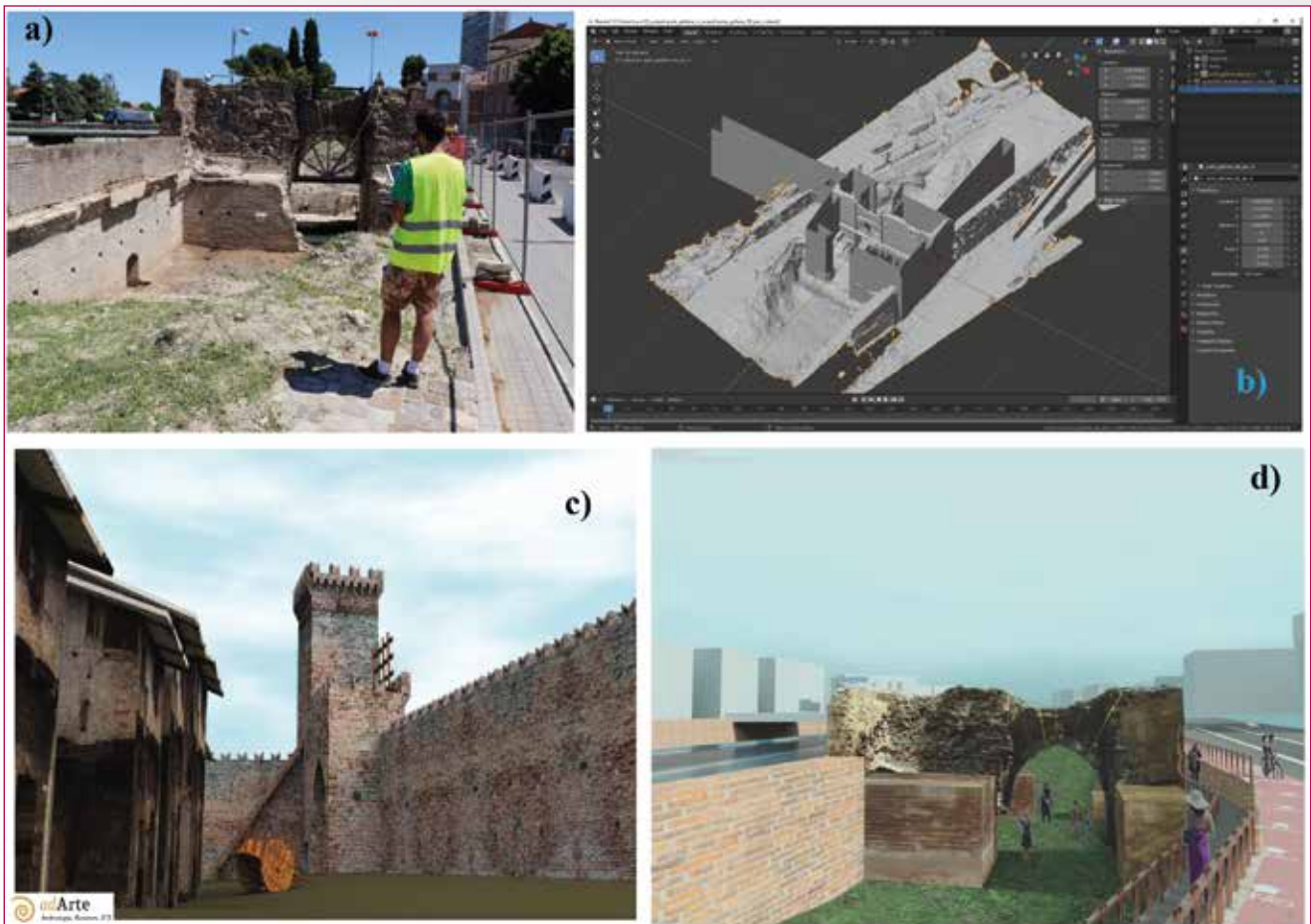

Fig. 20 - Example of workflow: from digital survey to reconstruction of original aspect of an archaeological site until its enhancement for touristic purposes. a) Photogrammetric survey by UAV technologies b) Digital survey and 3d reconstruction into Blender c) Rendering in Blender d) Final inclusion in the Landscape plan template. Image by Mandolesi L. 2019.

collected data, and the preservation and the enhancement of the various sites. Archeology has no reason to exist if it is not preserved, enhanced and shared.

As we demonstrated in this article, thanks to assets like *PyArchinit* and *Blender* it is now perfectly possible to go beyond the simple survey of an excavation to its three-dimensional reconstruction. There are many practical applications for these models in addition to the recording of site data. They can be used for educational and touristic purposes, but also as a tool for conservation[21] (Figure 20).

All of this would make the understanding of archaeological sites and ruins easier for non-experts,

increasing interest and awareness in archaeology and in the importance of its preservation (R.M.).

End Notes

1 This definition is just a personal review that takes its cue from other definitions: Mogorovich 2010.

2 For a general framework on the advantages of GIS refer to: Antenucci, Brown, Croswell, Kevany, Archer 1991; specifically for archaeology: Forte 2002.

3 Specifically, these consist of: US registers, Drawing registers, Photo registers, Sample registers, Site sheets, US sheets, Material sheets, Skeleton and Tafonomic sheets and may other.

4 About this topic refer to: Lelo, Travaglini 2009.

5 For more in-depth information on *PyArchinit* and its specific tools see: Mandolesi 2009.

6 They usually are plastic targets fixed on the ground with nails. Their number is also implemented step by step with the progress of the excavation in order to have constant updates and regular coverage of the whole surveying area.

7 The insertion of the geographical grid, in the cross shaped symbol, mainly serves to increase the accuracy of the georeferencing of the various manual drawings, always ensuring an adequate number of GCPs and as regular a distribution as possible. In fact, a distribution of the points in a single restricted portion of the area that must be surveyed compromises the good outcome of the georeferencing; About this issue: Campana 2003.

8 In general on the principals of the photogrammetry refer: Kraus 1994; Selvini 1994.

9 The advantage of georeferencing the 3d model of the various features consists in the fact of being able to extract from it not only georeferenced orthophotos but also Digital Elevation Models (DEM). DEM can be used within Qgis both to obtain the levels of the various archaeological features identified, avoiding, in this way, to the use of the "Dumpy level" and for many other Geoprocessing operations such as: extract terrain profiles, contour and others.

10 E.g. the "Aligns" tool of CloudCompare (Figure 10) or "Reference Scene" tool of Meshlab. For more in-depth see: www.danielgm.net/cc/; www.meshlab.net/.

11 Obviously the number of GCPs can be increased at any time according to the needs.

12 For more in-depth study about these arguments see: Montagnetti, Chiraz, Ricci, Pickel, 2019.

13 Sections can also be extracted from the photogrammetric 3d model to obtain georeferenced façade on which to draw the various contexts directly in the GIS using the PyArchinit tools. Although, in this case, the Y coordinates of GCPs should first be reversed with their Z coordinates. It means getting what is called a "Vertical GIS" (Chavarría Arnau, 2011). Nevertheless, these procedures ultimately take much longer than manual drawing on site and a very deep level of knowledge of GIS that not everyone can have.

14 Same procedure but multiplied by 10 if we have drawn sections in 1:10 scale.

15 If the section has been drawn on site on more than one sheet of graph paper, the same technique will be used to obtain a mosaic inside Qgis.

16 For more in-depth check: www.*Qfield*.org.

17 See: https://github.com/domlysz/BlenderGIS.

18 These contours may be related to the current landscape or may be those derived from archaeological data.

19 We challenge anyone to manually check the huge amount of paperwork of an excavation that lasted a few years, and where most likely hundreds of people have worked or to update the survey, relying only on hand-made drawings that must necessarily be put together manually on large overlays. Taking into consideration the fact that only very rarely you have available highly specialized staff in the archaeological survey at the expense of its accuracy and precision.

20 Geoprocessing operations are analysis techniques based on the vector format and used for the derivation of new data from incoming data; McCoy 2004.

21 Several of these projects, related to 3d prints of monuments and archaeological artefacts, for example, have been implemented in Syria following the destruction by ISIS; see https://www.stampa3dstore.com/la-stampa-3d-aiuta-restauratori-italiani-a-ripristinare-i-busti-distrutti-dall-isis-a-palmyra/.

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Abstract

The goal of this article is to provide several practical procedures for working within the GIS environment in the archaeological sector, with specific reference to the excavation site, through open source methodologies and software such as Qgis and PyArchinit.

It will also demonstrate how to use the data derived from the survey, processed and managed through Qgis and PyArchinit for enhancement projects such as 3d modeling and 3d mapping through Blender software.

Keywords

PyArchinit; Qgis; Qgis-Belnder; Blender; SFM; Digital Archaeology; Archaeology; Archaeological Georeferencing

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