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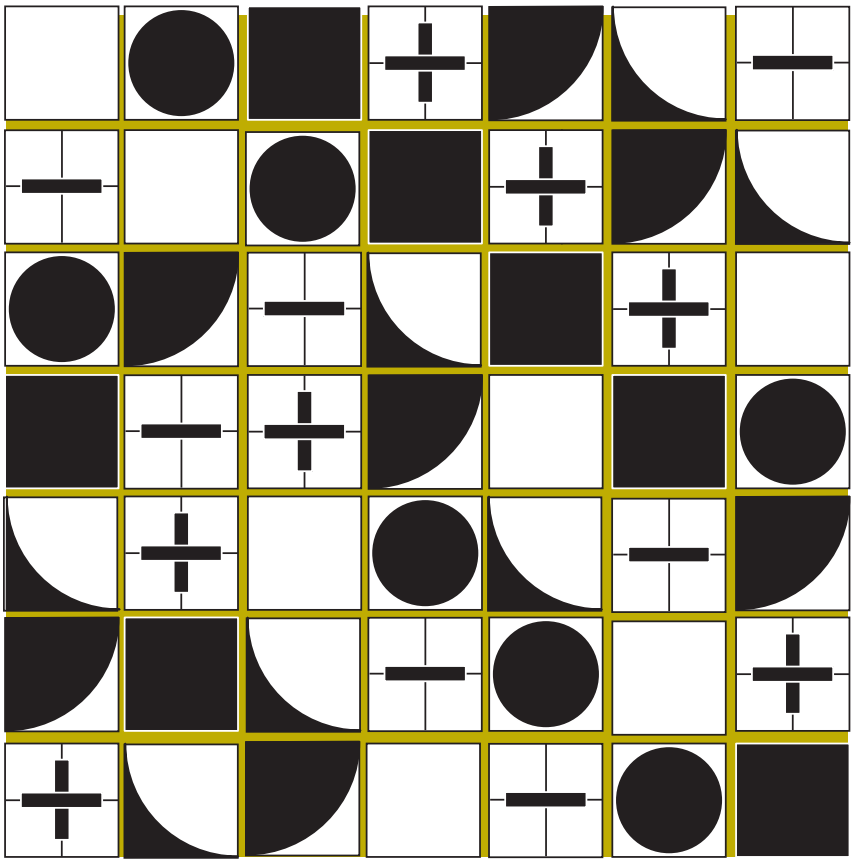

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Digital Representation of Archaeological Sites. Recent Excavation at Alba Fucens.

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Absctract
The use of digital technologies in the survey of archaeological sites arises some interesting methodological questions. This contribution aims to make analysis based on experience in performing in Alba Fucens, Latin colony of the fourth century BC, founded near the ancient lake Fucino for control important routes in the peninsula.
The activity of documentation and analysis that the research center of Rieti Sapienza of Rome “Critevat” is in accordance with the Department of Human Sciences University of Foggia, concerns old and new excavations.
The growing use of digital techniques, such as 3D laser scanner and photogrammetry, has as main consequence the tendency to objectify the data acquisition phase, shifting forward the time of interpretation and analysis.
In the archaeological field, perhaps more than in other areas, this dichotomy is most accentuated. The representation makes more use of rendered three-dimensional models but are often difficult to manage, because they are still not standardized by the professionals or by the people who needs to acquire information for dissemination.
The three-dimensional models often do not have the selection as a goal, but the "simple" repetition of a reality. The questions are: Are these models really objective? Is there a selection in the processing phase?
The quality of a points-cloud where the real space is discretized into a number of discrete points depends on different resolutions, on the presence of voids, on photographic renderings which in turn depends on focus or exposure.
We still think the automatic processes of continuous numerical surfaces and then of the mathematical (NURBS), which often use filters to reduce the "noise", based on algorithms developed for other applications.
The paper plans to clarify the problems encountered in the experience of Alba Fucens and proposed some ideas arising from the comparison between surveyor and archaeologist.

Keywords
Digital reprentation, Archeological site, Alba Fucens, Survey, Scanner laser 3d, Photogrammetry

1. Introduction
The use of survey techniques and digital representation for the documentation of archaeological sites is certainly a very topical issue which can be an important means of optimizing economic resources for the preservation and development of a multitude of small sites known to archaeologists and superintendents, but most often invisible to the community and then out of the local tourist circuits.
Digital technology has an enormous potential, even if we can find some contradictions in its use perhaps due to the cultural differences between specialists and mutual distrust.

The survey and representation in archaeology are disciplines consolidated in the last century that are based on rigorous methodological integration between the topographical instrumental survey and direct survey, then it returned into the various final draft [1]. Rarely, if not for the most important and famous archaeological sites, was used to photogrammetry has always been considered a technique of survey very specialized and expensive.
The digital age has opened new scenarios that are also growing increasingly investing in archaeology [2] [3] [4] [5], with different weights, all intervention phases: prior investigations, planning and documentation phases of excavation, analysis of findings, and management by superintendence, and activities of musealization, scientific publication and enjoyment by the community.
Digital technology, however, implies some contradictions: on one hand it makes the task easier, especially if you think for example of the enormous scope of information dissemination, the other produces strong specializations that sometimes do not communicate with each other. That happens usually when digital technologies are based on different platforms and standards, such as geographic information systems, software modeling three-dimensional or non-invasive diagnostics (for example GPR or modal analysis).
The research center of Rieti Sapienza of Rome “Critevat”, for some years carrying out research in the field of diagnostics and monitoring in many areas from the environmental to the architectural and archaeological heritage. In particular, a group of researchers have started some experiments on the use of survey techniques and digital representation for the documentation of archaeological sites [6] that are often abandoned or little-known such as the Terme di Vespasiano in Castel Sant'Angelo, the Roman amphitheater of Trebula Mutuesca in Monteleone Sabino, recent excavations in the Populonia Etruscan site. A recent agreement with the Department of Human Sciences, University of Foggia allowed to start an interesting collaboration between archaeologists and surveyors in Alba Fucens.
The examples described below relates to a particular area of excavation, that of the south-east of the Forum, where survey were conducted in two stages: the first in late 2010 and the second in the summer of 2011.

2. Alba fucens: the archeological site and the area of intervention

The excavation teaching (fig. 2) that the University of Foggia has been leading since 2007 in the southern sector of the Forum of Alba Fucens, Latin colony founded in the late fourth century BC as a military stronghold in fair territory [7], involves an area only partially affected by past Belgian research in the years 1949-1979 [8].
This is a sector that plays a nodal role in the urban, located as it is at the point of 'intersection of the axes of internal roads, - the way of the Pillars and its continuation to the north crossing the way of the Elephant - the point at which converge the political-administrative functions and the economy-trade of the ancient city.
The excavation involving the square and some buildings that flank the eastern side, in particular: a) a *taberna* from the long and narrow plant, in front of the colonnade and divided internally into compartments and different levels, overlooking the back on a elevated main road [9] b) almost half of a sizable monumental public building, articulated on different levels, whose intended character of worship must be confirmed by future surveys [10].

Fig. 1: Alba Fucens archeological site

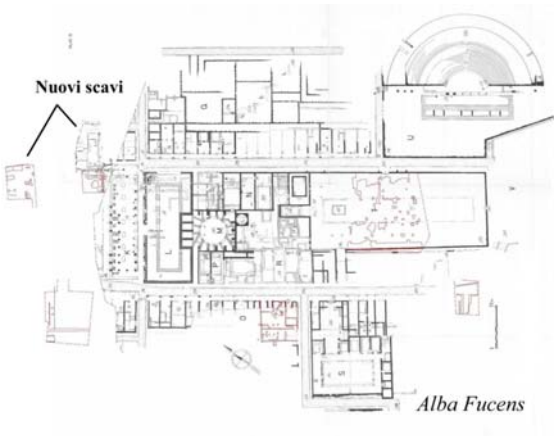

Fig. 2: General plan with indication of the excavation

The conservation status of the structures elevation is quite exceptional: the bounding walls of the rooms are kept to a height of about two meters, although they were affected, we would say in ancient times, by structural failure.
Compared to the latest discoveries (such as the redefinition of the widths of the square than now appears less offset from the plan road) the analysis of the area and the plans derived from the survey carried out important contributions to the chronological information, either in relation to the first monumentalization of the forum, whose pavement was to be later than previously thought, dating to Giulio-Claudia's age, or in relationship to the later phases of city life, when the area is affected by a series of story building that appear linked, in part, to the destructive action of an earthquake and whose stratification is found in her structural characteristics of masonry

3. The integrated digital survey

The main changes introduced by recent developments in digital technology are basically two: digital photogrammetry and three-dimensional modeling [11].
The first makes it possible to perform, beyond the technicalities and the related costs of excessive analytical photogrammetry implemented until some twenty years ago, survey operations which add up effectively to the pure metric data several additional information that only photography can give back such as for example the most minute textures of the masonry, the stratigraphic differences, the state of preservation [12]. Through digital photography it is also possible, with the commonly used software today, to prefigure project solutions in a very realistic.
Three-dimensional modeling, increasingly widespread, overcomes the scheme, at times too hard, for traditional graphical models such as double orthogonal or axonometric projections because it is unable to return multiple views and, through movement, to propose a new perceptive dimension of the object represented in a virtual simulation of great communicative value.
The combination of the two technologies, namely the photographic texturing of 3D mathematical or numeric models, not yet in common use today, is without doubt the best result that can be obtained as the product of an integrated digital survey conducted with the most modern technologies.
What is the element that unites these two technologies and represents an important discontinuity from the survey, so to say "traditional"?
In the operation of survey, you can always recognize two phases: a metric acquisition as objective as possible and a processing of the data, transcription selective metric information of the second predetermined codes and therefore is essentially subjective, interpretive. In truth they are the classic two sides of the same coin, or at least they were until the computer revolution.
The increasing use of digital acquisition techniques, such as 3D laser scanner and photogrammetry [13], has the main consequence of the tendency for objectification of the acquisition phase of the data, shifting forward, if not delegating to other professionals, the phase of interpretation and analysis of data acquired. In the field of archaeology, perhaps more than elsewhere, this dichotomy is most conspicuous, in the representation, for example, becomes more and more use of textured three-dimensional models do not yet fully standardized and is therefore difficult to manage either by experts or by who need to acquire information for dissemination purposes. Three-dimensional models often do not have as its goal the selection, but the "simple" repetition of a reality as faithful as possible to reality.
One has to ask first how much these models are actually objective or are the result of elaborations that, as such, are selective. Consider, for example, the quality of a points cloud in which the space continuous, real, is discretized into a number of points with different resolutions, with the presence of voids, with photographic renderings which in turn may contain factors inhomogeneity in the focusing or exposition.
We still think the "automatic" processes in numerical continuous surfaces (mesh) or math (NURBS) which are frequently used in filters to reduce the "noise", based on algorithms developed for other applications. One has to ask even if the three-dimensional models cover all the survey objectives or whether, must always use the traditional graphical models (although digital), there is a real integration and interaction between the data acquired with the new technologies.
These are the main questions that the research unit of Critevat was placed on experiments in Alba Fucens, where it became clear how important it is also being acquired as well as the continuous development and constant dialogue with archaeologists and with the supervisors of cultural heritage.
One of the interesting aspects of the experience, still in progress, and that the activity of digital survey did not rule out a parallel survey in accordance with procedures of "traditional" made detection of topographic points for reading elevations, levelling for the identification of different stratigraphy, an impressive photographic documentation able to fix the various phases of the excavation and identification of archaeological finds to be placed elsewhere.

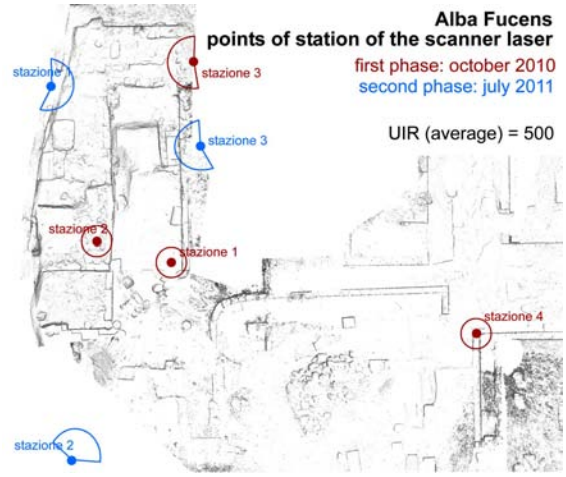

Fig. 3: Plan with points of station of the scanner

3.1 The data acquisition

The acquisition of the digital data of *taberna* of Alba Fucens was done in two stages corresponding to the two phases of excavation described above. A first acquisition was made in October of 2010 to complete the excavation of the tavern itself, the second between July and September 2011, as documentation of the subsequent campaign of excavations, adjacent to the previous one and that has brought to light some interesting remains of a public building in the north area of *tabernae*.

Were performed on both occasions scans with a 3D laser scanner, the Leica HDS3000 and photographic images were acquired using the internal machine and an external machine. Were also made many photographs not related to scanning with a digital camera equipped with a properly calibrated for the target software compensation of distortions.

Figure 3 shows the points of stations with the scanner related to the two different days.

The first day we identified four shooting stations, the first three refer to the area of excavation and the fourth, more distant, useful for a correct position on the archaeological site generally.

The second station was located on land that was later carved into the second excavation. In July 2011, when it had almost completed the first part of excavation of the public building in the area next to the *taberna*, has made a new acquisition with three other stations.

One of the main problems in the acquisition digitally using the 3D laser scanner is linked to the correct positioning of the stations on the context to be detected. The choice of the stations is determinative of a good quality of the discrete model constituted by the so-called point-clouds, from which they can subsequently derive the majority of the metric information, graphic traditional models and the polygonal three-dimensional models.

Each archaeological site presents the specificities although some aspects are applied quite frequently. The elevated structures are usually contained in height although, in contrast, "internal"environments are very small. The area to survey is often located below the horizontal plane of reference, the one which crossed the center of the instrument; should, where possible, to try to integrate the shooting low, ie, those made on the plane of the excavation, with the shoot from stations located as high as possible. The other factor that often affects the project intake is related to the field of view of the instrument that has a shadow on the bottom, with the support stand. Instrument located much higher than the area of survey on the one hand increases the visibility of structures in elevation, but at the same time also increases the shadow under the instrument.

Alba Fucens the shooting was in part facilitated by the topography of the area; station 1 positioned inside the room has been integrated with two other stations located at the top through which we were able to get a very good visual coverage altogether. Station 4 was identified as a docking station for future times that will cover the entire archaeological area and some of which have already been, meanwhile, carried.

The scannings of the second day, made in July 2011, focused on the part of the public building, with again three stations quite high compared to the area of excavations that have allowed a good level of coverage.

The registrations, that is the assembly in a single point-clouds, has been made with two separate procedures: the point-clouds refer to the same working day were recorded by the application in the field of automatic recognition with a target value tolerance of about 1 mm; the overall union of the two days instead was performed with a recognition procedure manual made possible by the many homologous points identified with a very high precision.

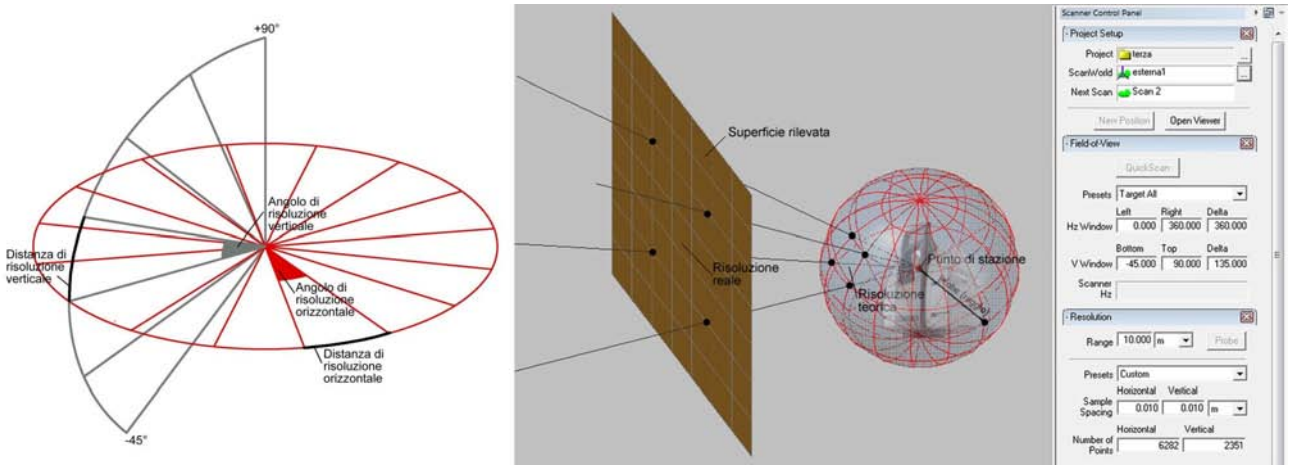

Fig. 4: Instrumental resolution and real resolution

It was determined throughout the setting phase of the shootings project the continuous exchange of information between the surveyor and the archaeologist, allowing to optimize all the phase of acquisition of digital data.
An element of concern highlighted by the archaeologists and the Superintendent has covered the wall in large stone blocks of north-west at the time of the discovery had a strong deformation in the central part, a sign of distress is due to natural causes but also to a static condition blocks of stone no longer optimal.
The second season of excavation has allowed much to lighten the burden imposed on the vertical structure even if problems of a static nature remain.
The digital detection was possible to verify, by comparing the scans made at a distance of 9 months the progression of the instability which was fortunately very contained in the order of a few millimeters.
The quality of the shooting done with a laser scanner as well as the careful selection of those stations also depends on a number of instrumental settings can not always be in the reports that describe the activity. One of these is the instrumental resolution, i.e. the amount of points in the unit of spherical sector, which is something different from the real resolution, i.e. the one obtained by the intersection of the laser beams with the object to be detected (fig. 4).
We can define the unitary instrumental resolution *UIR* (RSU in Italian), i.e. the one referred to a sphere of radius 1, which is obtained from the product $UIR = d \bullet r$ where *d* is the amount of points per meter, horizontal and vertical (generally equal) and *r* is the value of the range, ie the radius of the sphere. If, for example, setting an instrumental resolution of 2 cm with a radius of 10 meters, it follows that *d* is equal to 50, for which the value of *UIR* is 500. The knowledge of the *UIR* is important when it wants to estimate beforehand the setting time and the amount of information gained [14].
The real resolution but is never homogeneous and varies greatly depending on the shape of the surfaces and the distance to the station resumed. This has two important consequences in the setting of the project setting: choosing points of station to obtain a resolution as possible homogeneous parts found; choose multiple stations in order to compensate for excessive differences in the real resolution. And again, choose different resolutions, a lower over coating general, and other partial denser according to the specific formal characteristics of the object to be detected.
We already mentioned that all the shots were integrated with panoramic photographs taken with both the internal machine is the instrument with an external machine. Thanks to a special kit supplied, we can place the center of the lens of the camera coincides exactly with the center of projection of the laser beam, thus allowing a perfect match and interchangeability between photos "internal" is often not of good quality, and photos "outside" is best for resolution or for exposure[15].

3.2 The restitution through models

After the acquisition of digital data is followed a first phase of restitution in which a deciding factor was the continuous comparison between the different professional in the field.
If, as we said in the introduction, the phase of data acquisition by means of digital instruments feature tends to be objective, that is not selective (even if, as we saw in the previous paragraph, the quality of shooting is influenced by operational decisions is often not easy), the phase of restitution of the data through modeling necessarily involves a subjective interpretation.

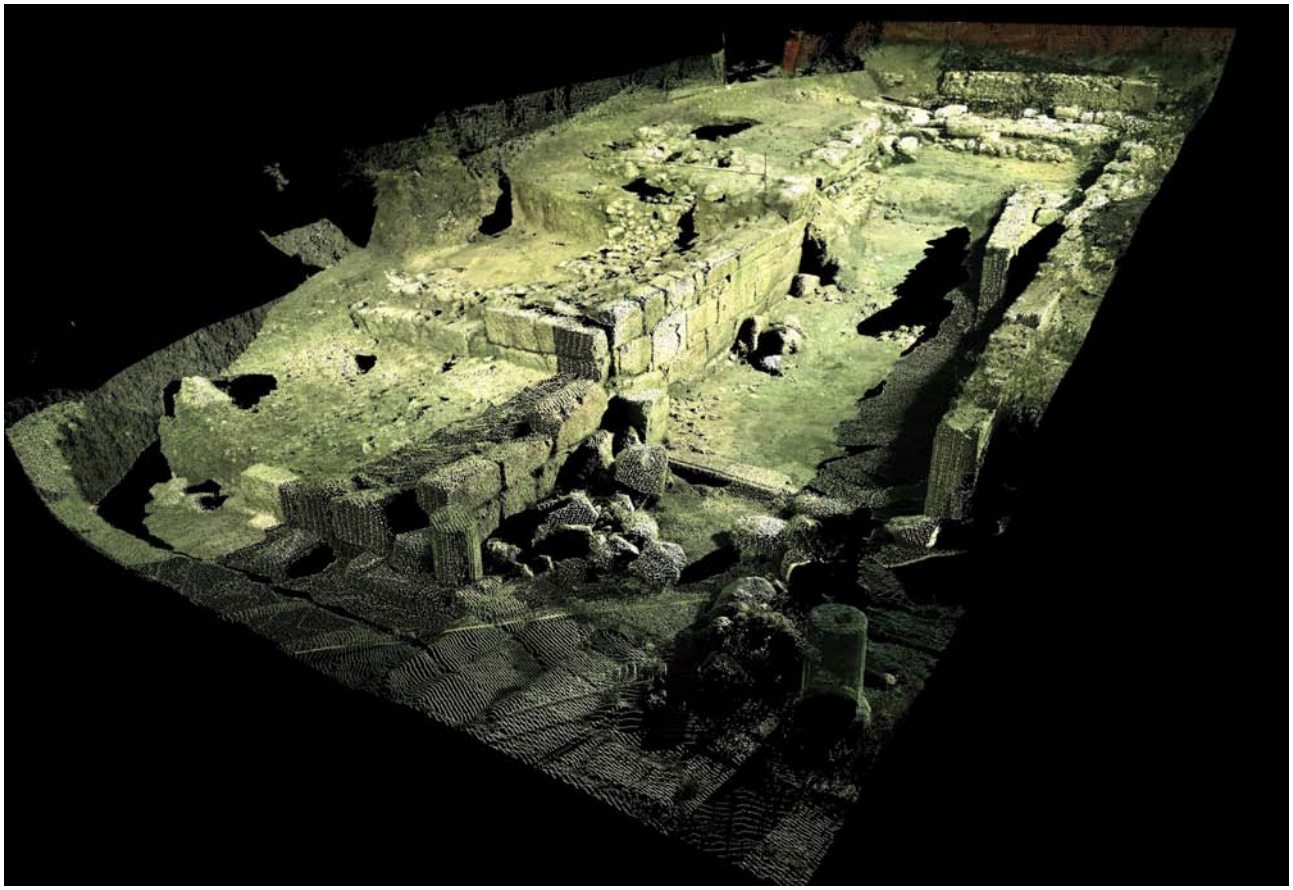

Fig. 5: Render view of points-cloud

The experiments under way at Alba Fucens not replaced the survey techniques and "traditional" restitution that remain in many ways necessary for the documentation of the actions in progress of excavation and finds. This gave way for archaeologists to compare the information is to assess both the reliability and above all the different communicative potential.
One of the most innovative on the digital survey using laser scanner integrated with photography is to have a three-dimensional model consisting of discrete point-clouds which can be associated with the color value derived from the image photo. This new model, available immediately, can be understood as a real three-dimensional photography. The model management is still the preserve of specialists because the need for dedicated software difficult to use and very expensive. But digital technology progresses exponentially is already available software "easier" through which they could use the model "raw" (fig. 5).
Another new feature is the ability to obtain "traditional" graphical models, all digital, but easier and immediate reading, that is, for example, plants at various levels, sections, elevations, possibly supplemented with information such as photos.
The passage is not automatic and refers to the codes of representation consolidated so that no three-dimensional model, as elaborated, will be able to replace. The development of the plan of figure 6 is an example.
We tried to get a planimetric image synthesis can better represent the complexity of the archaeological site where they were still recognizable emergencies that characterize the shape. The development of the point-clouds takes advantage of some of the many views that can be obtained by varying parameters such as for example, the background color, the color map, the point cloud rendering, the density of points viewable.
Nevertheless, it is still necessary to integrate the development made by overwriting certain information necessary for the representation, information that the surveyor was able to highlight only thanks to the determinant of the archaeologist.

Fig. 6: Plan of the excavation area

Fig. 7: overlap of plans

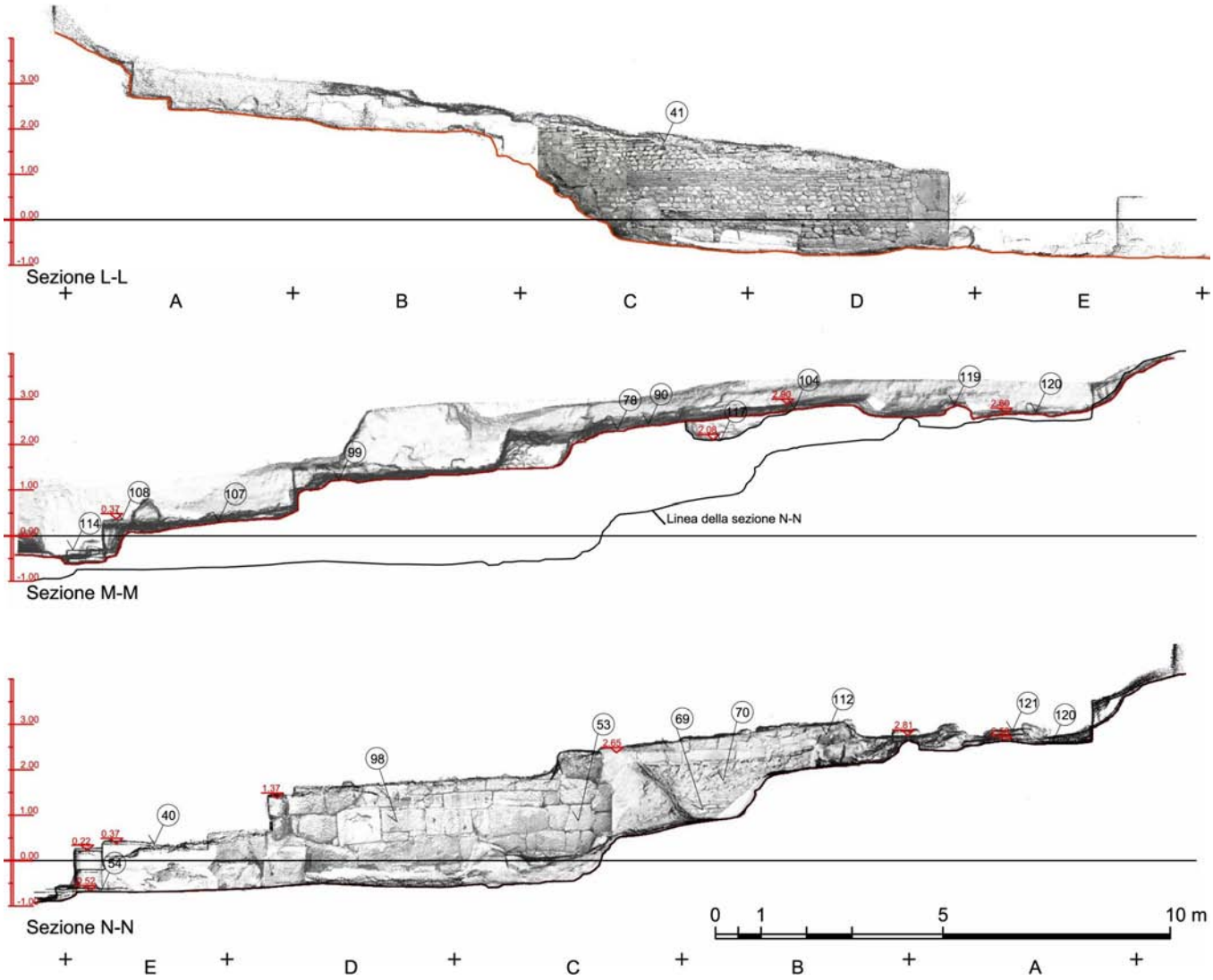

Fig. 8: sections of excavations area

The floor plan was compared with another plan prepared according to procedures previously "traditional" (fig. 7). In comparing the differences are obvious topographical, fairly small, but above all the different graphics made, based on the continuity between the artificial and natural elements of the former over the latter.
The steps identified for the development of the plan was also used for the preparation of sections, some of which were then integrated with the processing of photographic images scaled appropriately according to the corresponding orthographic views (fig. 8).
Research has therefore focused on two distinct ways of representation. The first revival of "traditional" graphical models characterized by an evident desire of interpretation, however, based on objective data as it is, those derived from the three-dimensional digital model of the point-clouds, so in essence the transition from 3D to 2D. The other processing of the same three-dimensional model in a different model 3D of the continuous type, based on polymesh modeling. In the latter case it is necessary to carefully evaluate the operations of filtering of the data "raw" for a controlled reduction of points (the cloud processed in two days and about 7 million and a half points), and noise. The main intention is that for which you want to make three-dimensional model, with a huge capacity that is representative evidently well beyond the 2D models, as much as possible "navigable" experimenting with the conversion of the continuous model in standard communication platforms like such as 3D PDF files.

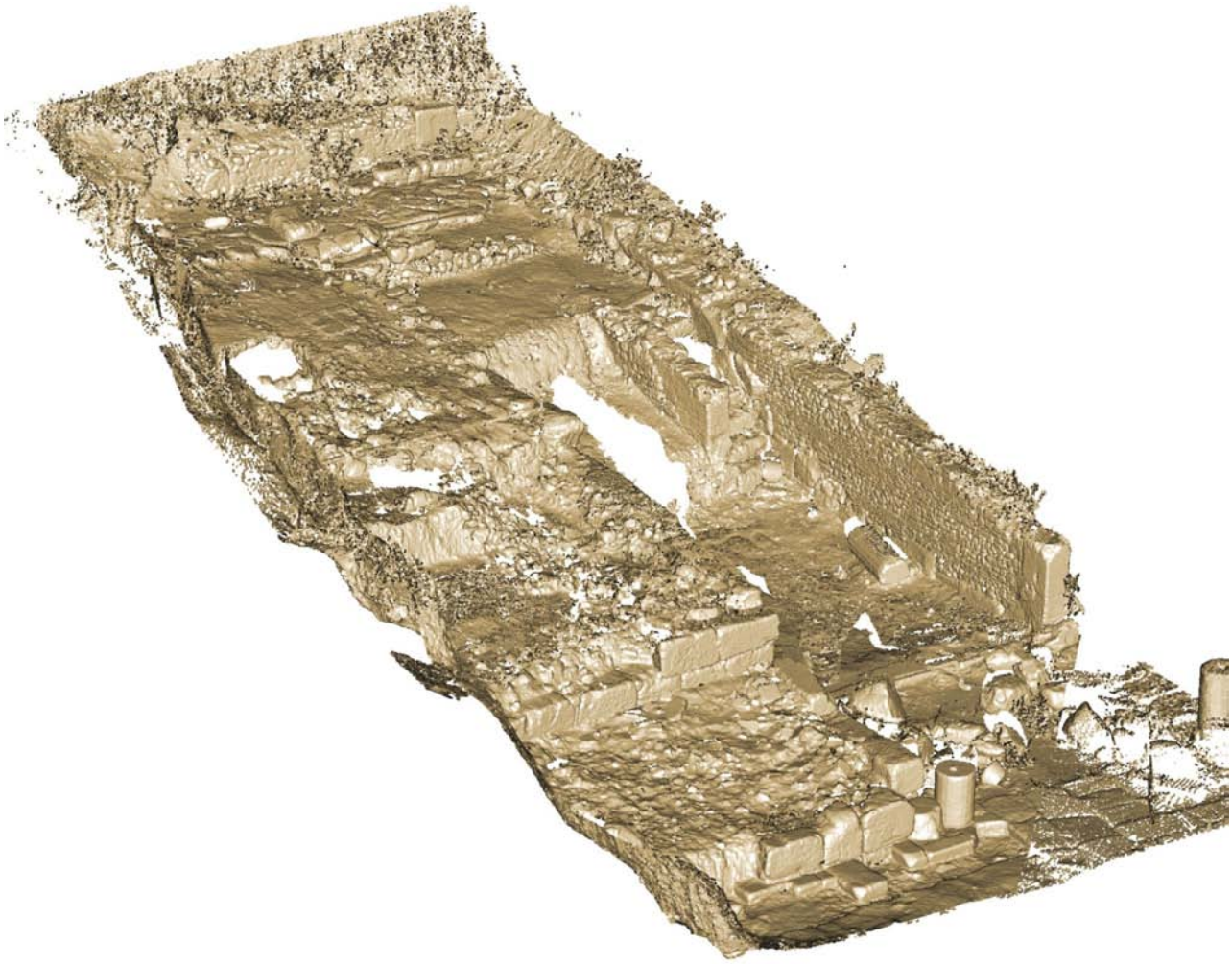

Fig. 9: 3D surface model

As part of these files in common use is also possible to implement the same files 2D acting on different layers to which associate possible interactive actions, such as for instance the comparison between sections at different heights or levels of activating or deactivating thematic analysis as for example the stratigraphic study or analysis of the degradation.

4. Conclusion

The experiments under way at Alba Fucens has highlighted some interesting issues which through a close collaboration between specialists have tried to give an initial response. The management of digital models that can be obtained from the use of new techniques for survey and representation can be varied according to different levels of usability. There is a first level, on the field, which covers the documentation of the excavation activity, where the processing is necessary to integrate the traditional with the first three-dimensional digital processing. There is a second level for the consumption of the scientific community in which the representation is true instrument of knowledge and verification of the first assumptions made in the field. The model must be able to display all its topographical objectivity but must also be able to return a first level of interpretation. It must be fully supported in order to be implemented through the historical considerations and first assessment of conservation. Finally, there is a third level of usability, the one to use and consumption of the community, in which the model of restitution must necessarily be more easily understood and manageable also and especially by means of disclosure of mass, and for example the web [16], through which give visibility to an immense fortune scattered and for this too often left to his fate. Being able to set a suitable and qualified network of interchange between the different levels is the foundation for the construction of the Knowledge Factory is able to activate virtuous processes not only cultural but also economic in common territory.

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