Giuliano De Felice – Nunzia Maria Mangialardi – Maria Giuseppina Sibilano – Giuliano Volpe

Late Roman Villa at Faragola (Foggia, Italy): Laser Scanning for a Global Documentation Methodology During Field Research

Abstract: Laser scanning is a tool that is increasingly being used in archaeology. While experiments often focus on its use as an instrument for surveying remains of large archaeological sites and ruins, it can also be used in the process of documenting and recording excavations. 3D registering of archaeological stratification is a challenging goal that requires a unique environment for a global set of documentation objects, including traditionally drawn overlays and plans. What a laser scanner cannot do is survey things that no longer exist. Our main concern was to merge digital born data from the laser scanner with traditional data that have to be implemented using different technologies and solutions.

Introduction

Presented here[1] are the first steps of a methodology we are working on to try to manage the whole graphic documentation of an excavation site in a 3D environment (see also Volpe / De Felice / Sibilano in press). The experiment involves just a small sector of a large late Roman villa in Southern Italy, but can be applied to every excavation site.

The *villa* of Faragola is a large, complex rural site, featuring important luxury structures dating to the Late Roman period. The first four campaigns of excavation showed up a series of rooms belonging to the baths and the residential zone that date to between the 4th and 6th century.

The room which is the focus of the experiment is an important space in the organization of the *villa* which has been interpreted as a *cenatio aestiva*, a banquet hall. In the room there are remains of the original decoration. The floor, which is composed of marble slabs taken from a former building, includes three panels realized in *opus sectile* made of small glass pieces. Another interesting feature of the *cenatio* is the *stibadium*, where parts of the original marble decoration are preserved. This structure is one of the few known *stibadia* in the Roman world (Volpe / De Felice / Turchiano 2004).

Building a 3D Model of Structures with the Laser Scanner

The 3D model of an archaeological object must first of all be a measurable representation of something that exists which allows us to identify the processes of creation and transformation it has undergone (Alessandri / Uccelli 2006).

Any 3D model should ideally contextualize great quantities of scientific information that are important at an investigative level (Forte 2006).

3D modelling is nowadays a product of digital elaboration, computational power and graphic visualization.

The recent introduction of laser scanners in archaeological research gives us an opportunity to test the reliability of this tool in the graphical reconstruction of deposits and stratigraphical volumes, as can be seen in the comparison of different surveying techniques carried out with both traditional tools and laser scanners (Monti et al. 2004).

Laser Scanning Workflow

Surveying

The survey of walls and floors was carried out with a Time of Flight scanner (Leica HDS3000). During

[1] The paper is the result of collaboration between all authors. In particular section 2 has been written and edited by N. M. Mangialardi, sections 3 and 4 by M. G. Sibilano and section 5 by G. De Felice.

Fig. 1. Aerial view of the Faragola site in 2006 (L. Baldassarro).

Fig. 2. General view of *cenatio* and *stibadium* (G. Volpe).

two days of work in January 2007 a survey of walls, floors and other structures was carried out. 12 stations were placed and a total of 11,000,000 points measured.

The scanning resolution was tuned to a different level of accuracy depending on the complexity of structures. 1 cm resolution was used for floors and walls, 2 mm for the *stibadium* and 1 mm for the front of the *stibadium* and the panels in *opus sectile*.

Raw data processing was divided in different phases:

Registration

Point clouds were first of all cut. Points outside surveying areas were deleted, and then the clouds were registered together by cloud registration of overlapping areas (Scopigno 2006), and then recomposed in a unique and referenced model, with an error of approximately 8 mm. The model was later subdivided in layers containing single parts of the monument.

Meshing

Point clouds were also used to reference digital photographs of the monument and to realize a texture mapping of the *stibadium* and of the floor (for an innovative experiment of integrated management of laser scanning and digital imaging data see Aguilera et al. 2006).

As meshing functions of Cyclone – the software provided by Leica – are very poor, we decided to use another package to realize the meshed model. A first attempt was made with Spider, following suggestions from other experiments (Monti / Fregonese / Achille 2003). Because of the high cost of Spider, we intend to test MeshLab – free software developed by the Epoch project – to realize different models with a decreasing number of faces. The TIN mesh created from large point clouds was processed by controlled deletion to reduce triangle numbers while keeping sufficient geometric accuracy. The result was a light 3D model with fast visualization, easily manageable on a normal PC.

Exporting

The model was finally exported to a 3D modeller. We chose to use Rhinoceros 4 for its ease of use, powerful surface drawing tools (see below) and competitive pricing.

Building a 3D Model from Overlays

Our experiment is based on the need to create, test and define good practice in the laser scanning work flow. Elaborating a model is a necessary prerequisite to integrating 3D surveying with the normal documentation process and to make it an essential component of methodology (Doneus / Neubauer 2006; Peripimeno 2006a; Peripimeno 2006b; Fabricatore / Cantone 2006; Grussenmeyer et al. 2006).

The global or largest possible reconstruction of a stratigraphical sequence has to deal with integration of archive data. Because it was impossible to "capture" layers with the laser scanner as excavation of the site had stopped for the winter, the use of the laser scanner to register the surfaces of every layer will be carried out in the next campaign. Laser scanning will be tested for 3D registration

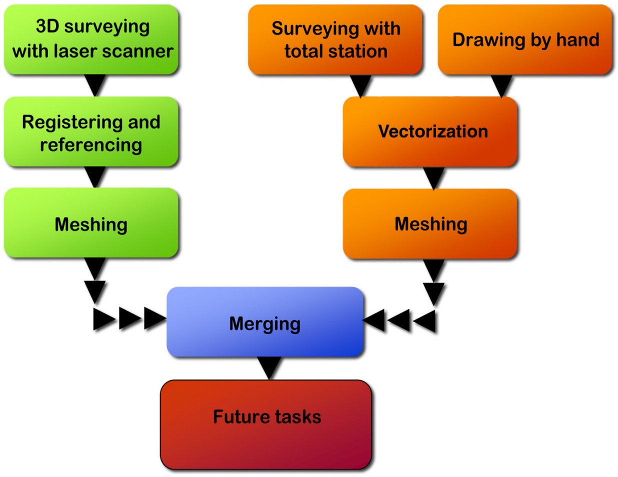

Fig. 3. Documentation workflow (N. M. Mangialardi, M. G. Sibilano, G. De Felice).

of any layer composing an archaeological stratigraphy, and included in the normal documentation process.

In this first phase of research, we have focused on realizing a model in which traditional 2D drawings can be implemented together with data from laser scanners.

Transparent overlays represent the bulk of our – and we imagine most – archaeological archives. From a methodological point of view, it is important to extract the third dimension from this kind of documentation as far as possible. If 3D documentation of monuments is now possible in real time with the aid of tools such as laser scanners, we would like to extend this methodology to every trace of the past to model – not only structures and monuments, but every component of stratigraphy, including "normal" layers that represent the most important source to reconstruct the history of a site.

We have tried to test for a process that allows archaeologists to transform a normal 2D drawing in an object containing its original three dimensions, and to put it in its original position within the stratigraphical sequence.

A very simple and fast procedure was followed to reconstruct a 3D form from overlays:

Acquiring

The first step of this procedure implies acquiring overlays drawn during excavations. Firstly, transparent sheets were scanned with a flatbed scanner at a resolution of 300 dpi and retouched.

Importing

The image was inserted as a raster image into a CAD application, and referenced to the main coordinate system of the excavation.

Digitising

The image was digitised with a 3D polyline; then every vertex of the polyline was Z moved to its original height. If there was no height measured near the layer borders, the closest height was chosen.

Points are added corresponding to height of the surface of the layer.

Modelling

This model was exported in Rhinoceros, and merged with the model of the structures from the laser scanner. With Rhinoceros surfaces could easily be drawn using curves and points. Finally surface patches of the layers were generated.

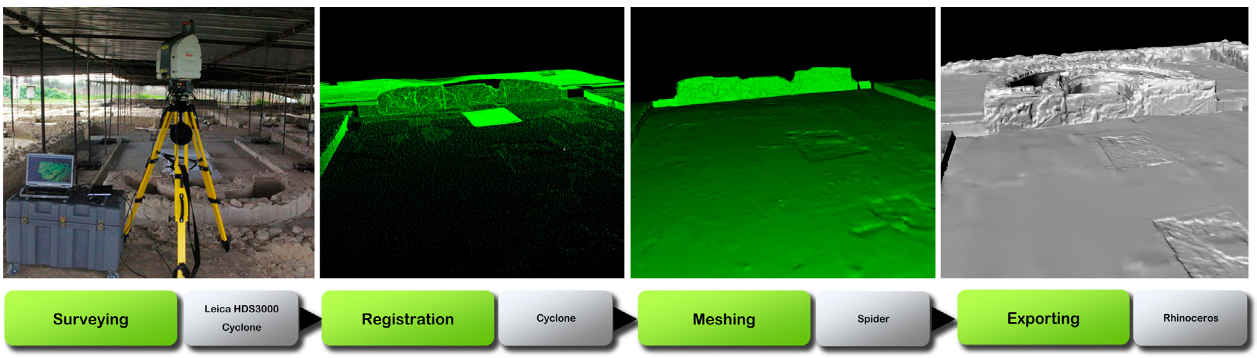

Fig. 4. Laser scanner workflow (N. M. Mangialardi, M. G. Sibilano, G. De Felice).

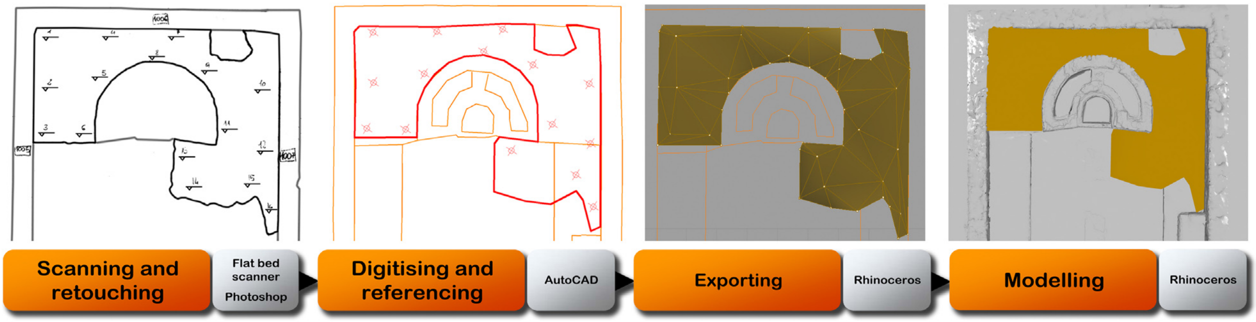

Fig. 5. 3D modelling of overlays (G. De Felice).

New Opportunities with 3D Documentation

Creating a unique 3D model of the whole stratigraphy allows us to control and manage the documentation process.

First of all, the 3D model provides a clear visualization of relationships between layers. Structures still visible appear together with destroyed layers so that the whole stratification can be virtually rebuilt.

The 3D model helps in the diagnosis of errors in hand drawings, such as incorrect heights. Mistakes made during field surveying are easily shown during meshing of the layers' surfaces.

The chance to perform virtual surveying operations enables us to produce plans and sections whenever they are needed, freeing archaeologists from the need to decide section lines during excavation.

The model is built with data from different sources, digitized with different technologies and methods. 3D modelling of archive data, recorded with old tools but respecting modern and/or good methodological criteria opens the way to recover data from old archaeological excavations (Lieberwirth 2008).

Lastly the availability of a 3D model of stratigraphy gives important extra value to experiment with 3D GIS, where it is possible to integrate different kinds of data to realize a unique virtual environment.

At the moment, however, managing the whole stratigraphy in 3D provides several clear advantages, such as excellent tools for diagnosis, control and improvement of the documentation process, helping to extract as much as possible information the process itself contains.

Tasks for the Future

The first steps of the project are now underway. In the near future, a series of new operations will be carried out. First of all we will try to implement layers directly with the laser scanner.

The main problem with extracting surfaces from point clouds is the lengthy period of post processing. Point clouds have to be cut into parts belonging to surfaces of different layers.

Testing the use of laser scanner in the day to day documentation of a site constitutes one of the main challenges in the next phases of the project.

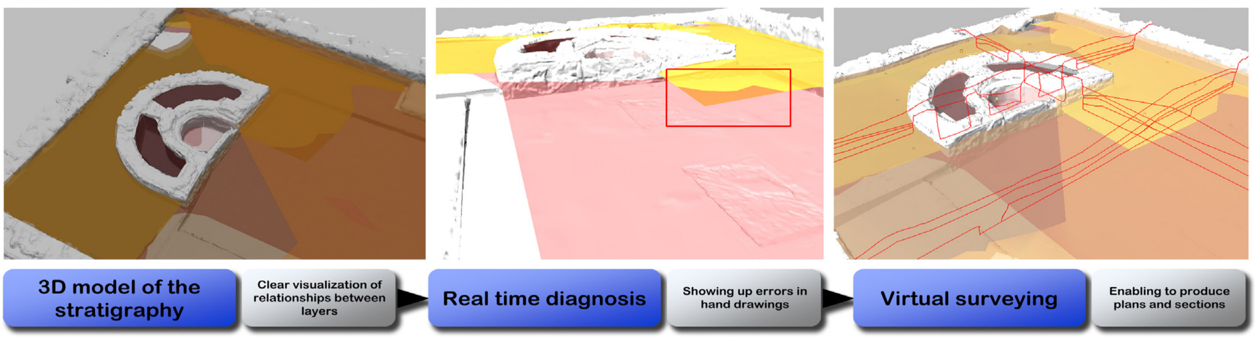

Fig. 6. Some new opportunities with 3D documentation (G. De Felice).

In large sites with complex stratigraphy it will almost certainly be necessary to continue using traditional drawing, including overlays, which can be realized without any special instrument.

Because of the high cost of laser scanning technology, the need to have a laser scanner on site every day, and other practical considerations, such as the need for a power supply, we will also try to use other technologies, such as photomodelling, to maintain the 3D information of layers.

Laser scanners in archaeological research have often been used as a "futuristic" tool to draw monuments and precious finds. Archaeology deals more with layers than with monuments and finds, however. We believe it is time to close this "flashy" phase and test this technology in a complex archaeological surveying pipeline. (A perfect example of what laser scanners can do is in Campana / Francovich 2006).

Inserted in a 3D documentation pipeline, the laser scanner can be considered the perfect tool to survey quickly and sharply every component of stratification (see experiment of 3D rebuilding of stratigraphy in Uotila / Tulkki 2002; Zhukovsky 2002; Barceló et al. 2003). The laser scanner allows us to eliminate the errors and approximations of other surveying techniques, but above all it allows us to preserve spatial information normally destroyed when the complex 3D reality of archaeological stratification is compressed on the 2D surfaces of overlays. Sections, which are normally the main tool for visualizing the third dimension in archaeological documentation, are no more than a selection of the infinite plans that can be realized.

Nowadays, laser scanner is the most powerful tool in building a methodology of 3D archaeological surveying. Nevertheless, it can be substituted by other tools in documenting 3D. The main goal that we propose in the future is not in fact linked with a particular technology or tool, but concerns the building of a 3D environment in which the whole of the spatial attributes of a site can be preserved.

We hope that our short experiment helps to demonstrate that excavations done correctly and with accuracy can easily be inserted in 3D space that does not depend only on the technologies used but primarily on the precision of methodology used during excavation. The shaping of 3D layers can also be achieved using the slight traces of third dimensions registered in overlays. The possibility for checking errors in real time and recovering them helps to show anomalous stratigraphical sequences and to keep the entire process of excavating (and destroying) a site under control.

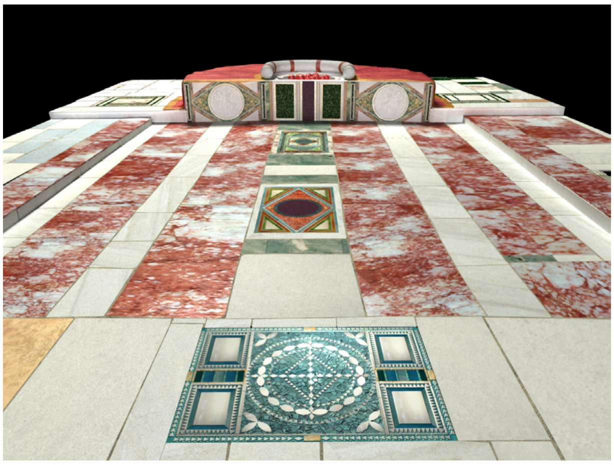

Fig. 7. Reconstruction of the original look of the cenatio (F. Gagliardi).

In short, this system strengthens traditional archaeological methodology. Stratigraphy is a 3D object, and its documentation has to be 3D too. 3D documentation allows us to transfer in a virtual environment an objective reality; it is not a tool to deform correct methodology. The correct use of new technologies must be driven by knowledge of stratigraphy and the skill to recognize layers. These are the first signs of a revolution in considering graphic documentation not as a mere practice of tracing and drawing but as an act that builds knowledge to a point where considering it as "graphic documentation" sounds reductive.

This process began when total stations and CAD applications were used to free the archaeologist from the need to think in "paper space". Wasting time in long editing processes was then removed thanks to CAD applications applied to archaeological surveying. New strategies of documentation have allowed archaeologists to invert the documenting pipeline, focusing on documentation process instead of graphical output.

Graphic documentation is finally in the hands of archaeologists, and has been transformed into an essential component of the excavation process. As technical aspects are pushed into the background, an interesting consequence of this has been the creation of a peculiar category of archaeologist who is not only able to use technology but also to posit questions to improve methodologies.

Thanks to the development of technology, nowadays we can rely on tools so intelligent as to be able to substitute many drawing activities. This leads us to ask critically to what extent technology represents a commodity rather than a distortion of the conventional, but slower, analytical method. Technology helps us by transforming the survey operation into the creation of a copy of reality. The role of technology is not to change correct methodology, but to help concentrate on questions and interpretation. Laser scanning technologies cannot yet be considered a revolution because costs are still prohibitively high. Since costs will not go down in the foreseeable future, the laser scanner will not become a tool for archaeologists as was the case a few years ago for total stations.

On the other hand, we must not forget traditional documentation and methods. Hand drawing is still an essential part of the archaeological documentation process and should not be discarded, even when technology is extensively used. Drawing layers, like any other archaeological find, is a way of interpreting reality.

Improvements from new technologies and strong analytic value from hand and low tech drawings lead to a new approach in managing graphic data, which, in turn, leads to new possibilities. Both considerations lead us to posit a real merge between direct surveying and technical approaches. The technical approach should work with, and not as a substitute for conventional techniques to stimulate and deepen research.

References

Aguilera et al. 2006

D. G. Aguilera / J. G. Lahoz / J. Herrero / A. L. Muñoz, Recording with laser scanning of Santo Tomas Royal Monastery: a travel into the past in honour of Christopher Columbus. In: M. Ioannides / D. Arnold / F. Niccolucci / K. Mania (eds.), The e-volution of Information Communication Technology in Cultural Heritage. Where Hi-Tech Touches the Past: Risks and Challenges for the 21st Century (Budapest 2006) 1–6.

Alessandri / Uccelli 2006

C. Alessandri / F. Uccelli, 3D Laser Scanner in integrated analyses of archaeological sites. In: Campana / Francovich 2006, 69–91.

Barceló et al. 2003

J. A. Barceló / O. de Castro / D. Travet / O. Vicente, A 3D model of an archaeological excavation. In: M. Doerr / A. Sarris (eds.), The Digital Heritage of Archaeology. CAA 2002. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 30th CAA Conference, Heraklion, Crete, April 2002 (Athens 2003) 85–89.

Campana / Francovich 2006

S. Campana / R. Francovich, Laser scanner e GPS Paesaggi archeologici e tecnologie digitali (Firenze 2006).

Doneus / Neubauer 2006

M. Doneus / W. Neubauer, Laser scanners for 3D documentation of stratigraphic excavations. In: M. Baltsavias / A. Gruen / L. Van Gool / M. Pateraki (eds.), Recording, Modeling and Visualization of Cultural Heritage (London 2006) 193–204.

Fabricatore / Cantone 2006

G. Fabricatore / F. Cantone, New Tools to Assist Excavation 4D Analysis. In: M. Ioannides / D. Arnold / F. Niccolucci / K. Mania (eds.), The e-volution of Information Communication Technology in Cultural Heritage. Where Hi-Tech Touches the Past: Risks and Challenges for the 21st Century (Budapest 2006) 100–107.

Forte 2006

M. Forte, Tra conoscenza e comunicazione in archeologia: considerazioni in margine alla terza dimensione. In: Campana / Francovich 2006, 23–40.

Grussenmeyer et al. 2006

P. Grussenmeyer / P. Patias / S. Sylaiou / L. Sechidis / I. Spartalis / E. Meyer / T. Landes / E. Alby, A Proposed Low-Cost System for 3D Archaeological Documentation. In: M. Ioannides / D. Arnold / F. Niccolucci / K. Mania (eds.), The e-volution of Information Communication Technology in Cultural Heritage. Where Hi-Tech Touches the Past: Risks and Challenges for the 21st Century (Budapest 2006) 145–149.

Lieberwirth 2008

U. Lieberwirth, 3D GIS Voxel-based Model Building in Archaeology. In: Present volume, on CD-ROM.

Monti / Fregonese / Achille 2003

C. Monti / L. Fregonese / C. Achille, Laser scanner application on complex shapes of architecture. Profiles extraction processing and 3D modelling. International archives of photogrammetry, remote sensing and spatial information sciences 34,5, 2003, 155–160.

Monti et al. 2004

C. Monti / R. Brumana / C. Achille / L. Fregonese, Rilievo e conoscenza di strutture complesse: prime elaborazioni da tecnologie laser-scanning integrate con strumentazione tradizionale e topografica-fotogrammetrica d'avanguardia. In: M. G. Sandri (ed.), L'eredità di Monneret di Villard. Atti del Convegno (Firenze 2004) 207–223.

Peripimeno 2006a

M. Peripimeno, Sperimentazione di tecniche 3D laser scanning in archeologia: l'esperienza senese. In: Campana / Francovich 2006, 143–157.

Peripimeno 2006b
M. Peripimeno, Sviluppo di un GIS 3D di scavo per mezzo di tecniche laser scanning: l'esempio Miranduolo. In: R. Francovich / M. Valenti (eds.), Atti del IV Congresso Nazionale di Archeologia Medievale, San Galgano, Italy, September 2006. Scriptorium dell'Abbazia (Firenze 2006) 18–23.

Scopigno 2006
R. Scopigno, Gestione efficiente dei dati prodotti dai sistemi di scansione tridimensionale. In: Campana / Francovich 2006, 41–68.

Uotila / Tulkki 2002
K. Uotila / C. Tulkki, Three-dimensional excavation plans and 3D Studio Max. In: G. Burenhult (ed.), Archaeological Informatics: Pushing the Envelope. CAA 2001. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 29th Conference, Gotland, April 2001. BAR International Series 1016 (Oxford 2002) 427–430.

Volpe / De Felice / Turchiano 2004
G. Volpe / G. De Felice / M. Turchiano, Musiva e sectilia in una lussuosa residenza rurale dell'Apulia tardoantica: la villa di Faragola (Ascoli Satriano, Foggia). Musiva & Sectilia 1, 2004, 127–158.

Volpe / De Felice / Sibilano in press
G. Volpe / G. De Felice / M. G. Sibilano, Esperienze di laser scanning su rivestimenti pavimentali e parietali: il caso della cenatio della villa di Faragola (Ascoli Satriano, FG). In: C. Angelelli (ed.), Atti del XIII Colloquio dell'associazione Italiana per lo Studio e la Conservazione del Mosaico (AISCOM) (in press).

Zhukovsky 2002
M. Zhukovsky, Handling digital 3-D record of archaeological excavation data. In: G. Burenhult (ed.), Archaeological Informatics: Pushing the Envelope. CAA 2001. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 29th Conference, Gotland, April 2001. BAR International Series 1016 (Oxford 2002) 431–438.

Giuliano De Felice
Nunzia Maria Mangialardi
Maria Giuseppina Sibilano
Giuliano Volpe

University of Foggia
Department of Humanities
Via Arpi, 155
Foggia
Italy
g.defelice@unifg.it