

Investigations on some Villa Adriana's vault systems using three dimensional digital survey

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Abstract: This is a presentation of a case study led on some Villa Adriana's Pavilions, in order to put in evidence the geometrical models and the construction systems applied in roman vaults. The goal of research is the comprehension of relationship between the theoretical model and the real shape of build structures. The study is based on the three dimensional laser scanner survey executed in Villa Adriana during last four years by the "Dipartimento di Progettazione dell'Architettura di Firenze". The data acquired with those digital surveys are now converted into three dimensional polygonal surfaces. This process allows characterizing the features of the structures regardless of their position. The software applications allow converting polygonal surfaces into surfaces characterized by boundary controlled by mathematical functions. The verification of the position and the level of deviation between the data acquired and the typical theoretical model of roman vaults geometry, this process permits to investigate the aspects linked to the original project and to the processes of the building. The research is still under development, but permitted us yet to put in evidence a close relationship between the geometrical architectural features and the masonry techniques and the carpentry systems.

Zusammenfassung: Dies ist eine Präsentation einer Fallstudie, die an einigen Pavillons der Villa Adriana vorgenommen wurde, um die geometrischen Modelle und die in römischen Gewölbebauten verwendeten Bausysteme zu belegen. Forschungsziel ist das Verstehen der Beziehungen zwischen theoretischem Modell und tatsächlicher Form der Baustrukturen. Die Studie basiert auf der 3D-Laserscanning-Vermessung, die in den letzten vier Jahren vom "Dipartimento di Progettazione dell'Architettura di Firenze" in der Villa Adriana vorgenommen wurde. Die Daten, die durch diese digitalen Vermessungen gewonnen wurden, werden jetzt in dreidimensionale Polygonflächen konvertiert. Der Prozess ermöglicht die Charakterisierung der Eigenschaften der Bauten unabhängig von ihrer Lage. Die Software erlaubt die Umwandlung von Polygonflächen in Flächen, deren Grenzen durch mathematische Funktionen beschrieben werden. Durch die Verifikation der Lage sowie des Grades der Abweichung zwischen den gewonnenen Daten und dem üblichen theoretischen Modell von römischen Gewölben, erlaubt der Prozess die Zusammensetzung und die Bauprozesse zu erforschen. Die Untersuchung ist noch im Gange, aber sie hat schon gezeigt, dass eine enge Beziehung zwischen geometrischen architektonischen Eigenschaften und Mauertechniken sowie Gewölbebauverfahren besteht.

Keywords: Laserscan, Stratigraphy, Monuments, Modelling, Analysis

Prologue: where we start from

Since the 2004 the “Dipartimento di Progettazione dell’Architettura di Firenze”¹ has programmed regular survey campaigns in the Hadrian’s Villa, Tivoli. This work was started (and brought on) in collaboration with the International Museography Workshop “Premio Piranesi”². All the campaigns were aimed to the digital survey of the monuments, gathering a large amount of information in a very short time. All the work, being a great documentation in itself, became soon the base for a series of researches, developed on the level of the architecture school didactic and Ph.D., or on the level of the architectonic investigation.

Three main paths have been followed at now: one oriented to design specific new solutions for the access and for the museographic system of the Villa archaeological area; one oriented to the better understanding of the project and the inner characteristics of the architectural monument; one based on the treatment of the laserscan data to produce enhanced representation and/or multimedia of the ruins as they are now, or as they could be in the past.

As just told, all the work produced starts from the specific survey campaigns to develop specific studies or researches, and little by little, because of the very poor budget available for this research, the digital survey coverage and the overall system of knowledge about the Villa is increasing.

Often a new line of possible research rise from the students, Ph.D. and researchers and a continue work is done to allow the collaboration between the architects who bear the main structure of this project and the archaeologist who guide the operation in this site to allow the best and more useful integration between the documentation/architectonic research and the deep knowledge and accurate investigation of the place. In this way there a continuous collaboration with the “Soprintendenza Archeologica del Lazio”, a fundamental partner in the global asset of this project.

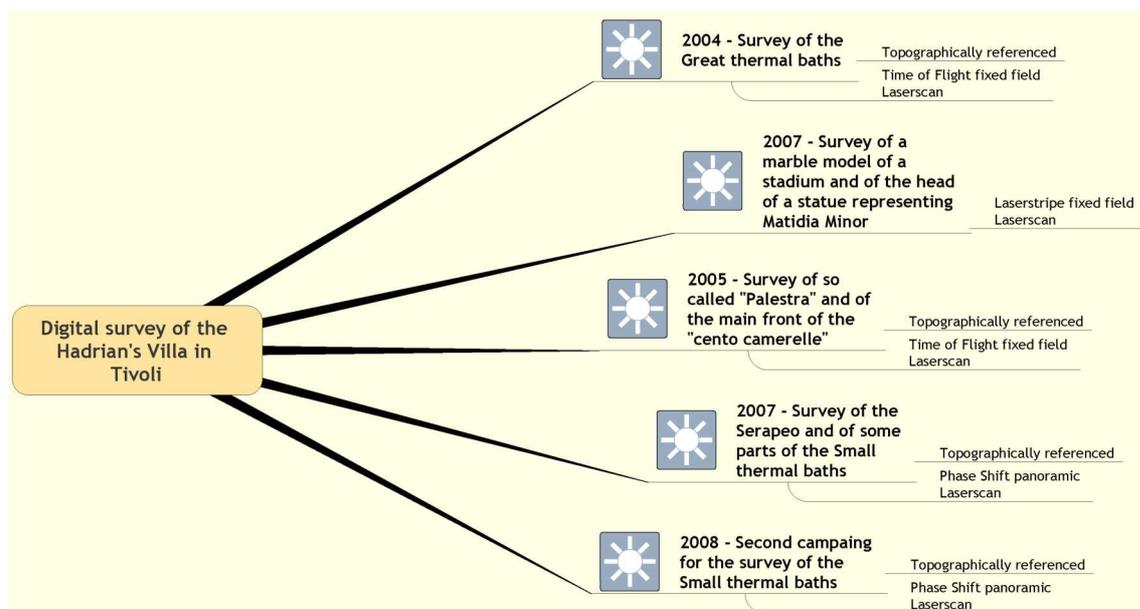


Fig. 1 – Scheme about the main survey campaigns operated by the “Dipartimento di Progettazione dell’Architettura in the past five years

The choice to give an “open” structure to the research and its links to the didactic environment has produced, through the years a wide range of hypothesis, projects and opportunities for new developments, sometimes even capable of some contradictions. As just told, the almost nonexistent resource support to the research allows only a slow development of the whole apparatus. The whole research project is aimed to a better understanding of the architectonic settlement, but it takes care about the “small” elements too, like statues and minor objects, while it’s in our believe to think that a right documentation and investigation of these single elements can bring a contribution to the whole state of the knowledge³.

Usually the laserscan survey is made with a reasonable accuracy and coverage according to the architectonic use of the information, all the tools in the project are always used at their best performance, but never pushed behind this, while, in our experience, this produce only hard to use model and low overall project quality. All the survey campaigns were planned to have a very short duration, from one to two days of survey, rarely up to three days; this not because the very low available budget, but also to have a “quick” image of the subject, according to the better characteristic of laser scanning, a sort of instant picture of the monument, ready to be processed, but also the representation of the building as it was exactly in that instant.

Some general notes about laserscan survey

Now a day any serious and technology enhanced survey campaign has to operate using a laserscan in its workflow. It’s a tool of our days, it is not completely understood by all the operators, but it’s clear that it takes part to any documentation project as an important opportunity of higher accuracy and it’s capable to introduce interesting new opportunities in the overall process. The problem to implement it correctly can be considered as a specific research field, but as any new tools it only need time and experiences to be fully integrated as a tool of knowledge. In 2004, during our first campaign in the Hadrian’s Villa⁴, our experience in the use of these tools was just at its beginning, while the survey laboratory of our Department start to work on laserscan based project just in the 2002.

After all this time and more or less one hundred of completed survey campaigns, a large experience has been developed, but the Hadrian’s Villa remain the favourite environment for experimenting solutions and methodology in the survey, data management and digital model treatment.

For these reasons the research project on the Hadrian’s Villa is not based on a single tool or a specific laserscan but over various machine and different, sometimes very different, procedure in the survey post processing. So the first two campaigns are based⁵ on the Leica Cyrax HDS 2500 laserscan⁵, while the 2007 campaign was a Cam2 Faro 8080⁶ to be at work in the Serapeo and in the small thermal baths. In the last campaign we used a Z+F phase shift scanner⁷ was used in the small thermal baths. But even if the machine for laserscan changes, the overall data gathering is not incoherent, an accurate Topographical survey, operated with a total station allows putting every scan in single campaign in a single accurate model. And the same survey goes to take part to the overall digital model of the Villa, according to the general topographic network developed and enlarged year by year.

In this way, no matter what scanner the points come from, an overall high resolution survey is produced⁸, this general model allow various types of use, the more direct and quick post processing is the virtual survey of the point clouds or the extraction of classical representation like plants, sections, fronts in the form on screen shots and vector drawings.

What approach to choose in data post processing?

It is quite clear that the point cloud in itself is a great solution and that it preserve the best accuracy from the original survey, in the original point cloud the not processed information are the closest to the real shape of the object. So the point cloud is a great solution for archiving the shape of the things and to prepare a versatile base to allow any confrontation, test or new development for the future, the only requirement is to make it enough robust and simple to face the risk of a fast obsolescence, this is done preparing some versions of the pointcloud suitable for an easy interchange with more then one software⁹.

Obviously the pointcloud in itself is not the more easy and clear way to allow the access to the survey information to a wide range of users. So an interpretation is needed and its processing to create surface models for detailed representation or for multimedia presentation is more and more an easy task because of the specialization of a large number of software. In this way the pointcloud become a sort of storehouse were all the information fit waiting to become part of some new researches while the digital model of the processed data start to be the usable version of the survey. In this research there are two main approaches to the post processing of the pointcloud information: one is oriented on the direct use of the pure geometry coming from the pointcloud, a method useful to quick investigate the object according to its shape. When a deeper investigation is needed, the extraction of geometrical elements and their analysis permit obtaining important information about the objects, it allows a solid compare process with ancient drawings; in this way, if a theory is based on a certain representation, the rereading of the new drawing can definitively confirm it or open again the discussion.

The second approach is based on the production of a model more close to reality, with a wide treatment of the texturing and an accurate representation of lighting and detailed geometry. This is not a simple multimedia approach, while the study about lighting is oriented to a better understanding of the nature of the place and of the original project.

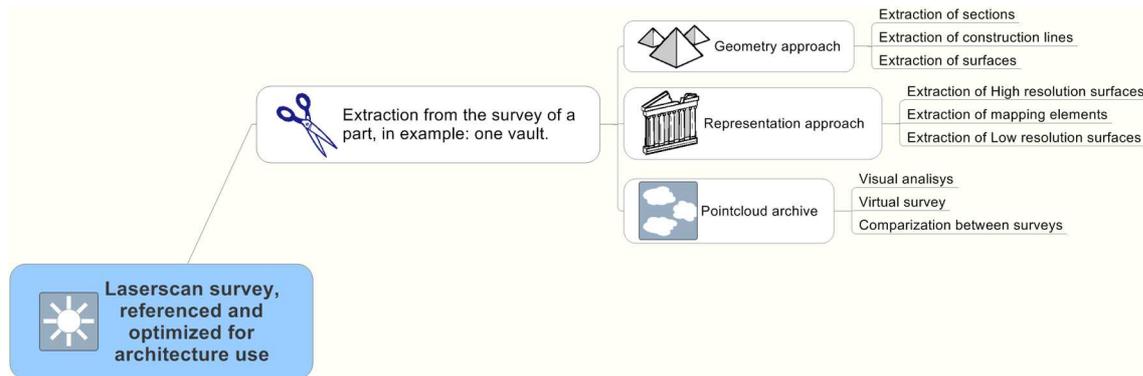


Fig. 2 – Scheme about the three main approaches actually in use for this research project, the first step is always the subdivision of the original registered point cloud in smaller and more manageable parts and then proceeding in one or more paths of the represented workflow.

At the same time the developing of an accurate model require a better understanding of the whole monument if compared to the one is get during the survey only, and that's a very useful issue according to the needs to enhance the real control over the shape of the studied object.

The use of recent solutions of the computer graphic allows to produce lighter models with an apparently high level of details, this procedure produce a very good level of realism on relatively easy to use three dimensional models, useful for single rendering representation but also for animation and for real time viewing.

The geometric approach for the use of the digital survey: the Serapeo

As told, the Serapeo was surveyed in the September 2007¹⁰. The registered point cloud model allowed reviewing not only the morphological characters of the complex, but also the thickness of walls and the relations between the building's different levels. This last feature of the digital survey is particularly important for the understanding of the monument considered as a huge scenographic machine. This was, in fact, the way the structure was used by the emperor during his fabulous banquets¹¹. Concerning this research, the investigation has been focused exclusively on the morphological characteristics of the Serapeo facade.

The study started from the elaboration of the digital survey data.

The digital survey campaign had as main goal was to document the Serapeo, included the two collapsed blocks from the superior side of the vault. These two fallen parts are made of opus caementicium and bricks. The first block is still at the position where it felt, near the vault base inside the basin of the Euripo.

The second was moved during the post-war¹² restoration and now is placed along the left side of the Canopo. The study of the digital model as well the research over the ancient and more recent representations of the Serapeo allowed to develop a reconstructive model.

Certain elements, highly evident in the 3D digital model, like the shelves, have been very useful in determining the original location of the collapsed mural blocks. In this way several hypotheses

regarding the façade became possible. But in this case two main different reconstructions have been proposed. According to the first resolution, the spring of the relieving arch should be close to the two columns which are leaning against the external wall of the long barrel vaulted corridor.

The second possibility is to put the spring of the arch right on the wall, leaving to the columns only the weight of the entablature.¹³ However both the hypotheses highlight the rectilinear shape of the top of the facade, suggesting the presence of a triangular tympanum.

The architectonic resolution of the round arch, under a triangular tympanum, was surely known by Hadrian. It was indeed present on the triumphal arch made for him in 129 A.D. in Jerash (Jordan). Given this fact, it is useful to reconsider the various hypotheses proposed about the reconstruction of the Serapeo's facade. These were made by Canina¹⁴, Sortais, Mastrosanti, Delvapoix, Mirri, Signorini¹⁵ and Apolloni-Ghetti. In contrast to the physical model of Gismondi¹⁶, all these reconstructions have a round pediment, which in analogy with the temples in the Egyptian style or connected with an Egyptian cult of the Hellenic tradition¹⁷. The remarkable amount of finds in the Egyptian style discovered near the Canopo Serapeo must have influenced facade's reconstruction¹⁸.

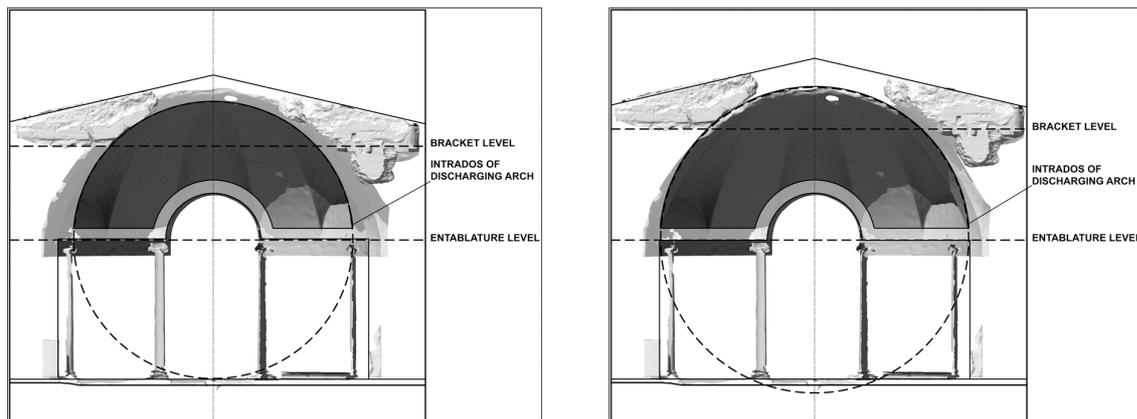


Fig. 3 - Two proposals for the solutions of the Serapeo façade.

The digital survey and the possibility of use reliable 3D data allowed us to revisit a problem of great interest since the 1950s.¹⁹

The use of digital technology allowed us to discover some hitherto unknown facts about how the surviving ruins can be reassembled, and this permitted us to propose a more accurate reconstruction of the principal facade of the Serapeo, one of the most memorable and important components on Hadrian's Villa.

The representation approach for the use of the digital survey: the small thermal baths

The survey campaigns of the 2007 and 2008 were aimed to the survey of the small thermal baths, in our project there is a future completion of the small thermal baths with all the external walls and the underground connections with the great thermal baths and Cento Camerelle area. The priority was

given to the interiors of the monument, because of its variety of vaults and architectural solutions, a real collection of interesting constructive details that can contain a key to read something more about the general Villa settlement²⁰.



Fig. 4 – Low resolution surface model of the small thermal baths, the walls in the background are treated using the normal mapping procedure, the foreground walls are still in their original condition.

So the need to develop a solution for reading and interpreting the shape of vaults is more than ever needed, according to all the previous parts of the research, two main guidelines are suited to face the problem and one main workflow is actually under development. The two main lines will be for first the production of surface digital models with the full reconstruction of the monuments as it is now, this will be done (and it's actually under processing) according to the latest solutions of low resolution polygonal models combined with normal mapping texturing, with the normal maps coming from an high resolution surface model. In this way there will be the development of an accurate surface model, suitable for any investigation needs, but also the development of a low resolution surface model, perfect for any multimedia needs but visually comparable to the results offered by the high resolution version. The second research line will go back to the geometrical approach and will follow the extraction of curves and development rails from the point cloud and from the high resolution surface model; this will be done to allow a better understanding of the geometry and the design of the vaults; as told before, the great thermal baths are a wide catalogue of solutions, so starting from the confrontation between vaults curves, the architectural design of the whole complex will probably

became more in its inner language and maybe it will become more clear and easy to understand. The approach to the extracted curves will be done completing it where there will be a lack of continuity due to fallen or missing parts, and it will be geometrical and mathematical. Two kind of curve will be the result of this operation the actual curve, due to the state of the monument at this time, and an “ideal” curve, the one coming from the original project and then adapted to the real constructive needs. All this geometrically extracted elements will allow a comparing with the main ancient theory and methodology about vault and building construction, in this way a direct relationship between the cultural architecture landscape of the time and the realization will be possible. As it is possible to interpret, this research workflow is under development, but the fact that the workflow of the project is well defined and all the methodologies have been proved on minor case studies from the research team, allows hoping in a relatively quick and positive progress in the next months.

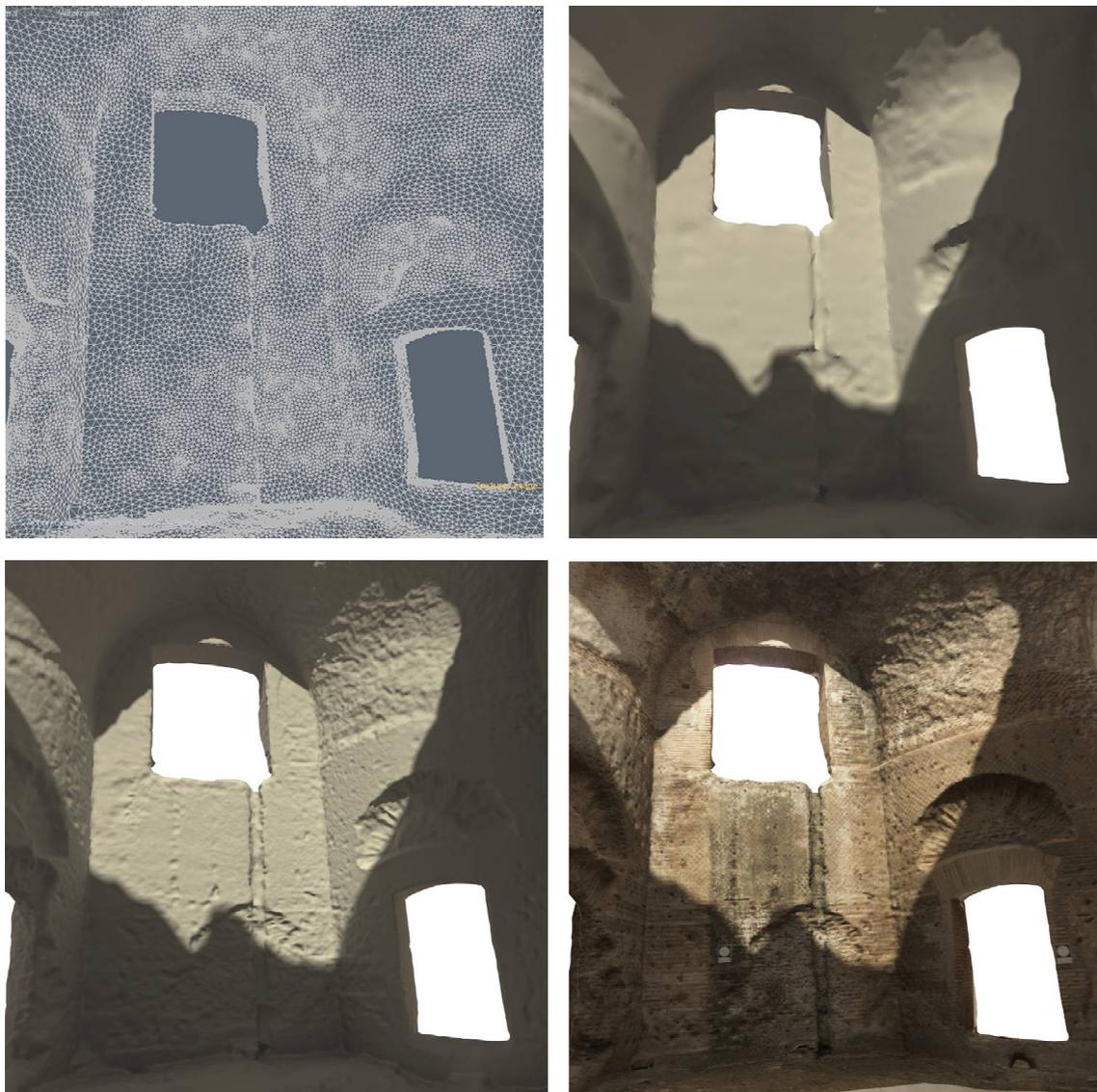


Fig. 5 – Treatment of the surfaces starting from a low resolution surface model processed out of the digital survey of the small thermal baths, from the top left: the wireframe model, the shaded model, the shaded model after the normal mapping process and the normal mapped model with texturing.

Conclusions

So it is possible to hope that this procedures will allow a better understanding of the monument putting again in evidence the value of an integrated knowledge upon a mere technological exhibition.

The possibilities spread in a quite wide range, and the little by little building of a relationship on a common ground between architects and archaeologist seem to bring to light how different competences can work to produce a real enhancement of the research instead of result duplicities or competence overlapping.

All the common tasks of the digital approach seem to be capable of meaningful enhancement: better documentation, better archiving of the gathered information, better reconstruction of digital model of the state of a monument, better reconstruction of the original state hypothesis, better validation of old or recent theory.

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¹ University of Florence, "Dipartimento di Progettazione dell'Architettura": Director prof. Ulisse Tramonti.

Section Architecture and drawing, Responsible of survey laboratory prof. Marco Bini. Topographical survey coordinator arch. Mauro Giannini, arch. Francesco Tioli. Responsible of the research for the 2004 and 2005 survey campaign: Prof. Marco Bini, responsible for the research for the 2007 and 2008 survey campaigns: dott. Giorgio Verdiani, Coordinator for the laserscan

survey of all the survey missions: dott. Giorgio Verdiani. Main Team unit for all the survey campaigns: Francesco Tioli, Giorgio Verdiani, Sergio Di Tondo, Filippo Fantini, collaborators in the single survey campaigns: Stefania Iurilli, Silvia Nicoli, Stefania Pini, Carlo Battini, Laura Angelini, Paolo Agostini, Alessandro Peruzzi.

² The Museographic Workshop: "Premio Piranesi" takes place in Villa Adriana each September since the 2003. Workshop director prof. Luca Basso Peressut, Workshop coordinator prof. Pier Federico Caliarì.

³ About this approach to the Investigation on the minor objects as a specific methodology to the Villa's knowledge it is very interesting the Ph.D. degree thesis from F. Fantini "Il modello di stadio da Villa Adriana, indagine su un progetto incompiuto" where the investigation about a "stadium" marble model is the occasion for a wider range of considerations about the Villa's settlement.

⁴ During last years the "Dipartimento di Progettazione dell'Architettura" has made the followings digital surveys. 2004: survey of monumental complex of the Great Thermal Baths and the Great Vestibolo. 2005: the Gymnasium complex (which is today the object of archaeological excavation) and a part of the Cento Camerelle along the street leading to Vestibolo. 2007: monumental complex of Serapeum and the octagonal room in the Small Thermal Bath. Furthermore, a topographical net was also created to connect all the surveys and a topographical survey of details points of some pavilions of the Villa, the Porticus Pecile, the garden nymphaeum near the the Small Thermal Bath, the building called the Antinoeion and the Canopo.

⁵ The 2004 and 2005 survey campaigns were done in collaboration with Leica Geosystems, a special thank to Marco Nardini for his support, fundamental for these first sessions. For more info about Leica HDS: www.leica-geosystems.com.

⁶ The 2007 survey campaign was done in collaboration with Area3D s.r.l., a special thank to Alessandro Peruzzi and Massimo Gualandi for their support. For more info about Area3D: www.area3d.it.

⁷ The 2008 survey campaign was done in collaboration with Microgeo s.r.l., a special thank to Simone Orlandini and Paolo Cocca for their support. For more info about Area3D: www.microgeo.it. *Npt available anymore.*

⁸ The overall digital point cloud model is imported to Leica Cyclone software, in time this solution has shown the best behaviours and the lower obsolescence together with the wider and simplest exporting solution toward other software.

⁹ In this way, in our experience, the creation of a set of PTX files from the pointcloud, even if very hard to manage and to store due to their huge size, is the best way to create a simple but very compliant archive, it is possible that this kind of file will be still easy to interpreted from other software in the long time.

¹⁰ For a more detailed description of this part of the research and for the full text about the reconstruction Hypothesis about the Serapeo, it is suggested the reading of: S. Di Tondo and S. Nicoli, Digital survey and investigations of the shape of the ribbed vault of the Serapeo at Hadrian's Villa (Tivoli, Italy), CAA2008 proceedings, 2008.

¹¹ Once the hypothesis of Serapeum of Villa Adriana as a temple for Iovis Serapis was discarded, a new hypothesis arose that this place was dedicated to banquets and the leisure activities (otium) of the emperor and his guests. Cf. E. Salza Prina Ricotti "Villa Adriana. Il sogno di un imperatore" L'Erma di Bretschneider, Roma, 2001, pp. 241-263.

¹² We refer to the excavations conducted by Salvatore Aurigemma between 1945 and 1949; see Bollettino d'Arte, Roma, 1954, 1955, 1956. Also important are the intervention by the school yards undertaken in 1951, by the Ministero del Lavoro e della Previdenza Sociale.

¹³ The more probable solution seems to be the second not only because it confers to the facade a less stumpy aspect, but also because it results compatible in comparison to the other solutions found inside the monumental complex of Villa Adriana.

¹⁴ L. Canina "Gli edifici di Roma Antica..." VI, 1856, tav 166. Salvatore Aurigemma "Villa Adriana" Istituto poligrafico della Zecca dello Stato, Roma 1996, p. 102

¹⁵ S. Gizzi " Per una rilettura della storia dei restauri di Villa Adriana dal 1841 al 1990" in "Bollettino d'arte" del Ministero per i Beni e le Attività Culturali n° 109-110 Luglio - Dicembre 1999, p. 26.

¹⁶ Gismondi is the only author who correctly interpreted the form of the tympanum. In his physical model, exhibited at the visitor orientation center at the entrance to the villa, he introduces a triangular tympanum, quite similar to that suggested by our investigation.

¹⁷ Cf. the architectural solutions in the Nile Mosaic at Palestrina where the temples are represented with the characteristic facades containing the reduced arch.

¹⁸ Cf. on the large collection of Egyptian material from Hadrian's Villa in the Egyptian Gregorian section of the Vatican Museums

¹⁹ We refer to the proposals for the replacement of the collapses documented by the correspondence among Roberto Vighi and Prof. Piero Romanelli, Soprintendente alle antichità, Foro Romano e Palatino, dated 1955. On his letter dated 2 December 1955 R. Vighi writes " [...]Appare pertanto più opportune limitare la costruzione (...) a quel tanto che sarà indispensabile per sostenere i due grandi blocchi di murature crollati dalla parte più alta dell'edificio, non impegnandosi nella ricostruzione della parte centrale che lascerebbe insoluti alcuni importanti particolari per i quali mancano gli elementi di ricostruzione" Prot. 975, pos. 21/A Villa Adriana, preserved in archive of the Soprintendenza Archeologica per il Lazio; in S. Gizzi " Per una rilettura della storia dei restauri di Villa Adriana dal 1841 al 1990" in "Bollettino d'arte" del Ministero per i Beni e le Attività Culturali n° 109-110 July December 1999, p. 67.

²⁰ The research about the small thermal baths is under developing and in full collaboration with Benedetta Adembri from the "Soprintendenza Archeologica del Lazio" and an archaeologist team composed by Alessandro Blanco, Barbara Marzoli and Francesca Mollo. At the same time the object will be developed in a architecture degree thesis by Mirco Pucci.