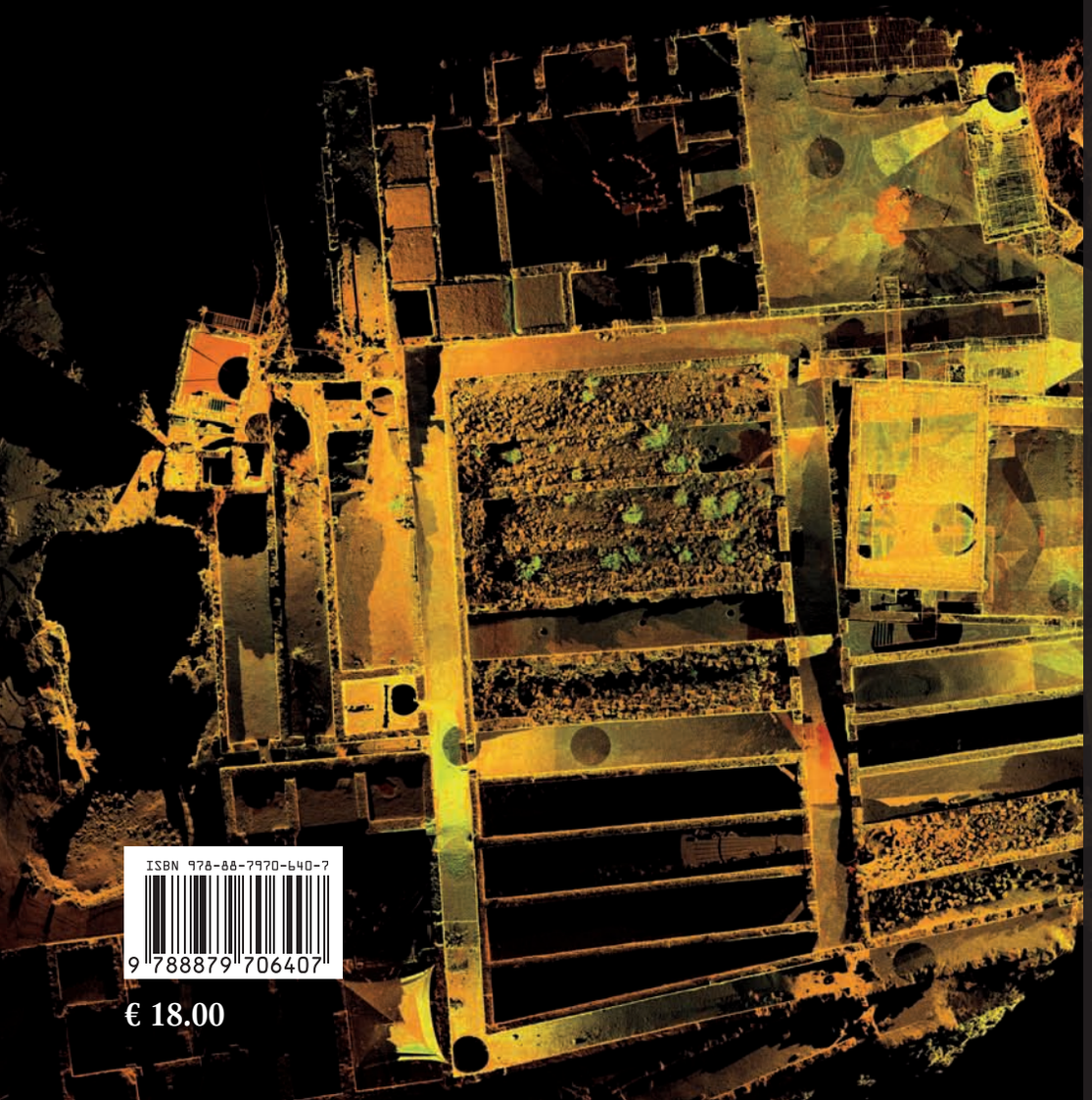
A program of International cooperation Italy-Israel

The Masada project was developed as an on-going research collaboration between the Department of Interior Building and Environment Design of Shenkar College of Design and Engineering, the Department of Architecture of the University of Florence and the Department of Architecture and Civil Engineering of the University of Pavia. Beyond the research aspects, the project has didactic aspects as well. The project, consisting in a proposal for digital documentation of Masada cultural heritage sites.



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DIGITAL SURVEY IN ARCHEOLOGY

STEFANO BERTOCCI SANDRO PARRINELLO REBEKA VITAL

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On cover: General view of the point cloud about Herod's Palace area.

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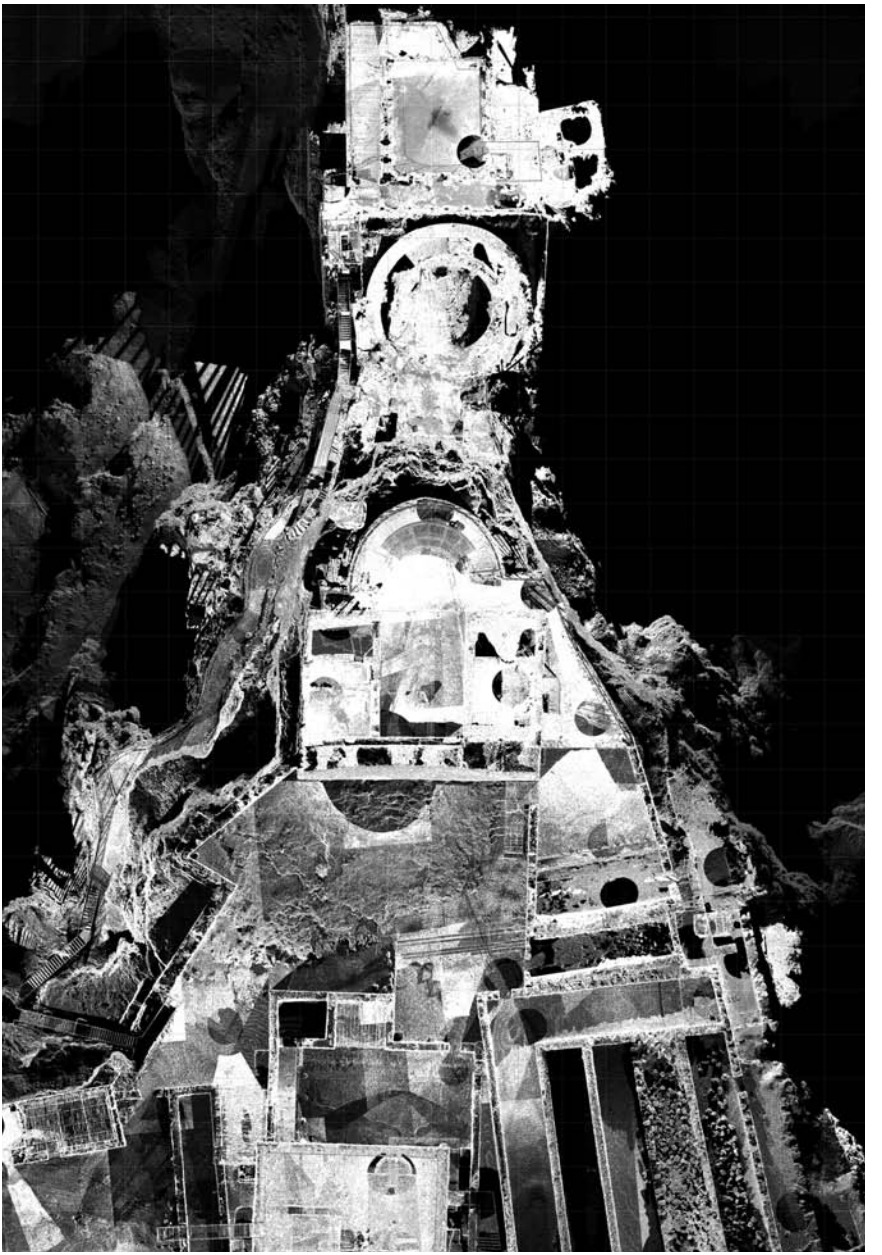


The survey of the Palace of Herod, from the point cloud to the two-dimensional drawings

Sara Bua

Introduction

To represent the architecture through a trustworthy survey means to understand the geometrical and morphological aspects and to be able to transfer these data within a system of two-dimensional and three-dimensional spatial representation, discretizing the data according to the order of representation.
The choice to detect Herod's Palace using laser scanner technology has allowed us to acquire a large amount of information about the spatial conditions of the monument, including its context, in a relatively short time, by delegating the considerations more properly associated with the drawing rules and representation of architectural questions to the next stage of the data reprocessing.
Topics such as, for example, the definition of the appropriate graphic scale for the development of descriptive drawings, able to frame the complexity of the architectural system and, at the same time, to express the material qualities of the architecture and decorations found, as well as the positioning of appropriate section planes, are aspects which have affected the design of the survey and the choice of procedures implemented in post-production for final processing of the acquired data.

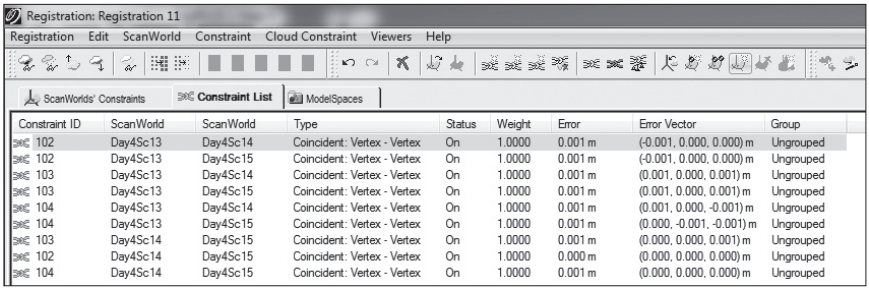
General view of the point cloud about Herod's Palace area.

Preliminary operations on the point cloud

Before starting operations relating to the graphic representation of the survey made on *AutoCAD* software, it's necessary to proceed with some preliminary tasks on the points cloud, using *Cyclone* software, including attention to the final check of the alignment of the individual *scanworlds* and the cleaning of the point cloud from unnecessary elements that were recorded during the data acquisition of the architectural building.

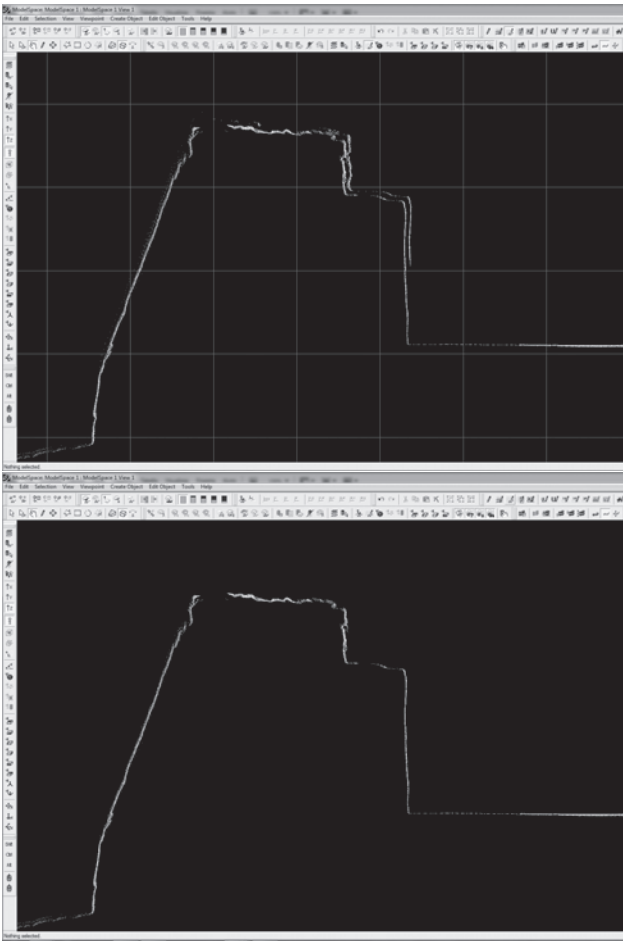
The first operation to carry out on the point cloud, after performing the registration operations of all the different scans, is the control of possible alignment errors occurred between the various scans. This operation, which in part is also carried out during the whole process of registration, is configured as an additional and necessary, verification check on the reliability of the final survey, before proceeding with the operations that lead to the graphic restitution of the architecture studied. This check, which is essential to solve possible problems of roto-translation of the individual "scanworlds", is necessary before proceeding with the creation of a section plane that allows to observe in a detailed way the points which describe a specific surface. Fixing the point of view perpendicular to the surface and parallel to the section

The step before the registration: here we control the alignment of the scans and their error.



Constraint ID	ScanWorld	ScanWorld	Type	Status	Weight	Error	Error Vector	Group
102	Day4Sc13	Day4Sc14	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(-0.001, 0.000, 0.000) m	Ungrouped
102	Day4Sc13	Day4Sc15	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(-0.001, 0.000, 0.000) m	Ungrouped
103	Day4Sc13	Day4Sc14	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.001, 0.000, 0.001) m	Ungrouped
103	Day4Sc13	Day4Sc15	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.001, 0.000, 0.001) m	Ungrouped
104	Day4Sc13	Day4Sc14	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.001, 0.000, -0.001) m	Ungrouped
104	Day4Sc13	Day4Sc15	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.000, -0.001, -0.001) m	Ungrouped
103	Day4Sc14	Day4Sc15	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.000, 0.000, 0.001) m	Ungrouped
102	Day4Sc14	Day4Sc15	Coincident: Vertex - Vertex	On	1.0000	0.000 m	(0.000, 0.000, 0.000) m	Ungrouped
104	Day4Sc14	Day4Sc15	Coincident: Vertex - Vertex	On	1.0000	0.001 m	(0.000, 0.000, 0.000) m	Ungrouped

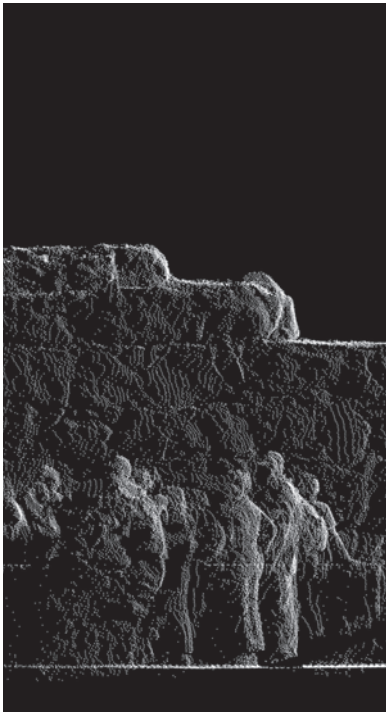
plane makes it possible to verify that the slice of the section appears unique, or rather that the scans that compose the architectural object, are aligned, as not to create offsets of the same portions detected. This is necessary especially when the targets are situated quite close to the instrument and, in case of even minor mistakes on the alignment of the target, it would generate offsets that are very evident on those portions



In the image below the self-made check of the error: in Cyclone we add a plan that cuts the point cloud to check the rototranslation error of the scans. In the first image we can see the alignment error that we can correct with a new registration. In the second image the same point cloud area with the right alignment of the points.

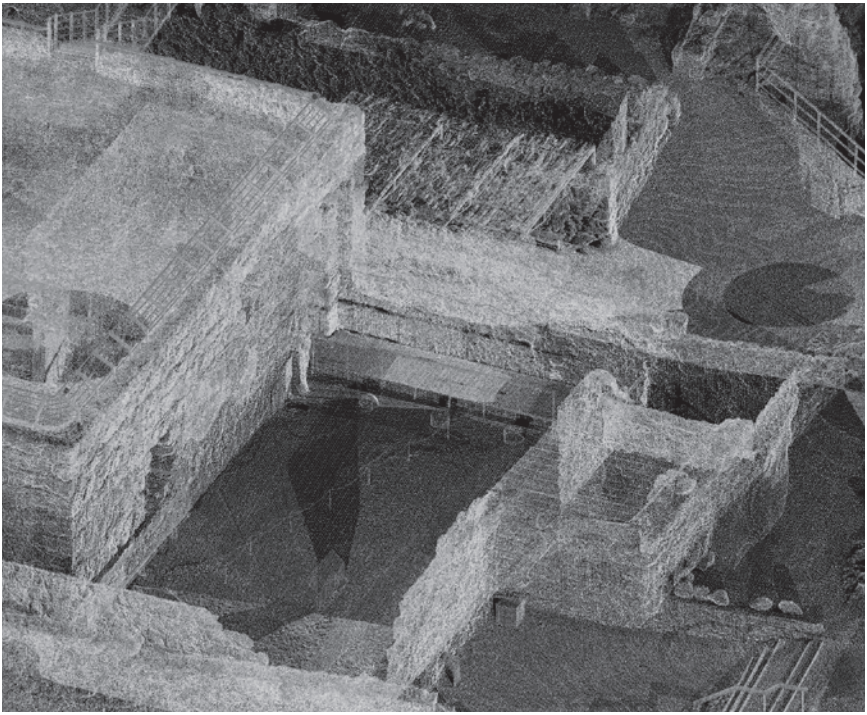
In these two images we can see the presence of silhouette of people who are not architectural elements.

of space, which are detected, instead more distant and outside geometries that are controlled by mutual alignments. In the event that problems, such as those described above happen, it's necessary to register different scans again, including alignment parameters.
In addition to the targets, one should include also surfaces of the architectural elements.
After verifying the accuracy of the registration process, it's necessary to proceed with a thorough cleaning of the entire point cloud. In this phase, the parts considered strangers (they are called "noises"), that are generated from accidentally moving objects present at the time of acquisition or incidences of the laser beam with specific lighting conditions, will be

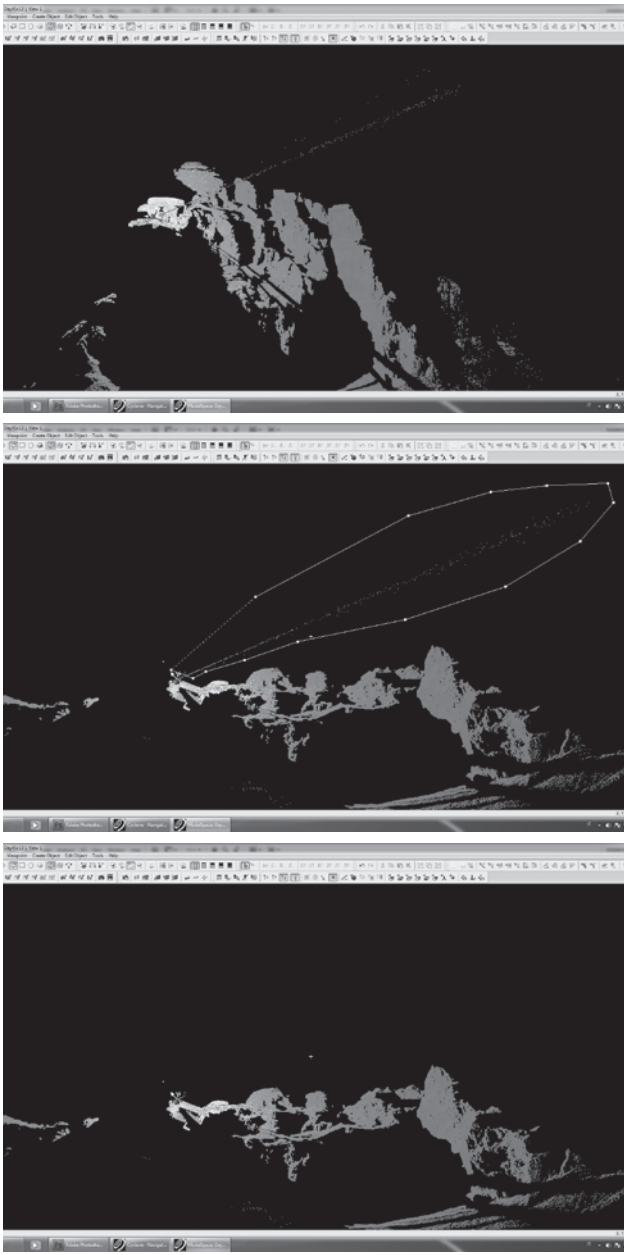


deleted. During the phases of survey of the site, it was necessary to close partially the area to the public visitors, especially the part affected by the activities of the survey. Still, during the realization of the scans by the highest positions (for example from the roofs of some buildings), some silhouettes of passing visitors have been accidentally acquired. . These objects often appear in orthogonal views of the point cloud that are used for the realization of two-dimensional drawings. Such overlaps may create problems of reading and understanding object of study. Once the cleaning operation of the point cloud is complete, it's possible to start with the two-dimensional and three-dimensional representation of the survey.

The same part of point cloud without noise made by external elements.



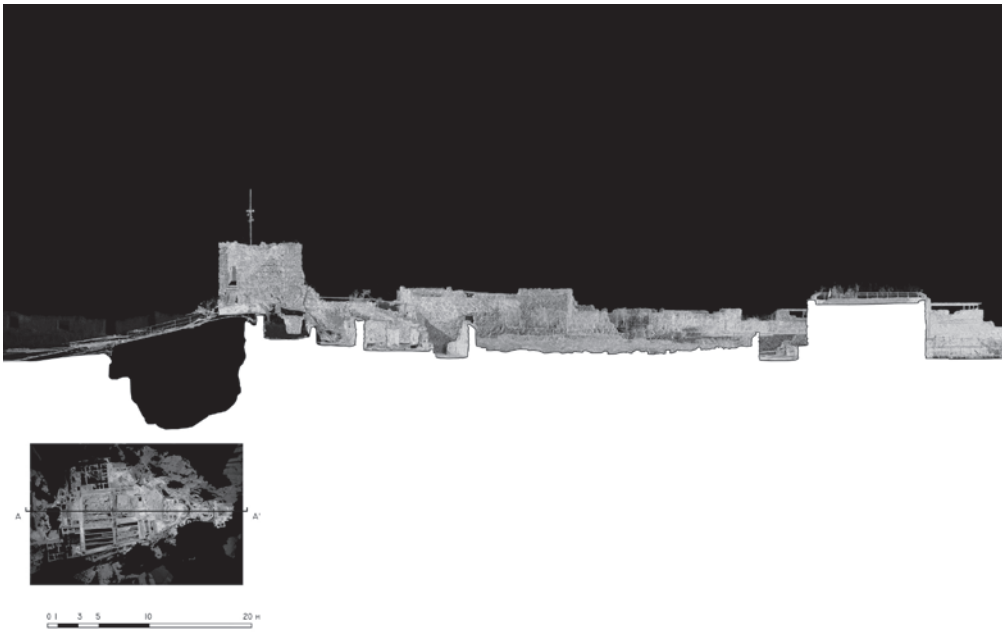
In these images the steps of removing noise from the point cloud.



The 2D representation of the archaeological site

Among the various methods for managing and editing three-dimensional databases with the *Cyclone* software, it's possible to define, what instruments and tools should be used, such as limit box and the inclusion of plans. By extracting partial views of the point cloud one can define which graphic sections must be simulated to describe better the architecture. The choice of the positioning of the plans sectioning is crucial because it involves a first discretization of the data acquired in the construction of a system of reference, which conveys the description of the place. The visualization of the virtual environment in parallel projection (isometric) then allows the return of two-dimensional designing of the survey, giving the possibility to compare the different sections and opting for those that describe more exhaustively the complexity of the site.
For the portion of the surveyed area, four geometric planes were chosen to make horizontal sections, placed at different heights, in order to adequately describe the complexity of the planimetric development of the area of the building. In particular, it was decided to place a plane for each of the three terraces that descend towards the valley and the fourth plane was arranged to dissect the different areas of the deposits and the thermal complex that lies on the highest plateau.
For the design of the elevations of the vertical planes were set longitudinally and transversely to the axis of the main development of the complex building, in order to obtain the best possible view of the majority of the elements present. If the development of research needs other detailing sections for an appropriate documentation of some areas and for increasing the restitution of the information on this site, it's possible, any time, to locate and include new cutting planes.

The use of *AutoCAD* with the *CloudWorx* plug-in gives the possibility to import the point cloud directly in the *AutoCAD* interface, and allows to make interpretations on the structures during the redrawing phase, while directly assessing the image generated from scans, as well as interpreting the shapes of the elements detected by the laser scanner. The possibility to import the database directly in *AutoCAD* allows you to maintain the reliability of the given metric compatible with the detected object, reducing possible dimensional errors, for example such due to processes mosaicking of the snapshot created in *Cyclone*. This way, one avoids the repositioning of the different images that make up the section, is done manually by using overlapping images that can cause an approximation of the positioning and an inevita-



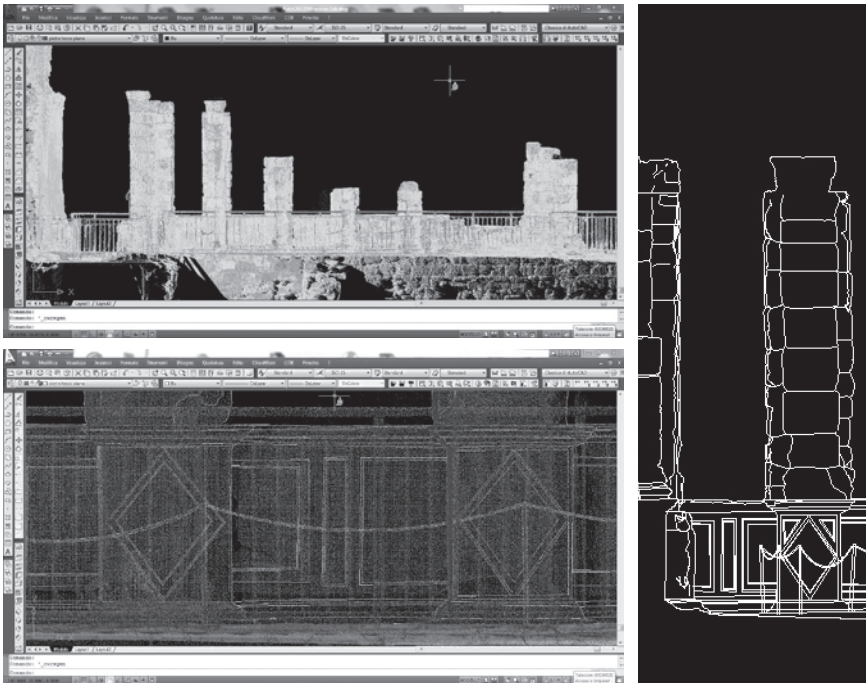
ble metric error. These errors can also be solved with the use of methods for the extrapolation of data with other features: for example, the realization of ortho image.
The use of *CloudWorx* allows you to work more quickly within *AutoCAD*, maintaining at each stage the redrawing and allowing a more reliable control of the respective portions of the individual sections. That's the reason why, after setting section planes in *Cyclone* and after setting the view orthogonally to redraw and set the amount of points to display for the different sections, which are open in *AutoCAD*, they are displayed with the same definition of appreciable detail thanks to the regeneration of *Cyclone* of the points cloud whenever necessary to display it in a different position.

Longitudinal section by Cyclone.

Drawing step in AutoCAD, starting from the point cloud.

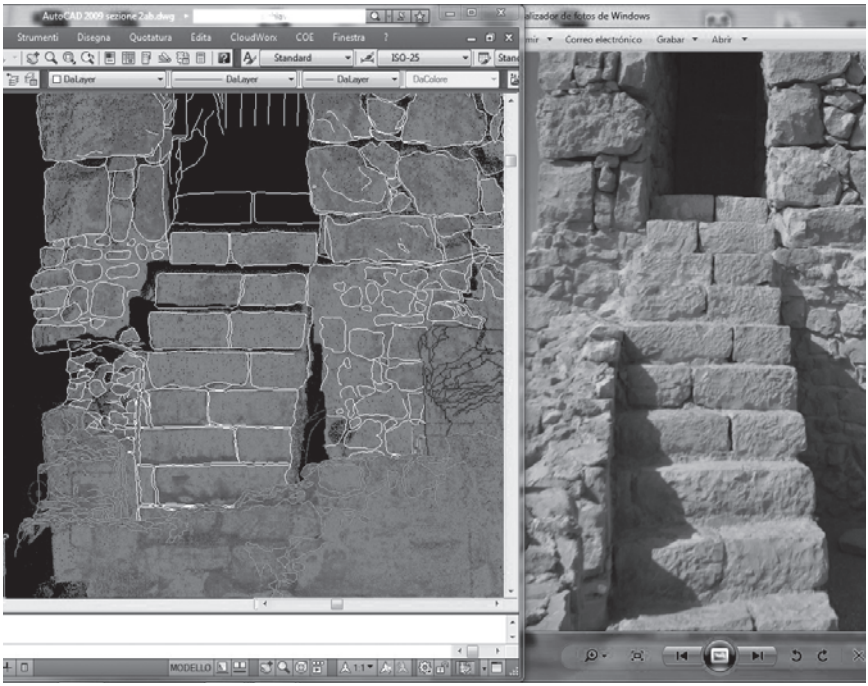
Operations of redrawing of the point cloud

Discretization of the data refers to the choice of the elements to represent and the processing that is applied to them in the drawing, depending on the metric scale representation chosen for the survey. Indeed, the purpose of the redrawing is to obtain a two-dimensional drawing where each element of the architectonical object will be recognized, preserving the morphological characteristics, so it could be measurable. With this operation, we obtain a kind of elaborate mesh called "wireframe", a type of drawing formed by the lines that represent all the parts that compose the architecture and which draw the contours, leaving white all the aspects and parts



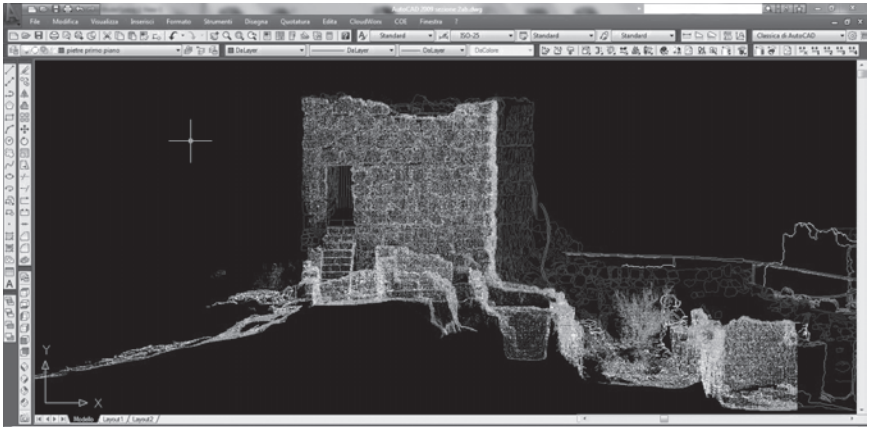
related to the decorations and to the material. The two-dimensional representation from the point cloud allows postponing to a later stage the choice of the metric scale of representation, thanks to the possibility to draw conceptually on a 1:1 scale maintaining a correspondence with the real architecture analysed. This aspect implies a greater control in the representation of details that still may not be independent of the choice of the unit of measurement to which it's necessary to print. The representation as to the type of masonry or decorations will be more detailed in relation to the metric scale that is chosen. The reworking of the survey is done through the redrawing of the point cloud in *AutoCAD* by tracing with the polyline command the elements that compose the archi-

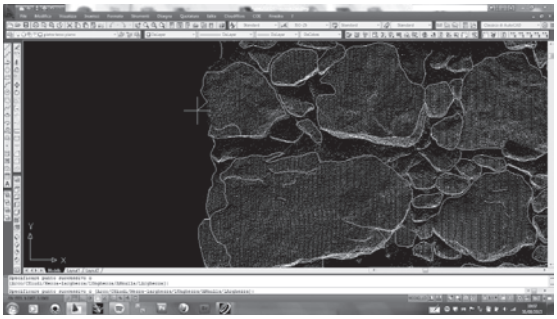
The use of photography for a better understanding of the point cloud.

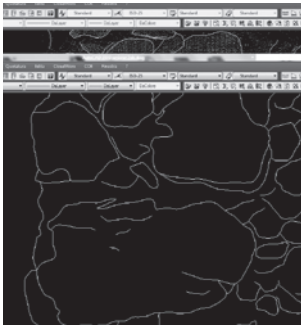


Drawing step in AutoCAD of longitudinal section, with the detail of the tower wall.

tecture. To perform these operations is essential to know the architectonical composition of the object analysed, controlling all the time the accuracy of the redrawing. That's the reason why, for the amount of information contained within the three-dimensional database due to the nature of the point cloud, it is important to be clear about the portion of the architecture that you are reworking to avoid problems of misinterpretation of displayed dots. This control is done by observing the static photos and QTVR panoramic photos, taken during the survey campaign, and observing from different angles the same point cloud directly with the *Cyclone* software.



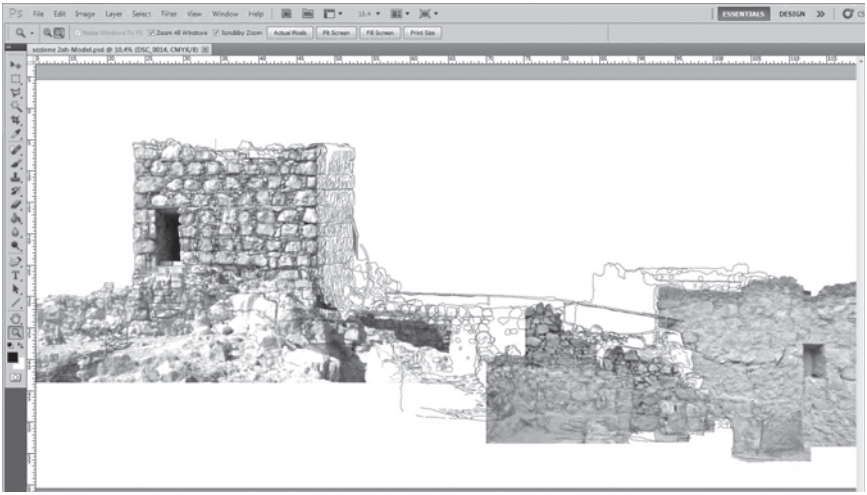


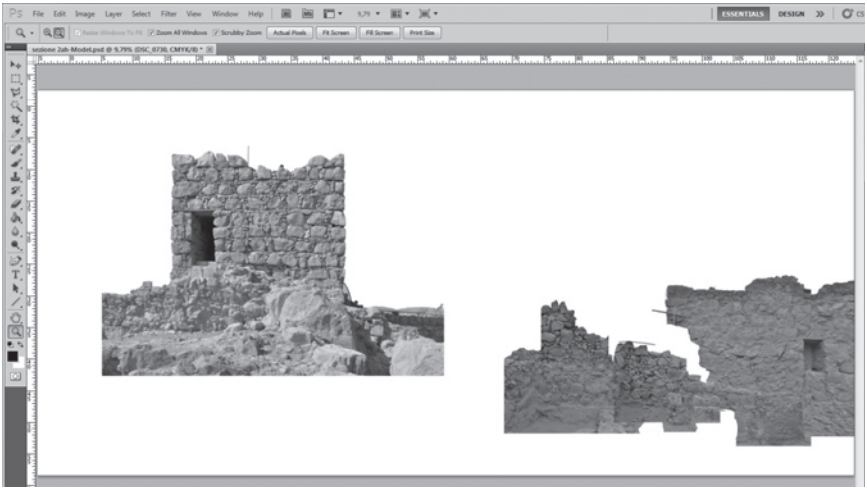


The restitution of the survey is done primarily by following a procedure that consists of three steps:

- The first step is carrying out a preliminary redesign of the section line, of the contours of architecture and stone elements that are more evident, in addition to the drawing of any other relevant elements

In the images the processing for the realization of the longitudinal section texturing.





present. In this phase a type of drawing is realized that will form the basis for the realization of *photoplans*, and will further help draw all the elements that allow the composition of the mosaic of the images that make the architecture. Then one can represent all the apertures found on the architecture, the stairs , the contour lines of the plaster or other materials in a summary way the mouldings.

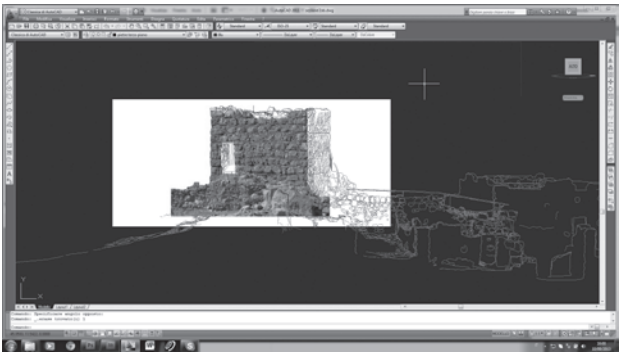
- Subsequently, the basic drawing is a merging and standardization of individual photos straight through the help of software such as *Archis* or *RDF software* that exploit the rules of photogrammetry for the elimination of perspective distortion within the individual images. For mosaicking to be realized in a correct way, the design will be reported in addition to a sufficient number of elements that make up the survey, also the mires white/black, used for photogrammetry, which have been supe-

Part of rectified photography of the longitudinal section along the tower.

rimposed to be consolidated during the photographic campaign.

- The third step is characterized by the improvement of the representation of the survey in CAD, vector drawing, by overlaying the basic raster image which is the photoplan. This overlap allows, thanks to the greater quantity of information contained within the photoplan, to further detail the architectural design by testing it and possibly to adjust the income, should there be some misinterpretation of the point cloud.

Drawing of the rectified photography section. Thanks to this we can understand much more details present in the architecture and data not acquired with laser scanner technology.



Drawings by Benedetta Bertoglio and Marco Benedetti.