

## ARCHAEOLOGICAL SURVEY: DATA PROCESSING EXPERIMENTATION AND DIRECT OBSERVATION

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### ABSTRACT

The survey of ancient buildings and its computer graphic representation set some questions, particularly about period, site, conservation, accessibility and quality of the building.

This research tests new computer programs oriented to the construction of three-dimensional models and graphics through non-metric photographs. The aim is to evaluate the relationships between modern methods, traditional ones and direct observation.

The test is about some small dimension archaeological buildings (or parts of larger buildings) in Pompeii, in which the question is to represent the various kinds of building materials and the colour of the surfaces, through drawings in different graphic scales. The research presents some results with a fairly good balance between the dimensional reliability, the general morphology and the quality of the details.

### 1. INTRODUCTION (D. Maestri)

The architectural survey must be understood not as simple representation of the visible parts of a building, but as an in-depth study of the same.

The study (representation and description) must be intended as a knowledge process of the characteristics that make a certain monument unique, in the world of architectural heritage. More and more, the survey is seen as an acquisition and restitution of what is photographable, rather than an interaction between what is obtainable with the help of computer programs and what comes from the direct observations and the global study of many other factors (bibliographies, sources of archive, observations and “eidotipi”, survey, study of the materials, etc.)



**Fig. 1:** Photo of the tombs near *Porta Nocera*.



**Fig. 2:** Photo of the Cryptoporticus of *Casa dell'Ancora*.

Ancient classical buildings, small, but rich of wall stratifications have been chosen as an example. These buildings are also rich of architectural elements which show their evolution: restorations were made following the earthquake preceding the eruption of the volcano as well as during the excavations done in the 19th century.

The target is dual: on one hand to continue on the testing of updated data processing programs, and on the other, not to neglect but to verify and deepen traditional graphics techniques for the direct study of buildings.

One of the more important phases of the architectural survey as a study of the building regards the analysis of the constructive processes through the direct observation and the draft of “eidotipi” (first free hand sketches of the survey).

The garden of the *Casa dell'Ancora*, for instance, is the most important element to know the history of the building for its complexity, and that is why it was chosen as a test of the survey with Photomodeler 4.0.

### Notes:

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## 2. BACKGROUNDS AND RELATED WORKS (M. Canciani, G. Spadafora)

The archaeological survey, as known, brings up a number of issues related to the nature of the survey object (difference between the physical reality of the object and the theoretical three-dimensional building model referred to the original construction time, complexity and significance of the wall textures definition, plasters, wall frescos), to the necessity of utilizing a survey method actually fast in all its phases (quickness and simplicity of survey phases and restitution, non-conventional methods employment, traditional, instrumental and photogrammetrics, in other words, economy in the work management), to the importance of an appropriate graphical restitution (explorable virtual models definition, and traditional hand drawings as well, in plan, elevation and section, carried out with the three-dimensional textured model aid).

These aspects of survey require the choice of a survey – restitution method which is required to have as fundamental features, quickness of the procedures, a non-conventional approach to the photogrammetry, the use of low cost tools and the possibility to obtain high quality results, computerized and traditional and, at the same time, a range of measures accuracy and precision, compatible with the restitution graphical scale.

The survey, carried out with traditional methods, is generally articulated in two complementary and distinct phases: the objective of the first phase consists in the structural definition through a wireframe graphic scheme, which shows its morphological features, while the second phase is based on the material representation applied to the original scheme, examining in depth the wall textures nature and the plasters, which characterize the architecture.

The two distinct phases seem to get together in the Photomodeler program application, whose operative method enables to structure a three-dimensional starting model, even though very schematic, by drawing directly on the photos all those surfaces that compose the various parties of the architectural handcrafts. These surfaces, properly jointed thanks to the use of two or more photos and without the necessity of further measures, define a three-dimensional object, which allows not only for three-dimensional views of elevations, but also to work out vertical and horizontal sections at different levels.

The possibility of working directly on the photos makes easier the identification of those surfaces more suitable for the genesis of the three-dimensional model and the amount of surfaces required to describe the object. Besides, it forces to an analytical work and to a synthetic restitution, which can be assimilated to the mental processes carried out while working out drawings during the direct survey. Clearly, the issue is then brought to the quality of the result that we want to get, since a greater accuracy of the final model implies a different valuation of preliminary and actual working times for the program employment.

This process has been adopted experimentally for few buildings in Pompeii's archaeological site survey: the *Casa dell'Ancora*, in the *Regio VI, insula n.10*, and three funereal buildings in the necropolis by *Porta Nocera*, marked by the numbers 10, 12 e 14EN (2). The same process has been utilised for few survey searches, related to modern architecture in 1999 and 2000, in an investigation on residential architecture in Rome Monteverde Vecchio and in a monumental building survey, Mercati Generali, located in Rome as well, in relation to the 3D model and the elevation definition (3).

## 3. THE GENERAL METHOD - (M. Canciani)

The general method that we employed was based on the use of a multi-photograms restitution program, Photomodeler 4.0 (4), supported by the analysis and the measurement on site of the handcraft with traditional methods, as well as by its philological reconstruction based on archive document and bibliographic research, and with the final aim of the realization of the model through a 3D rendering program and the drawing up of 2D analysis papers. This method can be broken down into different sequential phases, which imply decisional breaks, where the procedure to be adopted is decided and breaks to verify the data accuracy; these phases can be listed as follows:

- a) preventive analysis of the documents, analysis of the survey object and choice of a suitable method and the target of the job to be carried out;
- b) definition of a project of photographic hold, of the control points and the relative measurements, and the draft of "eidotipi" to develop on site;
- c) computer acquisition of images, and calibration of the camera, realized in laboratory;
- d) definite elaboration in Photomodeler, definition of the model, photos analysis, definition of the particular elements to draw, constraints definition, model creation through points, lines and surfaces;
- e) reduction of the mistakes, refining model precision;
- f) "dressing" of the model with textures, export of the model in cad 3D program and following elaborations.

There is here some specifications about those phases:

a) Such method can not leave out of consideration, in fact, a preventive analysis of the historical and archive documentation, the bibliography, and a first inspection to verify dimensions and the conditions, in order to prepare a survey adequate to the characteristics of the place, to establish the specific target of work and the kind of results that expected. Already in this phase, after a careful analysis of the survey elements, it was decided to use traditional survey tools, aided by accurate "eidotipi", an amateur camera for the photographic holds (device Nikon F601 with fixed focal 35mm) and the programme Photomodeler for the computerized graphitisation and the software 3DSmax 3.1 for the 3D modelling.

### Notes:

- (2) The archaeological site of Pompeii was divided in *regiones, insulae and numbers* by G. Fiorelli, in the XIXth century.
- (3) The work about *Monteverde Vecchio* in Rome regard a national reserch titled "Emergenza Rilievo", coordinator prof. D. Maestri. The survey of elevations of *Mercati Generali* regards general plan of Ostiense-Marconi area in Rome, coordinator Francesco Cellini.
- (4) Photomodeler version 4.0 by EOS system inc. is a non-conventional photogrammetric program that extract measurements and 3D models from photographs.

b) On the site it was set a project of photographic holds so as to have always three points of view for each surface to survey, and to have on this, four checkpoints at least, noticed according to a xyz coordinate system. Such work was coordinated with the use of “eidotipi”, realized on site, with the indication, for every element and surface surveyed, of the orientation and location in relation to the context, from the measurement of control points and of a few additional detail observations.

c) In the following laboratory phase, one provided to the calibration of the photographic device, through the Photomodeler supplemented form, camera Calibrator 4.0, and to the images acquisition through a scanner device.

d) In Photomodeler one proceeded to the definition of a draft graphic model, according to the checkpoints (measured on site and defined in Cartesian coordinates with elaboration to the cad in dxf format) providing two photographs at the time. Through the analysis of the photographs the elements of detail that would have constituted a widening or a modification of the main theoretical model have been highlighted, in forecast of a further representation to a greater graphic scale. The coordination of the images with the checkpoints dxf model is necessary for the individual photogrammetric models or couples of photograms, by making the ordered composition of all the photograms in a set model easier. Such a result is the addition of reference points, which have been identified on few photograms by the lines of the corners and by the surfaces that constitute the main part in the final graphical representation, by characterizing the model with the specification of the surfaces textures as they actually are. Photographic holds must consider the whole view of every surface or element from at least two positions, the possibility of subdividing the texture of a surface on different photographs, and the covering of every reference wall with at least 4 control points, indispensable for the orientation.

e) Defined the model in all its parts, and once identified the detail elements, it is possible to obtain a few control measurements (distances and areas) and to verify the approximation degree of the measures, so as to intervene on those points that are beyond the established precision range, by correcting eventual typing mistakes.

f) The final phase of the graphic representation makes use of the exported vml model that can be observed by several points of view dynamically, with all the points noticed, the lines and, above all, the surfaces. The model can be reworked in a three-dimensional programme as 3dstudiomax 3.1 for the sections design, both horizontal and vertical. By print out these drawings, it is therefore possible to execute a few hand-drawings and working out any analytic and synthetic process required by the archaeological survey.

#### 4. TWO APPLICATIONS

##### Tombs 10, 12 and 14 (EN) of the necropolis of Porta Nocera in Pompeii - (M. Canciani)

The general method described firstly, when regarding funereal buildings at *Porta Nocera* involve a series of adjustments to be chosen while progressing.

The three buildings appears as some cubes, dimensioning about 3,5m. x 3,5m. x 4,4m. (S x S x H), with a basement enlarging about 20 cm from the superior structure. One of them is enriched by a niche on the south side. Them all are conceived in blocks of lava set in *opus incertum* for all sides, while the corner are reinforced with scarf of bricks. The whole is covered with plaster, partially still *in situ* and partially ruined or collapsed that allows to see the below structure.

Referring to point 3, it can be observed:

a) It has been established, since beginning, to have a restitution whose approximation should be detailed for a representation in scale 1:50 / 1:20.

|                |        |                           | max | min   | avg |
|----------------|--------|---------------------------|-----|-------|-----|
| PHOTO          | 42     | POINTS PER PHOTO          | 35  | 568   | 177 |
| TOTAL POINTS   | 3700   | PHOTO COVERAGE (%area)    | 32  | 81    | 60  |
| CONTROL POINTS | 21     | FIDUCIALS PER PHOTO (%)   | n/a | n/a   | n/a |
| REGULAR POINTS | 1527   |                           |     |       |     |
| SURFACE POINTS | 2152   | RAY PER 3D POINT          | 1   | 9     | 3   |
| POINTS ON ONE  | number | ANGLE INTERSECTION        | 1   | 89    | 65  |
| PHOTO ONLY     | 16     | RAY TIGHTNESS (% of size) | 0   | 1     | 0   |
| POINTS ON TWO  | 333    | APPROXIMATION MAX         |     | 0,053 |     |
| PHOTOS ONLY    | 21     |                           |     |       |     |

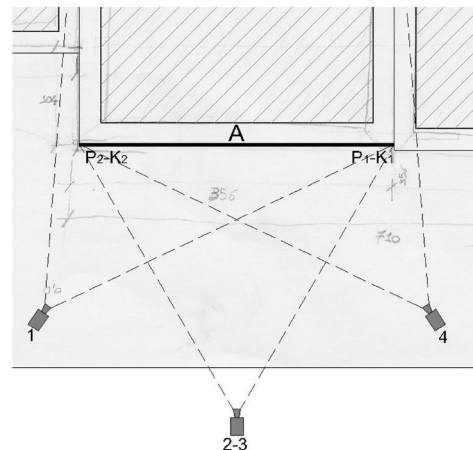
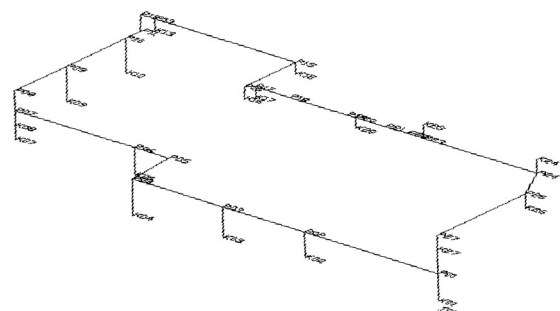
Fig. 3: Summarizing table of the datas concerning the survey of tombs.

Fig. 4: Model in dxf format of control points.

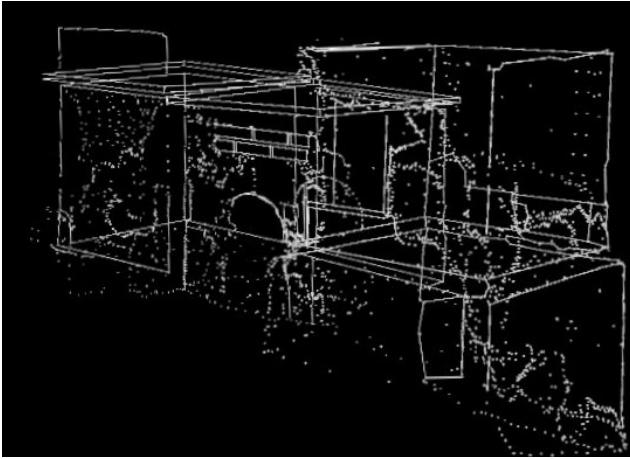
|                |        |                           | max | min   | avg |
|----------------|--------|---------------------------|-----|-------|-----|
| PHOTO          | 8      | POINTS PER PHOTO          | 111 | 110   | 110 |
| TOTAL POINTS   | 111    | PHOTO COVERAGE (%area)    | 56  | 32    | 44  |
| CONTROL POINTS | 4      | FIDUCIALS PER PHOTO (%)   | n/a | n/a   | n/a |
| REGULAR POINTS | 107    |                           |     |       |     |
| SURFACE POINTS | 0      | RAY PER 3D POINT          | 8   | 6     | 8   |
| POINTS ON ONE  | number | ANGLE INTERSECTION        | 89  | 80    | 86  |
| PHOTO ONLY     | 0      | RAY TIGHTNESS (% of size) | 0   | 0     | 0   |
| POINTS ON TWO  | 0      | APPROXIMATION MAX         |     | 1,079 |     |
| PHOTOS ONLY    | 0      |                           |     |       |     |

Fig. 5: Summarizing table of the calibration of camera.

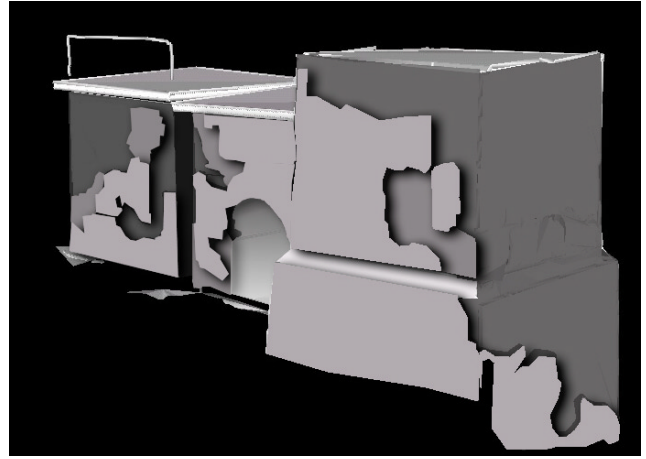
Fig. 6: Optimum condition for the surface A.







**Fig. 7:** A 3d model with reference points, surface points and lines.



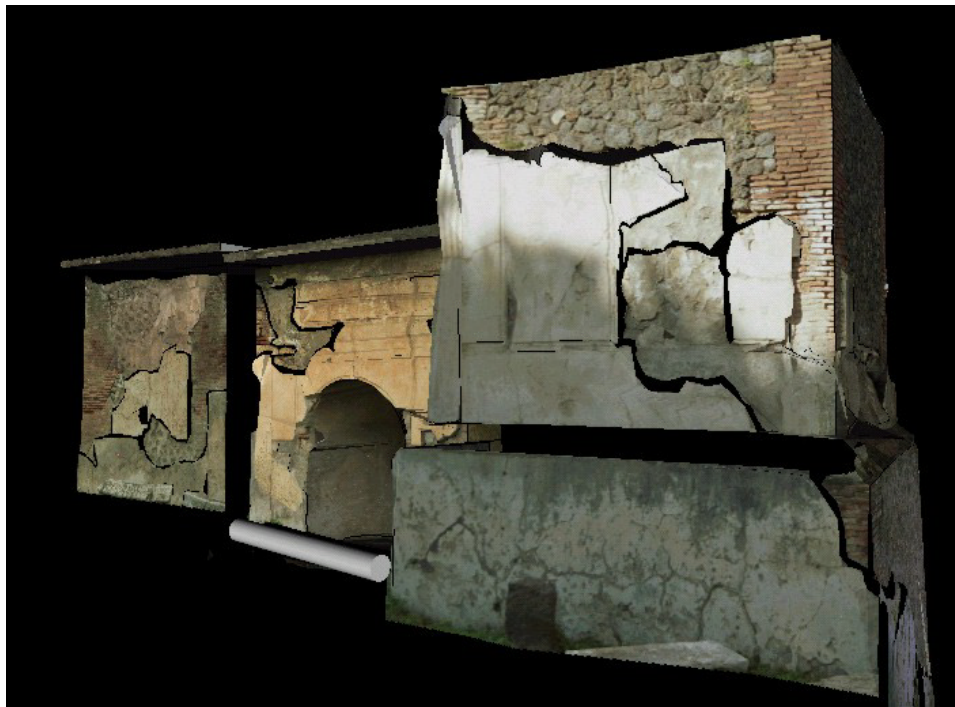
**Fig. 8:** A 3d model with surfaces of three level: exterior (finishing plaster), middle (background plaster) and interior level (masonry).

**b)** The project of photo taking has been defined to show every side surface of each tomb from at least four different positions: corners, right and left, frontal, top side and lower side, showing the relative markers of the control points, four for every photo, signed, at least, on corners of buildings. The control-points are disposed according to two horizontal alignments placed between them, at a distance of 30/50 cm. That it is, the 3D model that derives is relatively simple. Contextually, while marking each quoted point, some “eidotipi” has been drawn for every façade of the buildings, suitable for taking back measures and every annotations of survey.

**c)** In the phase of computer elaboration it has provided to acquire the photographs directly by negative, through scanner Nikon LS 30 (scanning by 1200 dpi,) to calibrate the camera (indispensable process for correct restitution and good approximation) and to define a model in dxf format of the control points, surveying on the site.

**d)** On the basis of the visual analysis of the construction and, subsequently, on the study of the photos, it has been noticed that the buildings have a generically prismatic spatial conformation, with a more wide basement, though the real configuration is changed by the fall of the plaster in several areas. So it has been established to define the walls according to planes parallel between them, easily detectable from the photos. They are conceived as following: 1) the outside plan, referring to finishing plaster; 2) the intermediate plan, referring to background bottom plaster; 3) the internal plan, referring to the masonry.

This elaboration of the model considers the real formal configuration of the buildings and the characteristics of each constructive material. To obtain that, some “constraints” are used in Photomodeler in order to better determine some point: 1) membership of a generic plan condition; 2) plan disposition according to the boards axis; 3) flat plan disposition according to the yz axis. The conditions



**Fig. 9:** A 3d model with textured surfaces with the material characteristics of three level: finishing plaster, background plaster and masonry.

of membership allows to locate global characteristic of the made surface, through the following steps:

1) procedure of referencing points from several photos; 2) identification of plan through reference points; 3) realization of line as geometrical patch of points; 4) association of that points belonging previous referenced plan; 5) fulfilment of remaining intermediate region as responding to the coplanar characteristics of membership. The undoubted usefulness and speed in the execution of such process consist in the fact that the surface points do not need further elaboration, since belonging to the already referenced surface, and can be simply identified by one photo. The returned model is determined, at first, by trending single photograms through control points; then, through the referencing of about 1500 points; finally, through about 2150 surface points, needed to describe those superficial elements belonging to different layers, besides lines and surfaces.

e) The model identified one from references points, surface points, lines and surfaces provides for an approximation degrees equal 2%. Since that, it has been further elaborated, relocating points whose range exceed 1%, in order to obtain a final result below such value.

f) The final phase of the graphic elaborations makes use of the model exported in 3dsmax with the surfaces textured, defined geometrically by the program, containing the materials that correspond to the textures elaborating by the photographic images. On final 3D model, using a software CAD, has been taken some vertical and horizontal (slice/sections) with an approximation compatible with the scale 1:20 predetermined.

### The cryptoporticus in the *Casa dell'Ancora* in Pompeii (G. Spadafora)

This second test regards the survey and the drawing of the cryptoporticus in the *Casa dell'Ancora* (Regio VI, Insula 10, n. 7). Though the project of photographic shooting and dimensional survey regarded the whole complex, in this paper we present only the results concerning the eastern wall.

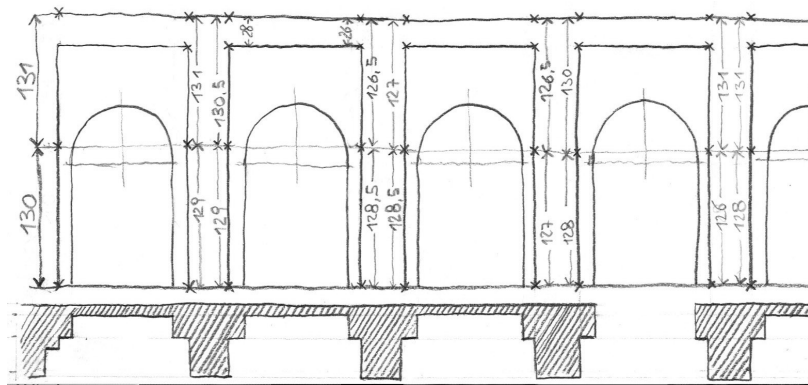


Fig. 10: Preliminary "eidotipo".

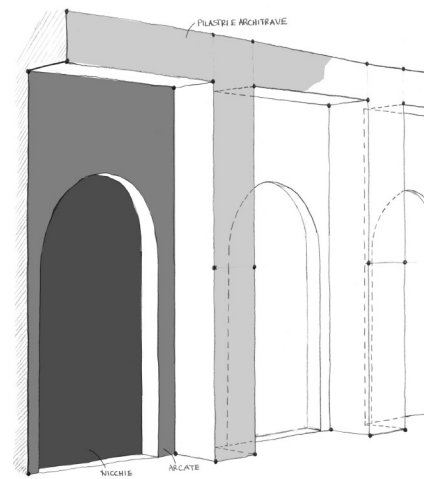


Fig. 11: Indications of the datum planes for the survey.

The final aim in dimensional accuracy guided the preliminary operations of the test: the construction of the graphic support model, the choice of significant points on the object able to allow a quick orientation of each photogram, and the location of the best views for the visual yield. The first question was to obtain quickly a schematic three-dimensional model to display the characteristic elements of the cryptoporticus, through the immediate perception of the materials and building techniques compatible with a representation scale of 1:100. The second question was to have a detail of the general model, telling the plane of the dry wall from the plane of the plaster with an approximation compatible with a representation scale of 1:50/1:20.

To synthesize the description of the operating approach relative to the first question, we list the succession of the different phases beginning from the analysis modalities.

a) The eastern wall of the cryptoporticus in the *Casa dell'Ancora* shows three different planes: the outer one is shaped by the pillars and by the epistyle; the middle one is determined by the arcades; and the interior one is determined by the background of the roundels. Actually, the detachment of the plaster on large part of the building surfaces determines other accidental planes. However, the survey project was somewhat simplified in order to obtain a three-dimensional model that synthetically describes the general architecture of the garden.

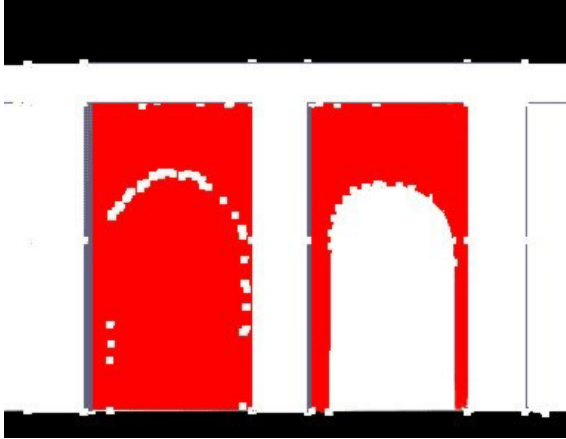
b) The above considerations limited the operations on the spot to the construction of a regular graphic model of support, through very few measurements. The markers were placed on the pillars to a height of about mt 1.30, in correspondence with the bricks, uncovered by the plaster that is mostly in the lower part. Having in mind this horizontal plane of reference, upper and lower elevations of the pillars were measured as if they were on a vertical line. Also the depth of the pillars was measured for the definition of the plans of the arcades lying behind. The project of photographic shooting considered the number of plans to draw and therefore provided at least three photograms for the arcades, two angled and one frontal.

c) The acquisition of the photographs, directly from negatives, by scanner Nikon LS30 and the calibration of the photographic device were made in the same way as for the Tombs of *via Nocera*, described in the previous paragraph.

d) The following phase, in laboratory, concerned the realization of a 3D model in CAD environment, on the basis of the measurements made on the spot. The export of the 3D model in DXF format allowed the immediate visualization in Photomodeler. This software required the orientation of the photograms on the basis of the 3D points detectable on the photographs thanks to the coloured markers.

| PHOTO                     | 48     |   | POINTS PER PHOTO          | max   | min | avg |
|---------------------------|--------|---|---------------------------|-------|-----|-----|
| TOTAL POINTS              | 502    |   | PHOTO COVERAGE (%area)    | 8     | 28  | 18  |
| CONTROL POINTS            | 169    |   | FIDUCIALS PER PHOTO (%)   | 23    | 80  | 50  |
| REGULAR POINTS            | 4      |   |                           | n/a   | n/a | n/a |
| SURFACE POINTS            | 329    |   | RAYS PER 3D POINT         | 1     | 6   | 4   |
| POINTS ON ONE PHOTO ONLY  | number | % | ANGLE INTERSECTION        | 0     | 89  | 63  |
|                           | 0      | 0 | RAY TIGHTNESS (% of size) | 0     | 2   | 0   |
| POINTS ON TWO PHOTOS ONLY | 2      | 1 | APPROXIMATION MAX         | 0,488 |     |     |

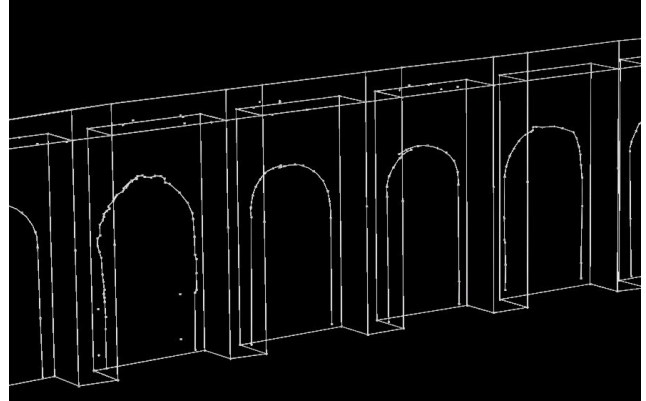
**Fig. 12:** Summary table of the survey data relating to eastern façade of cryptoporticus in the *Casa dell'Ancora*.



**Fig 14:** Indication of the rectangular support surface and of the surface points.



**Fig. 13:** Viewpoints of the photographic shooting.



**Fig. 15:** Indication of the surfaces of the arcades and some surface points.

The final model is given up by 181 lines, 169 control points and 329 surface points. The plane of each arcade was built subtracting it by a rectangular support surface, referenced with 4 control points shot in 2 photograms at least. The curve of the arcade was traced on the support surface, through a set of surface points (points belonging to the surface that do not need the reference process). Subsequently, the arcade defined by the perimeter of the control and surface points was built. The rectangular support surface was afterwards erased in the 3D modeller software 3DS Max 3.1, used for the final rendering of the images.

e) The model was several times elaborated in order to reduce the admissible deviation at a level lower than 2% through the hand correction of the data resulting with a not acceptable approximation. The schematic settings of the model produce an error of about 5 cm on the entire size, that is acceptable in consideration of the preliminary statements.

f) Then the base model was enriched with further details through the use of photographs so as to become measurable in every part. For instance, we can measure the bricks or the stones directly in 3D model. A subsequent elaboration with a specific rendering software (in



**Fig. 16:** Eastern façade detail. Elaboration through more accurate graphic model.



this case 3DS Max 3.1) allowed to obtain a set of images such as the façade in orthogonal projection.

Regarding the second test, the final result was a more exact graphic model of some arcades through a greater number of points for single photogram. The model uses the same number of control points but a greater number of referenced points for the definition of the various structural planes.

## 5. ISSUES AND RESULTS (M. Canciani, G. Spadafora)

The main problems during the test of the survey method concerned the quickness of the procedures and the accuracy level of the measurements, not always equal to the appointed task. Indeed some procedures could be improved in effectiveness and reliability, for instance by using an electronic theodolite that automatically generates a three-dimensional DXF file, or by setting up pre-printed markers to point out the control points more distinctly. Concerning the acquisition of the images, the procedure could be improved by using a digital camera that also makes easier the calibration process. Besides, it could be useful to go deep into the check of the data as well as into the accuracy of the geometric model. By the way, the use of new and updated instrumentations would involve obviously an increase of the survey costs, but would reduce the time required for the computer elaboration and would improve the accuracy and the reliability of the process.

As regards the obtained results, the more convincing part of the work seems to be the definition of a navigable vrml model exportable in other cad programs, and definable “opened model” for following elaborations if by computer (any kind of horizontal or vertical section or axonometry) or by hands (drawings executed on the orthogonal projections cad printed).

The program therefore allows a remarkable saving of time in the realisation of three-dimensional schematic models in which the interest is more in the general architectural appearances than in the details, with the advantage to have measurable objects in orthogonal projections in short time. In this sense Photomodeler can be counted among the expeditious survey methods whereas with this denomination we mean the possibility of drawing with such a tolerable deviation in the final scale of graphic representation.

One of the advantages of Photomodeler use is the possibility of obtaining a view of the elevation in orthogonal projection with rectified photographs, from a three-dimensional object; vice versa the rectifying procedure and the following assembly of single photograms in the drawing needs longer operating time and produces a result limited to the single specific projection.

The final result can't only end with the elaboration of the numerical model. That, in our opinion, should be the statement for following analyses that graphically synthesize the gathered data and turn them into signs able to communicate the nature of the represented object unequivocally. In fact, the model of the whole eastern wall, in his approximation, can be used to serve to consider the structural and morphological character and it gets evaluation only if connected with its environment; vice versa the more accurate arcade model simplifies the drawings of structural elements. The last aim of the survey can't, in fact, be the return of a mimetic model of the reality. The numerical elaboration of the single arcade was, therefore, set up in a way that following graphic elaborations could be readable in a scale of 1:20, suitable for taking back the characteristics of the materials and the presence of the plasters.



**Fig. 17:** Cryptoporticus in the *Casa dell'Ancora*. Eastern elevation in Photomodeler.

## 6. CONCLUSION (D. Maestri)

The creation of data processing three-dimensional models as well as the three-dimensional dynamic visualizations and the various rendering elaborations have since been taken as granted.

A following step will be to increase and to examine in detail the solution of the various problems in the architectural studies developing the collaboration between users and software houses (in this case the Eos System). Beyond the photographic precision and the reliability of the imagines in the process of surveying, the core of the question becomes the quality of representation. This fact must be a fundamental prerogative of all architectural data processing. As usual, in our case, the drawing of “eidotipi” had fundamental importance to improve the use of data processing programs and to choose the best representation scale.

## 7. FUTURE WORKS (D. Maestri)

The future research foresees two principal fields of study: on one hand the data processing programs and the survey processing will be oriented toward the representation of the volume and of the internal space of buildings; on the other the continuation of the data processing tests is needed to improve the quality of the graphic restitutions, especially in the archaeological field.

The possibility of quickly obtaining the elevations in orthogonal projection, for instance with the application of photographic textures, could take a valid help in the study not only of the topographic evolution of the *Casa dell'Ancora*, but of the whole *insula*.

Greater searches will be made on a series of buildings to reach a careful and strict graphic representation of the constructive techniques, the materials and their superficial manufacturing.

Other aspects concern, in graphic representation, the identification of the problems coming from the differences among photographs (contrasts of light, angulations, etc.), from the relation between the photographs and “eidotipi”, and from the choice of the best graphic characterization in the three different scales of representation (1:100; 1:50 and 1:20.).

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