PSEUDO-METRIC ANALYTICAL PHOTOGRAMMETRIC SYSTEMS: COMPARISONS AND CONTROLS.

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ABSTRACT

Different analytical systems that are on the market use a simplified and low cost instrumentation (plane-table, stereoscope, PC). So it seems necessary to compare the different systems with respect to their accuracy, their economy (for time and cost) and their applicability.
We tested only tridimensional systems whose application was proved that we could analyze.
The comparison was carried out in some experimental fields with respect to only numerical examination without taking into consideration graphic representation problems.
The evaluations on various systems compatibilty with regard to different field requirements (possible applications, scale of representation) will be made on the basis of obtained results.

KEYWORDS

Metric, Architectural, Non-conventional, Photogrammetry.

Outside the perimeter of the Roman city, in an area dedicated to the pagan divinity Iside has been founded the monumental complex of Santo Stefano in Bologna, known today as "the seven churches"; a name derived from the successive construction of Christian buildings on the same site.

Saint Petronio, patron saint of the city, was the bishop of Bologna from 431 to 450. During his life he visited Jerusalem where in 415 were found the relics of Santo Stefano, the worship of whom spread rapidly throughout the Christian world.

Legend has it that Saint Petronio founded this monastic complex to symbolically recreate the sites of the passion of Christ and according to the tradition of the time has been buried there. Medieval ecclesiastical sources refer to this large monastery as the *Sancta Hierusalem* because of the centrally planned building, the "rotunda" of Santo Stefano, built in imitation of the *Anastasis* or shrine of the Holy Sepulcher in Jerusalem constructed during the Costantine period to protect the holy site.

The urban renewal and rebirth of the building industry throughout Europe dating back to XIth century was of interest to the Benedictine monks of Santo Stefano who invested in vast and articulate programs of embellishment and transformation of churches, cloisters, and chapels. It was here that in the year 1141 the ancient relics and grave of Saint Petronio, which had been deliberatly hidden to preserve them from barbarian pillage were rediscovered.

At the beginning of the XIIIth century the cloister was raised one floor over the twenty arches on the ground floor dateble to the year one thousand, above which

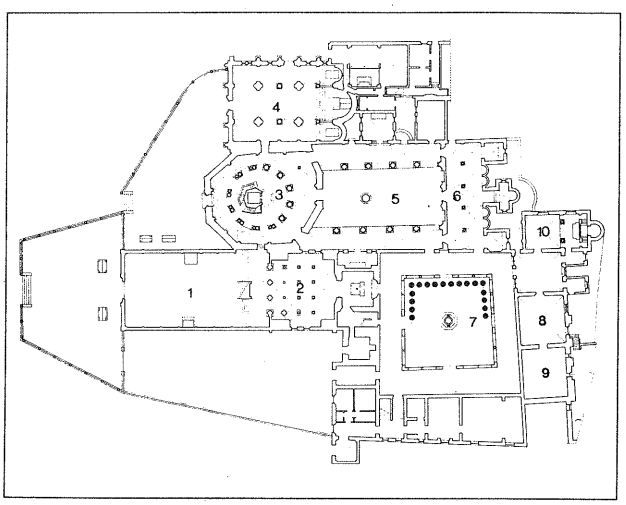


Fig. 1
General plan of the Monastery; the dotted line shows the test object. The various buildings are named as follows: 1. San Giovanni Battista; 2. crypt; 3. Santo Stefano; 4. Santi Vitale e Agricola; 5. Atrium; 6. Santa Croce del Golgota; 7. cloister; 8.9. museum; 10. Sancta Sanctorum

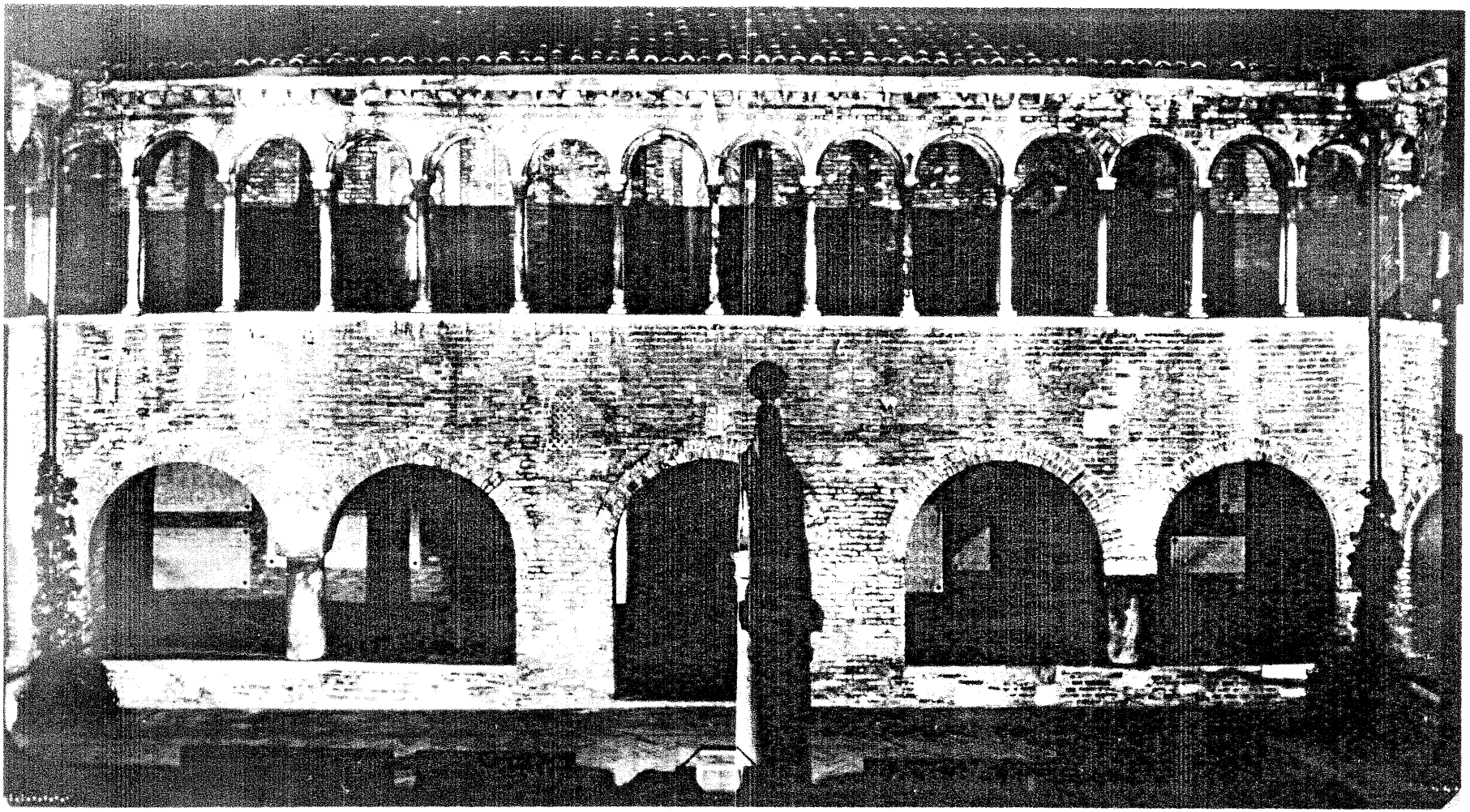


Fig. 2
Orthophotograph of the north facade.

have been superimposed four different corner columns and fifty-two small twin columns some of which have capitals decorated with grotesque and anthropomorphic figures.

1 - THE AIM OF THE WORK

The research program was jointly initiated by the Istituto di Topografia of the University in Bologna and the Photogrammetric Laboratory of the Centro Cartografico of the School of Architecture in Venice. The purpose of this program is to compare non-stereoscopical photogrammetric systems in view of a standardization which will regulate techniques and procedures of architectural survey. The ultimate goal is to clarify the limits of compatibility of the various systems.

With this goal in mind, the cloister of Santo Stefano has been identified as an ideal field of experiment for the following reasons:

- the architectural configuration on two levels simplifies the organization and the operations as the area on the first floor is protected and easily accessible;

- the stone columns have bases and simply decorated capitals and do not present particular difficulties in the phase of restitution;

- the wall structure is visibly off axis and out of plumb. The brick surface has been restored in different periods with the insertion of stone elements and small brick decorations at the top of the walls. It will be therefore possible to verify all the systems at the various scales of representation.

We foresee two phases of experimentation:

- the first is to determine the accuracy of the various systems;

- the second is to verify the suitability of the systems in the survey and representation of different architectural elements.

In the first phase the intention is to operate only on marked targets to check the optical characteristics and the quality of the hardware and software, excluding for the time being the identification of homologous architectural points. The experimentation will be conducted on one hand rigorously respecting the applicable principles dictaded by the various systems, and on the other hand by imposing our own criteria to have a more homogeneous and therefore more comparable results in the field of precision.

We have therefore created a univocal reference system that is determined by the position of points surveyed with multiple forward resection and distance measurement. The points have been marked on half the perimeter of the cloister (fig. 1). This spacial disposition allows one to evaluate the various photogrammetric systems with special attention to the possibility of detecting systematic effects produced by depth variations on the surveyed object.

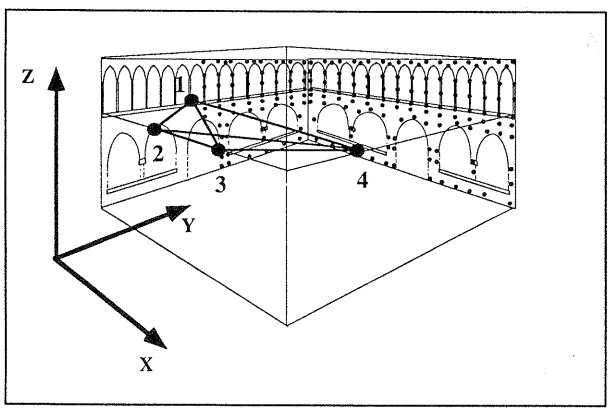


Fig. 3
The topographic stations and the targets of the west and north facade

2 - THE TEST OBJECT

The area to survey is made up by the entire north facade (fig. 2) and half of each of the adjacent facades. The surface has been marked with 245 targets (fig. 3); each target consists of a disk three centimeters in diameter made of a special reflective film upon which is printed a grid. The use of this reflective film allows to take the distance measure with EDM.

The diameter of the disc and the grid correspond to the demands of precision in topographic measurement and in collimation during photogrammetric restitution.

The targets were distributed across the three facades according to a grid of about 1 x 0,7 m which was kept as regular as possible excepting of course in those areas impossible to mark due to the geometry of the architectural elements. On the north facade 121 targets were distributed in 9 lines and 15 columns.

The survey was then taken from four marked stations that establish the vertices of a plano-altimetric network with a trapezoid shape (fig. 3). Each vertex was marked following the principles of forced centering.

The measures were taken with a total station Wild TC 2000. The targets of the main facade were surveyed with linear and angular measurement from at least three stations while the adjacent facades were surveyed from the two stations on the opposite side.

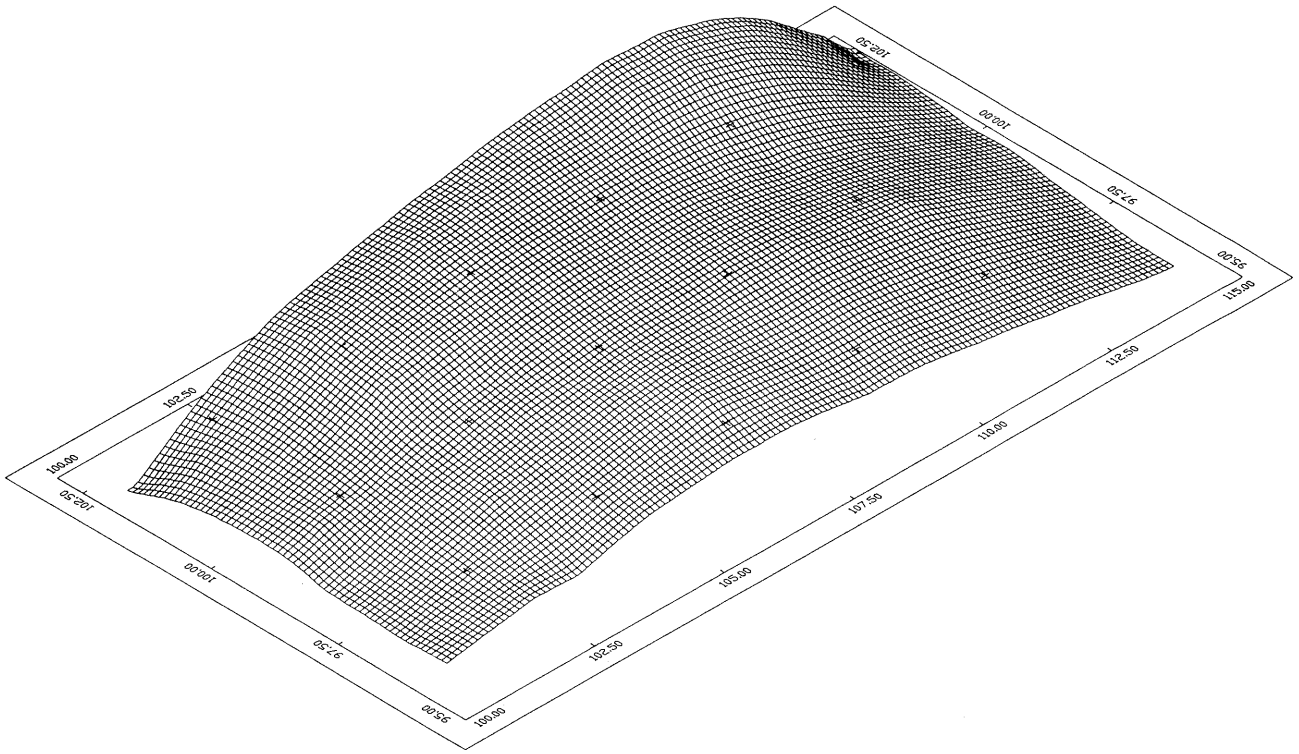
The results of the tridimensional adjustment in reference to the O-X-Y-Z system indicate that the standard deviation of the coordinates Sx, Sy and Sz for nearly all the targets never exceeded 2 mm. A digital model of the north facade has been performed using the measured points pertaining the brick surface (fig. 4). A series of color photographs were taken also with Galileo Veroplast metric camera and to complete the test, an analytical restitution has been made with Galileo Digicart 40 (fig. 5 - 6 - 7).

3 - THE USE OF THE TEST OBJECT

The work will be articulated in two phases:

1) evaluation of accuracy;

2) evaluation of different survey procedures.



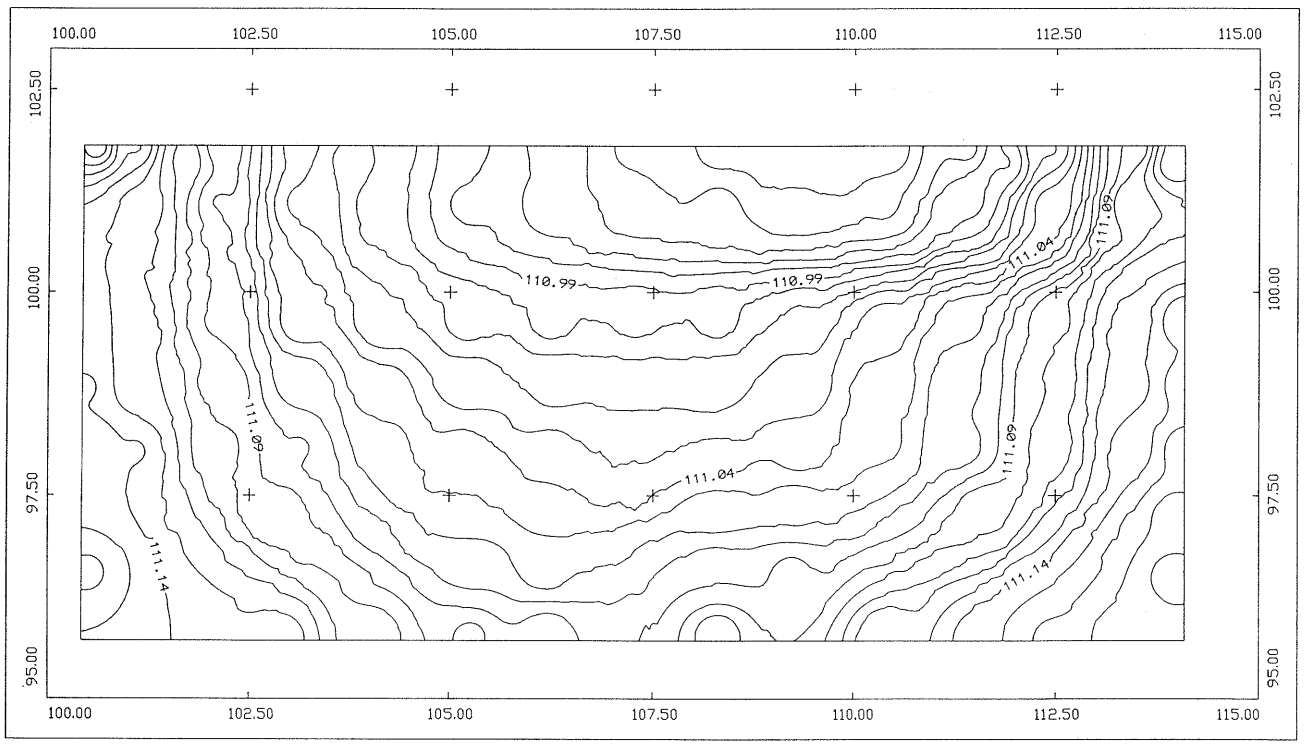


Fig. 4 - 5
DTM of the north facade: representation in isometric axonometry.
The scale factor in depth is reproduced ten times larger.
Contour lines: the contour interval is 1 cm.

Accuracy

With accuracy as the essential question in point, it has been decided to adopt two different procedures:

1 - the systems are tested following the instructions supplied by the manufacturer and using their hardware and software;

2 - some of the components of the various systems are varied to control their influence on the final result. In both cases only the marked targets have been used to minimize the errors of collimation.

Evaluation of accuracy (according to the instructions of the manufacturer)

The first case tends to reproduce the situation with which the generic user who acquires the system is confronted. The attempt has been made to use the system to the best of its possibilities, following the instructions of the manufacturer. This means that the camera, the digitizer and the software are those supplied by the company as the format of the photographic enlargement is the one suggested. The orientation operations were homogenized and optimized to obtain residuals of similar order of unit; the same control points were used for all systems in such a way as to avoid introduction of errors from topography. The comparison of the different orientation systems was made through the residual errors of the coordinates of the control points, this being the sole comparable results of the various systems.

The restitution was done by taking five different readings of each point in order to eliminate eventual gross error. The accuracy of the restitution of the points was determined by comparing the coordinates taken photogrammetrically with those taken in topographical survey.

We are completing these experiments and the results will be published as soon as possible.

Evaluation of accuracy (with comparable criteria)

To carry out the various conditions of homogeneity with which were compared the different systems, one proceeds to evaluate the elements that, in non-stereoscopic photogrammetric procedure, greatly influence accuracy of end results.

These elements are:

a - the camera and the distorsions of the used lens;

b - the dimension of the film and the scale of the photograph;

c - the enlargement of the print used for the restitution;

d - the number of crosses on the reseau;

e - the quality of the digitizer with which can be compared:

- the lenght of the minimum increment;

- the quality of the cursor (lighting fittings, crosshairs dimension, lens magnification);

- the number of points used for orientation;

- the number of prints used for restitution.

Tests will be made on the various parameters to check their influence on the system.

The applicability of different procedures and techniques of survey are going to be referred also to other factors such as cost, technical staff, time required.

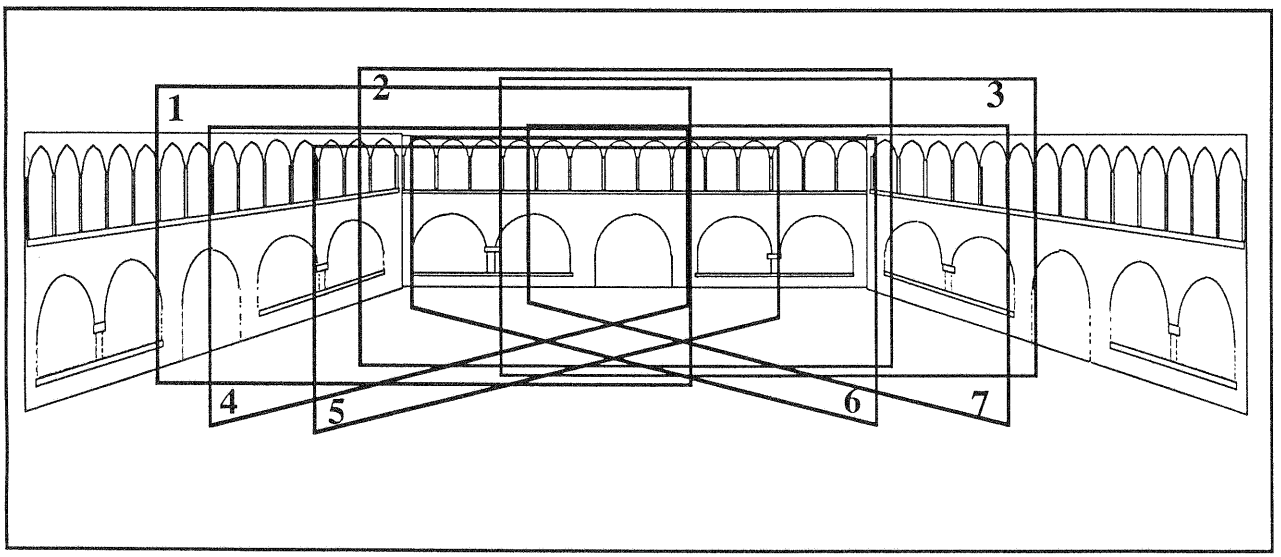


Fig. 6
The four photographic models taken with the Galileo Veroplast camera.

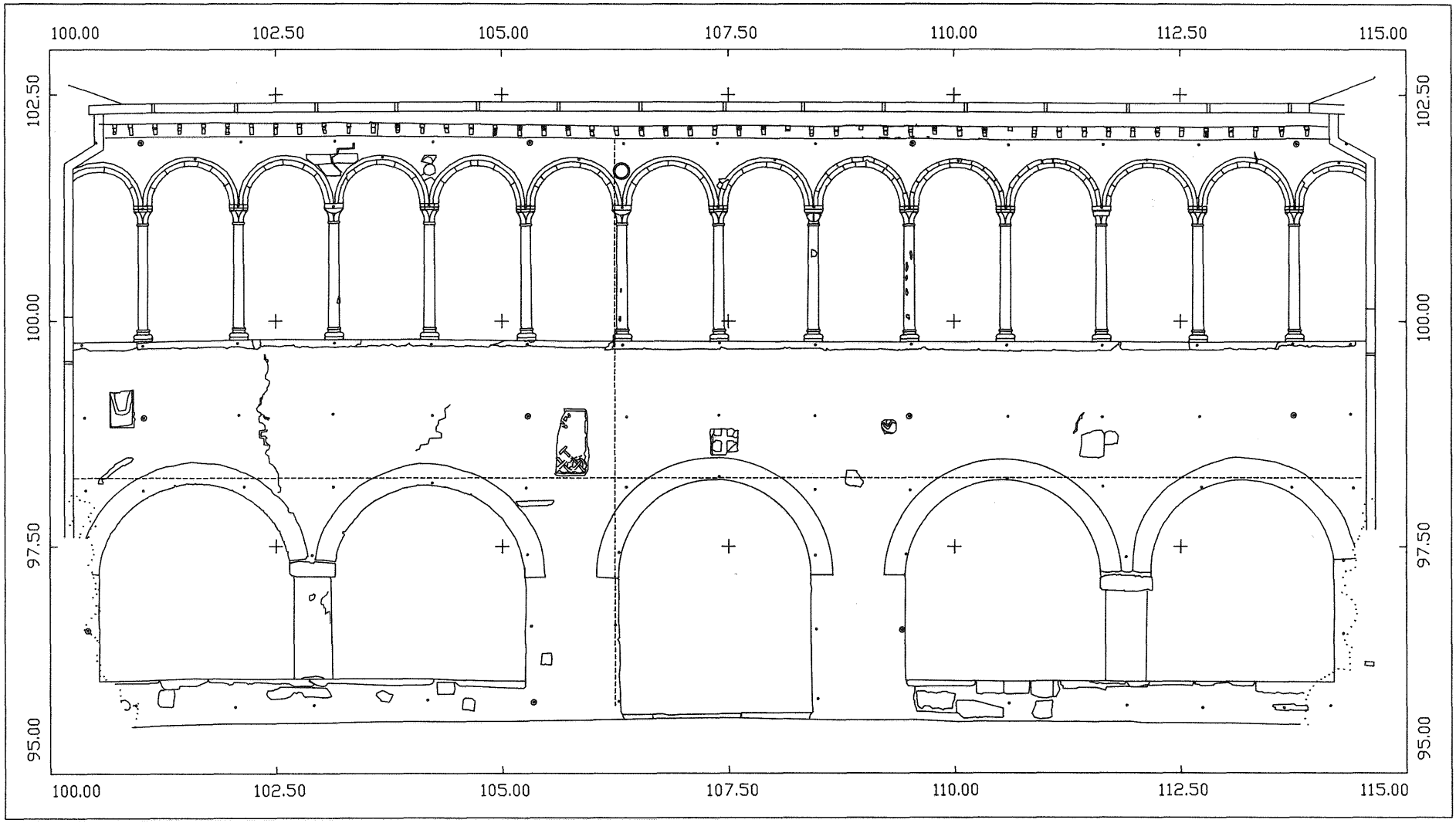


Fig. 7
Analytical restitution (Galileo Digicart 40) of the north facade; scale of the original 1: 50.
The control points are marked with a point; orientation vertices are underlined with a circle.
The two dashed line show the position of the horizontal and vertical sections analysed in fig. 9.

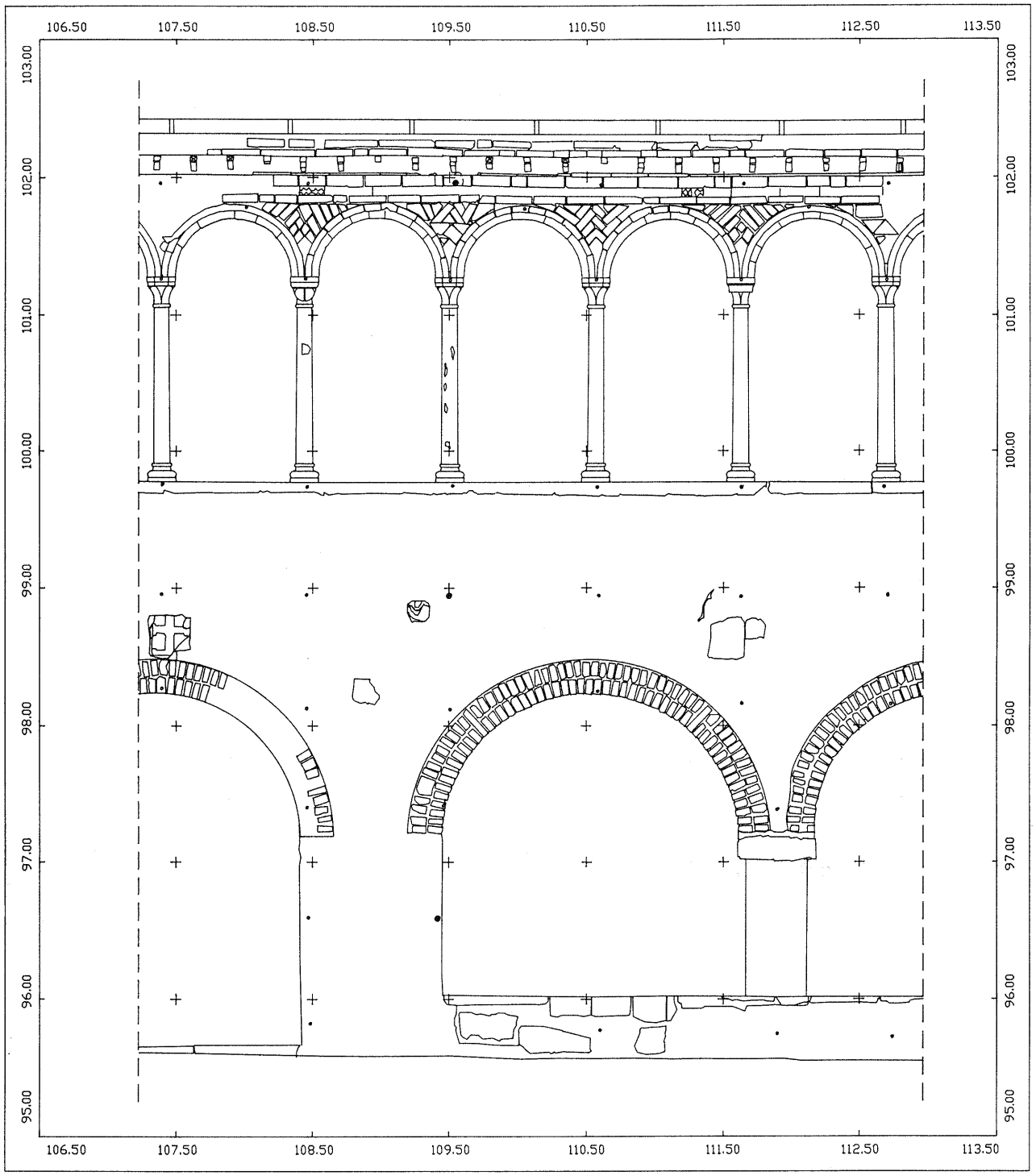
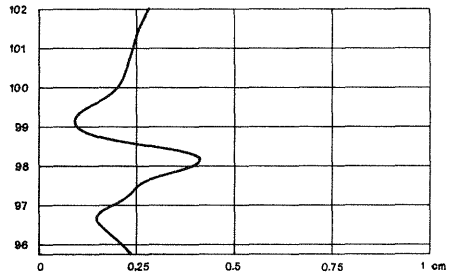
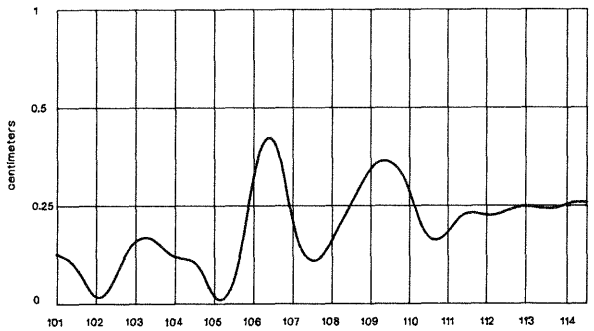


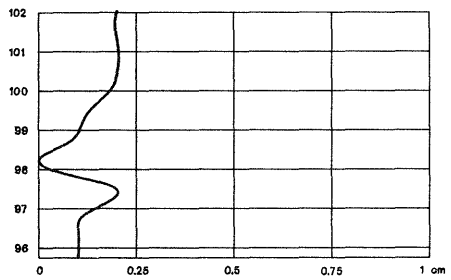
Fig. 8
Analytical restitution (Galileo Digicart 40) of a detail of the north facade; scale of the original 1: 25.
Three orientation vertices are clearly visible.
The architectural decoration as well as the stone elements need a larger scale to be fully explored.



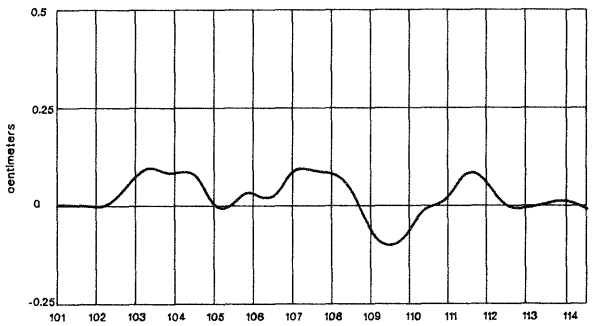
1 Vertical section.
Distance (vector error) between topographic and photogrammetric points.



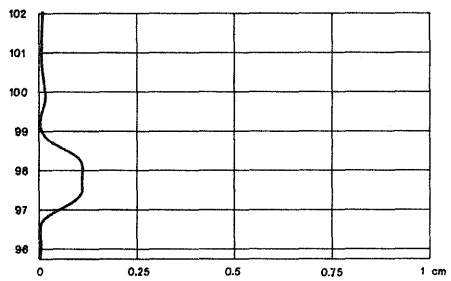
2 Horizontal section.
Distance (vector error) between topographic and photogrammetric points.



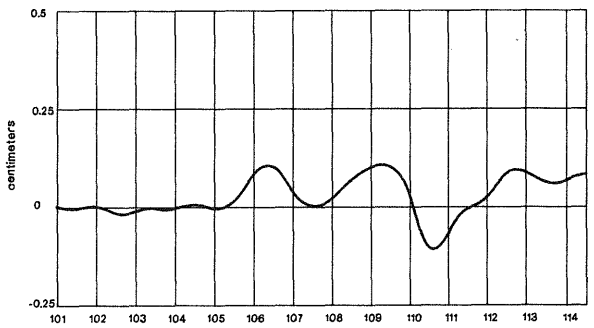
3 Vertical section.
Difference on X (horizontal axis) between topographic and photogrammetric points.



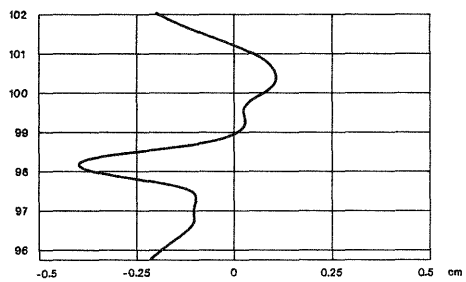
4 Horizontal section.
Difference on X (horizontal axis) between topographic and photogrammetric points.



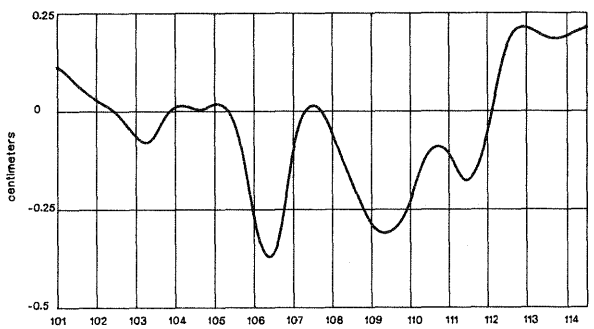
5 Vertical section.
Difference on Y (depth axis) between topographic and photogrammetric points.



6 Horizontal section.
Difference on Y (depth axis) between topographic and photogrammetric points.



7 Vertical section
Difference on Z (vertical axis) between topographic and photogrammetric points.



8 Horizontal section.
Difference on Z (vertical axis) between topographic and photogrammetric points.

Fig. 9
Metrical comparison of the analytical restitution (Galileo Digicart 40) with the topographical measurement along two central lines. The error is generally less then half a centimeter.