ANALYTICAL PHOTOGRAMMETRY FOR THE SURVEY OF THE GOLDEN ALTAR OF S. AMBROSE'S BASILICA IN MILAN

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ABSTRACT

The golden altar of the Saint Ambrose's Basilica in Milan is considered one of the great wonders of the goldsmith art. It was decided that, before starting with necessary restoration work, it would be useful to make a photogrammetric survey of the altar, in order to determine its state at present and therefore to be able to monitor any deterioration with time. Since permission would not be granted to place targets on the altar, the single-photogram raster-photogrammetric method was used for the analytical restitution of more than 1000 points for each side of the altar. Actually a mesh of points with a reference system was projected onto the object by a metric projector and only one photogram was necessary for restitution of the projected points. To each point projected on the object correspond two plate coordinates on the photogram and two plate coordinates in the mesh. The plate coordinates were measured using a precision monocomparator. A specifically designed software was employed to calculate the 3D coordinates, XYZ, from the above mentioned plane coordinates. The photographs were taken with two cameras positioned symmetrically to the middle of the altar and a metric projector central to the altar. The two stereoscopic photograms allowed the restitution of the points which were inside the mesh of projected points. Several photograms were taken with different kinds of film, both coloured and black and white, and the best were chosen to identify the bas-reliefs.

1. INTRODUCTION

The golden altar of Saint Ambrose's Basilica in Milan is a work of great artistic value and is considered one of the wonders of the medieval goldsmith art. It consists of a rectangular wooden case, panelled with leafs of pale gold or in silver. The leafs mostly represent events in the lives of Jesus Christ and of Saint Ambrose.The altar, which is approximately 2.2 m long, 1.1 m tall and 1.3 m wide, has, in time, suffered some damage. The Abbot of Saint Ambrose decided, in conjunction with the Superintendent for the Artistic and Historical Artefacts, that it would be useful to create a precise record of the present state of the altar by photogrammetric survey, in order to monitor any deterioration with time. Fig. 1 shows the East side of the altar.

Figure 1 East Side of the Golden Altar of Saint Ambrose Cathedral in Milan

This work was made possible thanks to the collaboration of AGIP S.p.A. and of the technicians who provided both the highly specialised equipment and operational experience.

2. PHOTOGRAPHIC EQUIPMENT

The equipment AGIP made available was:
(a)Two large-format, wide-angle, universal UMK 10/1318 Jenoptik-Jena metric camera fitted on an orientation system with a Horizontal circle and a device to tilt the photogrammetric axis .
(b) A metric projector developed at AGIP in a study under the direction of the author (Baj, 1988) mainly obtained matching a UMK camera 10/ 1318 and a projector without lenses.
(c) A synchroniser, pulse emitter, allowing simultaneous photography.

3. SURVEYING METHODOLOGY

The photogrammetric survey can be divided into two phases; the objective of the first phase is to obtain a dense mesh of control points, which could be determined with great accuracy, on the sides of the altar. These points, which can be linked to a topographic survey for their absolute orientation and for scale problem, are not significant in plotting the altar. The second phase aimed instead at plotting points inside the mesh in order to map the altar and its reliefs.

3.1 First Phase

In the first phase, since it was forbidden to place targets onto the altar, the methodology by us termed one photogram raster-photogrammetry was employed.
With this method the equivalent of targets on the altar were obtained by projecting onto it a mesh of known geometry employing the metric projector:
On the back of the camera-projector, in the principal plane, an optical glass on which a mesh and a reference system are etched, was positioned so as to ensure that the reference system of the mesh and the axes defined by the camera's marks coincided. (The etched plate with the reference system will be referred to as pseudo-photogram - fig. 2)

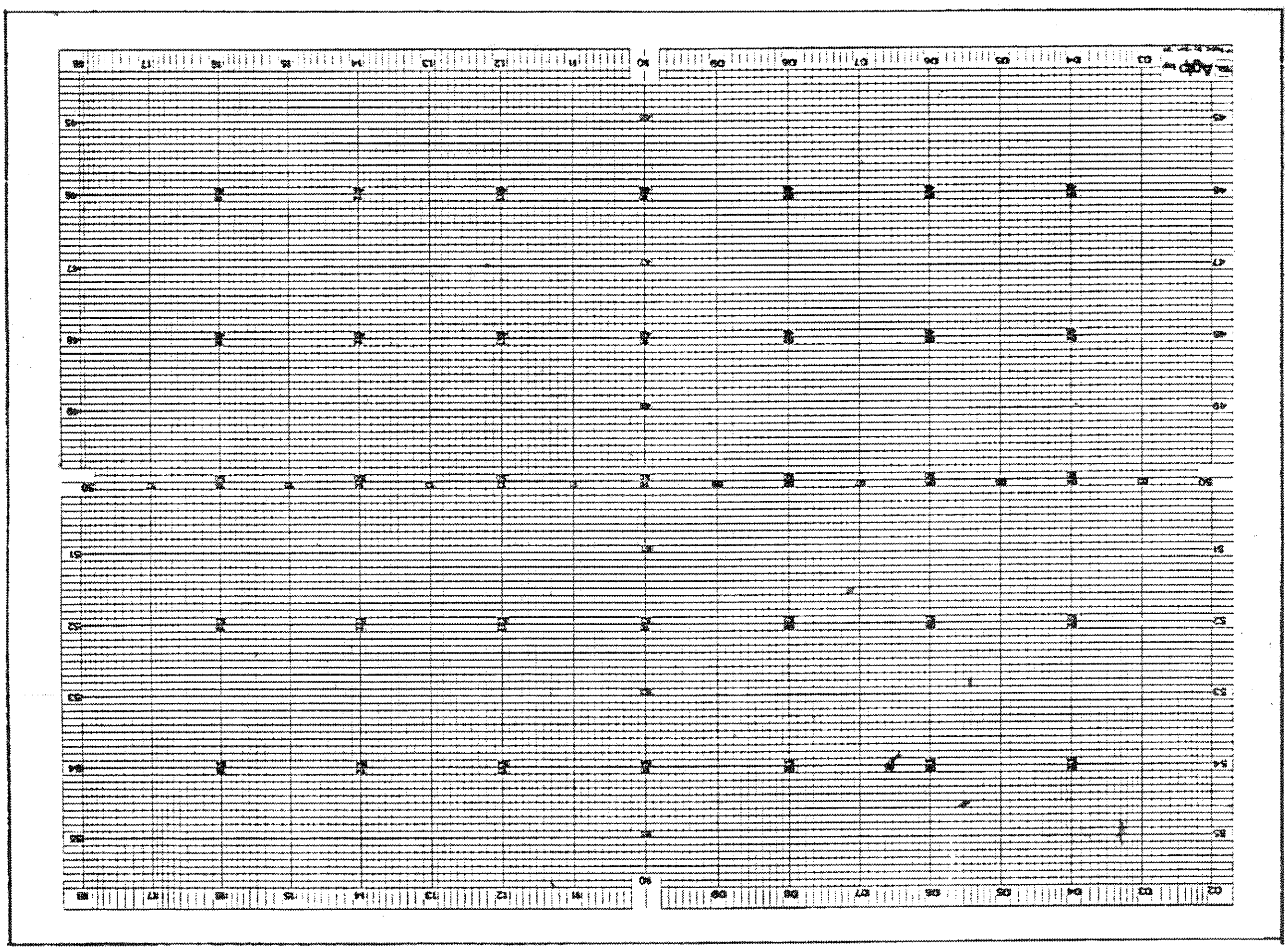

Figure 2 Pseudo-photogram

If a mesh is projected onto an object by a projector having the same optical characteristics as camera employed, the photogram of the object with the projected mesh (raster-photogram)and the pseudo-photogram constitute the equivalent of a stereoscopic pair. Actually each projected point has an image on the raster-photogram (fig. 3) and an image on the pseudo-photogram (fig. 2). It is therefore possible to obtain the coordinates of the points projected on the object. This restitution is analytical and requires a specifically designed program which reconstructs the model from the plate coordinates of each point, measured on the raster-photogram in monocular observation, and from the coordinates of the same point on the pseudo-photogram.

Figure 3 Portion of a Raster-photogram

The accuracy of the monocular reading is directly related to the sharpness of the lines of the mesh. In fact this "sharpness" should be correlated to the device employed for the monoscopic measurements. The pseudo-photogram employed, which was already existing as it had been previously used for another survey, has the following characteristics:

Two types of vertical lines, having variable (pseudologarithmic) spacing:

a. Principal lines, 0.08 mm thick, equally spaced 10 mm apart and identified with marks every 20 x 20 mm
b. Secondary lines, 0.04 mm thick, of variable spacing. Starting from the centre, the sequence of intervals is as follows:
   S(1)=1+1x(+0.05;+0.04;+0.03;+0.02;+0,01;-0,01;-0,02;-0,03;-0,04;-0,05)
   for the first centimetre,
   S(n)=1+1x n x(0,05-i)
   for the i^{th} space of the n^{th} centimetre.

Two types of horizontal lines:

a. Principal lines, 0.08 mm thick, equally spaced 10 mm apart and identified with marks every 20 x 20 mm
b. Secondary lines, 0.04 mm thick, equally spaced 1 mm apart.

The plan for the raster survey is shown in fig. 4; the altar to camera distance is approximately 2.30 m for 3 of the sides of the altar and 2.60 m for the West side. The distances were conditioned by the presence of steps around the altar which made it impossible to place an object the size of the projector any closer. The projector/camera base about was 400 mm. We tried to make normal exposures with a horizontal base parallel to the altar and the axes of the camera and of the projector normal to the base.

The bas-relief is so detailed that a greater photogram scale, that is a shorter camera to object distance, would have been appropriate.

The projected points of the mesh are separated, on the altar, by a horizontal and vertical distance of approximately 2 cm. As can be observed in fig. 3, since the surface relief of the altar is fairly small, the points are rarely not visible; it is also uncommon for the background to hinder the points' visibility because of it's darkness.

More than 3000 points were projected on the smallest side of the altar, the North one.

3.2 Second Phase

As mentioned previously, the second phase, which has only just begun, aimed at plotting points inside the mesh. For this purpose two stereo raster-photograms were necessary. Actually the 2 photographs were taken with the two cameras positioned symmetrically to the middle of the altar while the position of the metric projector was central to the altar. In fact, adhesive targets were placed on the edges of each side of the altar: these targets were connected to an external topographic network and made it possible to check the scale of the model and to relate the surveys of the four sides of the altar to the same reference system. The two stereoscopic raster-photograms made it possible to perform the restitution of the points which were inside the mesh.Figure 4 shows the arrangement used.

4. TAKING PHOTOGRAM

Problems arose due to the reflections produced by the golden or silver surface of the leafs, which were only partially solved. Tests regarding lighting position were made in order to reduce reflections. Several exposures were made with films of varying sensitivity. PEY64 film was employed, generally with a diaphragm setting of 11 and exposure times varying from 3 to 6 minutes. All exposures had to be made at night because the Abbey was being used during the day. The film was assured to be unshrinkable but in fact was found to exhibit some deformation in time.

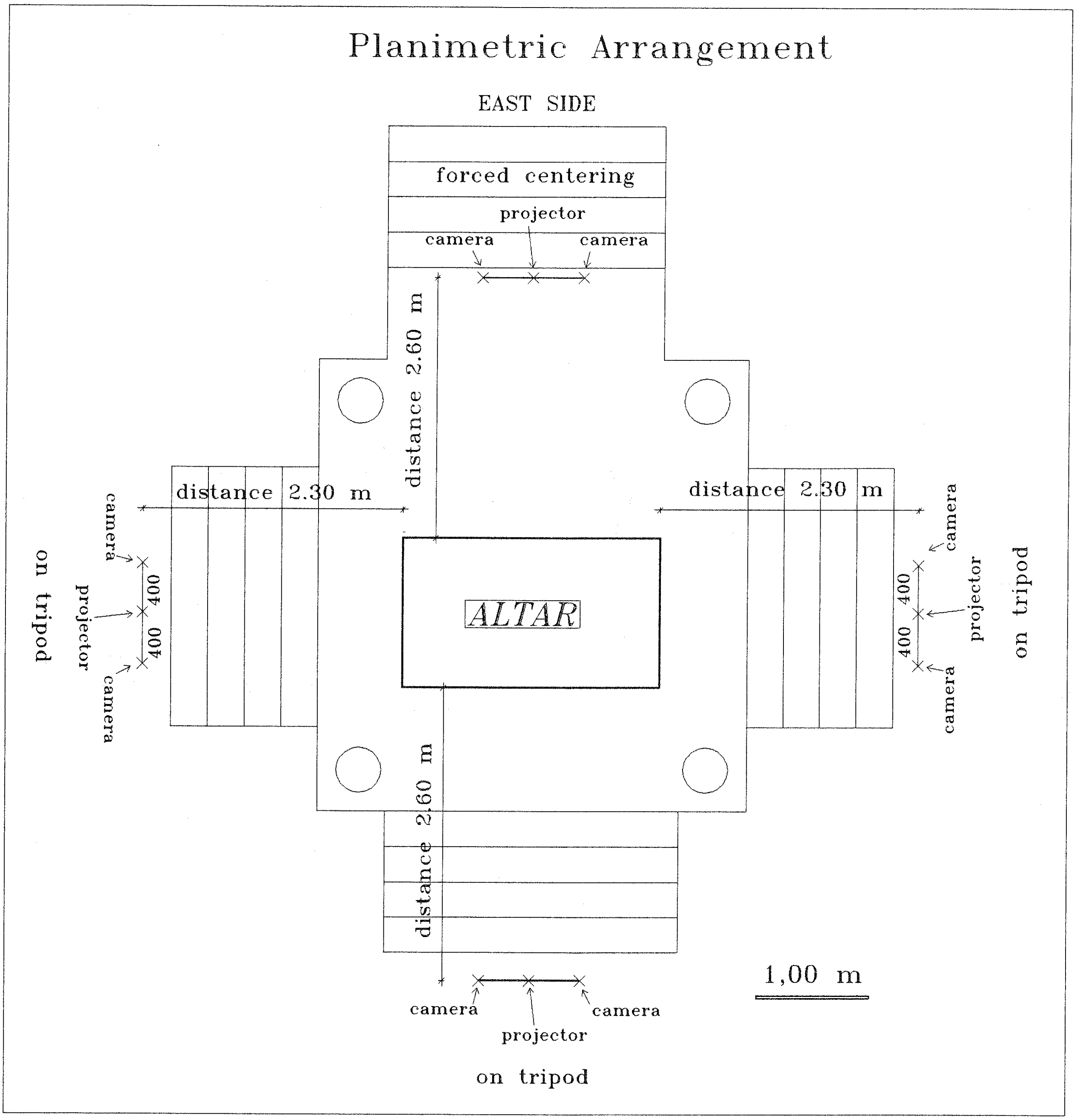

Figure 4 Plan for exposure

5. RESTITUTION

The software required for relative orientation and for the creation of the model for the projected points writes the collinearity equations, in the case of a normal exposure, relative to the camera and to the camera/projector.
In particular the first line is defined by the 2D coordinates of each projected point image on the raster-photogram and by the nodal point of the camera; whereas the second line is defined by the same point on the pseudo-photogram and by the nodal point of the camera projector.

The program includes an implicit correction to the projector position (relative orientation) which is assumed to be slightly different from the theoretical one. In this way only the relative position of projector to camera is corrected.
The algorithm for relative orientation calculates the projector rototranslation which minimises the sum of the square distances of the collinearity equations for each point of the projected mesh.
When the optimal projector rototransaltion has been evaluated the 3D final coordinates are calculated by interpolation.
A short analysis was performed of the errors caused by the lenses' distortion. Two diffferent approaches were followed; an

exact one and an analytical one. In both cases there was minimal or no improvement.
Actually the mesh of points were also restituted with an AC1 Wild to compare them with the coordinates obtained analytically.
A BC3 Wild instrument was subsequently used in order to restitute the points inside the mesh. The restitution was performed by FO.A.R.T. of Parma. The restituted points are approximately 1 mm apart in all directions.

6. RESULTS

The average distance between collinearity straight lines for each side of the altar is reported in Table 5. Three cases have been considered: basic, which is calculated not accounting for any distortion; parabolic, which considers a parabolic distortion and official, which takes into account the distortion reported by the manufacturer. These distances give a significant indication of the precision of the projected mesh points. Such a dense and precise mesh makes very accurate restitutions and rectifications possible.

Altar Side	**distance** (mm)
West	
basic case	.1667
parabolic case	.1657
official case	.1678
North	
basic case	.1166
parabolic case	.1153
official case	.1184
East	
basic case	.2312
parabolic case	.2329
official case	.2313
South	
basic case	.2364
parabolic case	.2330
official case	.2408

Table 5 Distances of Collinearity Straight Lines

The precision of points restituted inside the mesh is definitely lower mainly due to the difficulty of collimation on the shiny surface. Figure 6 shows the DTM obtained from the restitution of a triangular section of one square of the North side of the altar. More than 35000 points were restituted. The area examined and the processed DTM points are shown in Figure 7. The processing was performed at FO.A.R.T. in Parma.

7. CONCLUSIONS

In this specific case, where physically targeting the object was not allowed, it was necessary to project points to be used as targets. The projected points create a dense mesh of points which can be readily checked, analytically or graphically, for blunt errors even if relatively small. In effect the spatial coordinates of the projected points must be sequential and must follow at regular intervals, with a regularity that is inversely proportional to the object's depth. Furthermore it is possible to read the raster-photogram automatically (Baj 1984), on a digital two tone image, greatly reducing elaboration times, even though some precision is lost.
In our opinion the results obtained demonstrate the validity and strengths of the single and two-photogram raster-photogrammetric method.

REFERENCES

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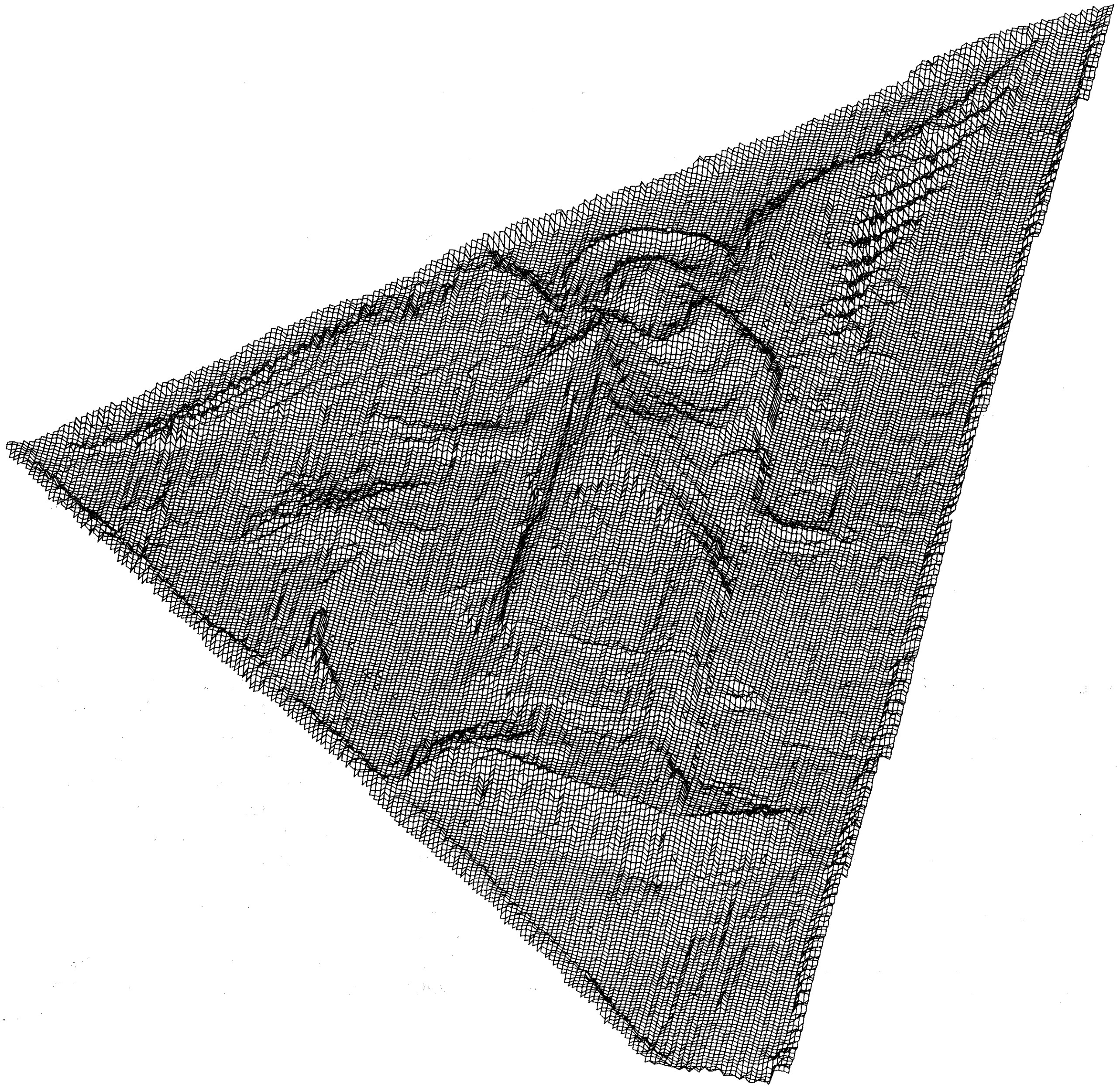

Figure 6 DTM of a Tiangular section

Please pay attention to the colour pages at the end of the volume

Figure 7 Portion of the North face of the altar and processed DTM