# SIMPLIFIED METHODS IN ARCHITECTURAL PHOTOGRAMMETRY

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ABSTRACT

The requirements of cultural resources for their inventory, historical analysis and restoration, do not in the majority of cases demand the high accuracy offered by photogrammetry, hence the continued usage of traditional systems. A simplified methodology must be established for photogrammetric surveys of architecture. In this paper, different methods for simplifying the photogrammetric surveys are described for the use of semi-metric cameras and analytical plotter with special attention to the ADAM MPS2.

For many years the extended use of photogrammetry as a technique in the recording of cultural resources has been principally based on the greater accuracy which it offers in comparison with traditional techniques, excluding topographic ones. There exists a constant rivalry between traditional and instrumental techniques, due to the conflicting accuracy-cost relations, and this has led to a deadlock in the development of photogrammetric applications, on being restricted to applications in which specific accuracy is demanded, subject to the possibility of meeting the high costs.

Photogrammetry in its traditional applications inevitably has elevated costs owing to the high price of the instruments and the operations which have to be performed (photographic shots, measuring of control points, etc) which up till now were compulsorily determined by the work methodology itself. In contrast to this, traditional measuring systems, using a tape measure, plumb line, spirit level, etc, can easily accommodate their costs according to the demands of accuracy needed, and only when maximum accuracy is demanded are there any real problems. The flexibility of traditional systems in their adaptation to the requirements of precision constitutes the most direct cause for photogrammetry not having extended as a method of surveying, due to the fact that the systems used up until now, even if highly accurate, are always costly and do not allow for flexibility between the elements of precision-cost. It should be taken into consideration that the requirements of cultural resources for their inventory, historical analysis and restoration, do not in the majority of cases demand the high accuracy offered by photogrammetry, hence the continued usage of traditional systems which offer greater flexibility and adaptation to the cost-accuracy elements.

The appearance of new photogrammetric instruments, and above all the establishment of analytical systems of surveying, allow us to consider fresh possibilities and adapt the systems of photogrammetric surveying to actual demands. Therefore it is necessary to establish photogrammetric work methods which offer the availability of low-cost surveys combined with the required accuracy, while on the other hand dispensing with highly-skilled personnel. Only in this way could photogrammetry become the main technique and offer maximum advantages for architectural and archaeological recording.

In our opinion, a simplified methodology must be established for photogrammetric surveys of architecture. A simplified method must be one which allows for the cost reduction of surveying, adjusting the precision to existing requirements. The setting of these requirements is essential in this respect, as it must be taken into account that the accuracy-cost relation may be compared with a logarithm-type function[1]. The establishment of accuracy requirements within the actual necessities of surveying therefore constitutes the basis for any work on planimetric recording.

We can analyze the different elements involved in a photogrammetric survey, and we shall take a look at the ways of simplifying the various operations.

Traditional photogrammetric survey.

| OPERATION | INSTRUMENTS | PERSONNEL | TIME |
|---|---|---|---|
| Photographic shots | metric cameras | specialized | t |
| Topographic control | theodolite | specialized | 2*t |
| Orientation | Plotter | specialized | O |
| Plotting | Plotter | specialized | R |
| Simplified photogrammetric survey | | | |
| Photographic shots | semi-metric | non-specialized | 0.3*t |
| Control | tape,plumb and level | non-specialized | 0.1*t |
| Orientation | analytical plotter | specialized | 1.5*O |
| Plotting | analytical plotter | specialized | R |

The question raised by this chart is that data-taking jobs can be reduced by practically 7 times, at the same time using equipment whose cost is about 5 times less.

Ways of cost reduction in surveys:

Use of less costly instruments: semi-metric cameras, reduced format plotters, plotters based on tablet digitizers.
Non-topographic control: a theodolite is unnecessary and measuring time is reduced.
Non-specialized personnel: pre-determined procedures are used.

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[1] See related to this the diagram by H. Foramitti. ICOMOS-CIPA, 1983. Hans Foramitti et le développement de la photogrammétrie architecturale. p.12.

Procedures for operating with simplified control

Independent models:

Set orientation of cameras: normal case (bi-cameras)

Left-hand camera as a reference point:

Levelling of camera. Rotations=0

Formation of model by relative orientation

Deduction of base by means of verification of a measurement

Introduction of base for absolute orientation.

Setting of orientation elements on the object

Plumb line or orientation marks and measurement of distance between two points.

Formation of model by relative orientation.

Deduction of base and of the rotations by measuring on the model with the plotter

Absolute orientation by means of the data deduced

Overlapping models:

Orientation through an overall model of a lesser scale; based on this the control points of larger scale models are measured.

Setting of orientation elements on the object:

Plumbs, levelling marks and setting line.

Measurement of distance between points.

Orientation of blocks by bundle adjustment. This procedure will be subject to a more detailed analysis at a future date.)

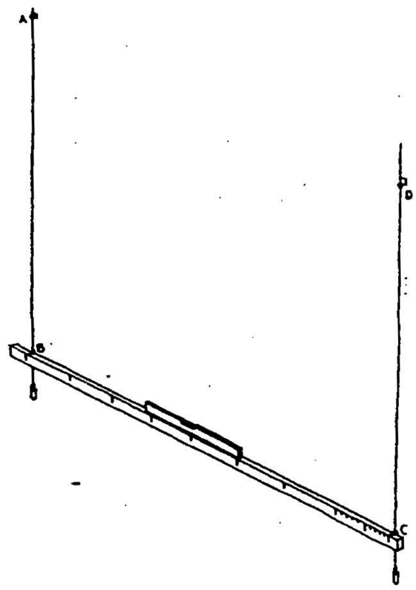


Fig 1, Method for fixing control points without geodetical survey

INSTRUCTIONS FOR PHOTOGRAPHING WITH NON-METRIC CAMERAS

The first point to be considered is the desired scale for the plotting. This should never be greater than ten times the size of the negative. The scale of the negative is determined by the focal length of the lens used, and by the distance from the camera to the object.
We shall consult the obtainable scales in this chart:

40 mm. lens

| Distance | Negative scale | Plotting scale recommended | Plotting scale maximum |
|---|---|---|---|
| 40 | 1000 | 200 | 100 |
| 20 | 500 | 100 | 50 |
| 10 | 250 | 50 | 25 |
| 4 | 100 | 20 | 10 |
| 2 | 50 | 10 | 5 |

80 mm. lens

| Distance | Negative scale | Plotting scale recommended | Plotting scale maximum |
|---|---|---|---|
| 80 | 1000 | 200 | 100 |
| 40 | 500 | 100 | 50 |
| 20 | 250 | 50 | 25 |
| 10 | 125 | 25 | 15 |
| 8 | 100 | 20 | 10 |
| 4 | 50 | 10 | 5 |

The visual field will depend on the distance and the lens used. The lens to be used must be chosen according to these variables.

The camera may either be operated mounted on a tripod, which will facilitate the approximate orientation and the levelling of the camera, or it may be manually operated. In this case the levelling proves to be more problematical, but if control points are available, then this will present no drawback.

The base (distance between the camera stations of two stereoscopic photographs), must be between a 1/3 and 1/10 relation to the distance to the object. The former value is not advisable if the object has considerable relief, unless difficulties are foreseen later in stereoscopic vision. With a relation of 1/10, appreciation of the depth may be insufficient, and therefore the accuracy of the measurement too. The average value recommended could be 1/5.

Both of a pair of photographs should have approximately the same scale. To achieve this they should be taken at an equal distance from the object and with parallel axes. A slight convergence may be admitted and may even prove beneficial to the accuracy, but if this is too great, there may be differences in scale towards the edges of each photo, which would be incompatible with a correct stereoscopic vision. The maximum admissible convergence is one that is produced with an angle of 15° between the optical axes of the two photographs

The ideal shot is one which has the planes of the negatives parallel to the plane of projection of the plotting. In principle, there is no limit for tilting the axis of the camera upwards or downwards, or even right or left. In such cases one should endeavour to take the two shots with a similar tilt. However, it must be remembered that in the more distant areas the scale is smaller and the base/distance relation will also be smaller, and therefore there will be a lesser degree of accuracy in measuring these parts. In these cases we have to consider that plotting is necessarily more laborious, since the planes of the object and the projection are not parallel

When taking photographs it is essential to take note of the approximate values of the distance to the object, the base and the tilt of the camera. It is equally ESSENTIAL TO TAKE NOTE OF THE LENS AND THE POSITION OF THE FOCUS USED since in non-metric cameras the figure corresponding to the principal distance is not printed on the negative.

PROCEDURES FOR CONTROLLING THE PHOTOGRAPHS

In order to plot a pair of photographs, it is also necessary to have the data of their orientation, or in other words, we must know the position from which the photos were taken with respect to their three coordinates X Y Z and the three rotation angles of the camera in each position $\Omega$ $\Phi$ K ( $\alpha$ $\Theta$ K in the case of terrestrial photogrammetry).

These values may be obtained either directly, measuring them simultaneously with taking the shots, or indirectly by ,measuring the control points. This latter procedure is the more frequent of the two and the one which assures greater accuracy in results.

The orientation data can be calculated in the plotter if we know the three coordinates (x y z) of at least four well visible points in each pair of photographs[:]. The coordinates of these points are usually the intersection of lines of sight.

The control points should be chosen in such a way as to incorporate the area to be plotted within the perimeter determined by those points. The control points may be marked and measured previous to obtaining the photos, or they may just be points of the object measured simultaneously or even afterwards. In both cases special care must be taken to ensure their easy identification in both photographs.

A simple way of defining two control points which have been previously marked is by placing two plumb lines or correctly-weighted surveying rods and a string,ruler or horizontal rod which passes through the base of the former (Fig 1). The string, ruler or horizontal rod should be parallel to the plane of projection.

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[:] In fact the minimum requirements consist of knowing the three coordinates of two points and the coordinate in the direction of the optical axis of a third point. Usually the orientation programmes of the plotters (such as ADAM MPS2) demand knowledge of the three coordinates of at least three points. Anyway, it must be taken into consideration that with just this data the programme is unable to check possible errors in the coordinates, as there is no redundancy. Therefore the minimum information essential is the coordinates of at least four points. For a more complete information on minimum control requirements see P.WALDHAÜSL, J.PEIPE, **Control Information in Architectural Photogrammetry** Invited paper, XIIIth International Symposium of CIPA, Cracow, October 1990.

Then we measure the distance between the vertical lines (plumbs or rods) and the height from the horizontal rod to an easily visible point on each vertical rod which can be marked with an adhesive tape or similar. With this information it is easy to calculate the coordinates of four control points. If rods or sights are used, then it is unnecessary to measure anything. In extreme cases, one vertical line may be enough, marked with two points, one at the top, and another half-way.

Another straightforward method, although somewhat less accurate, of determining the orientation data, is with the use of a camera level. In this way we are able to control two of the rotations ($\Theta$, K). The third rotation ($\alpha$) and the base can be calculated taking the distance between two points which define the plane of projection. This system is only valid in the case of independent stereoscopic pairs, and of photographs with the plane of the negative in a vertical position.

For the plotting of several consecutive pairs we must establish a reference system which is common to all of the pairs, such as a string which is horizontal and parallel to the plane of projection. On this cord we must mark visible points, at least two of which should appear in each pair of photos and if possible at the edges of the area common to both photograms. The distances between the marked points are then measured. (Fig 2)

Although these systems make the orientation of models in the plotter more laborious, they simplify data-taking considerably. At any rate, we must advise that because of the lesser accuracy obtained, the system should be avoided for measuring objects of great depth. Areas to be plotted should be between planes reasonably near to the plane on which horizontal distances have been taken. Complementary measurements, whether vertical or of depth, may be of assistance in controlling the accuracy of the plotting.

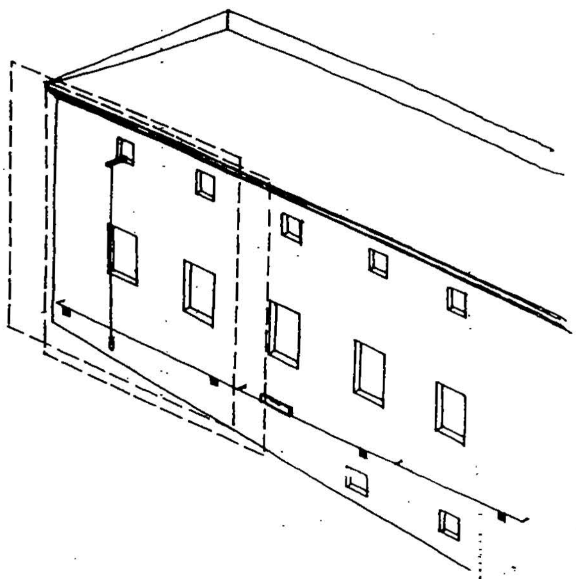

Fig 2, Method for relating consecutive models

WAY TO OPERATE IN SOME SIMPLIFIED CASES OF PHOTOGRAMMETRY

1st case:

Independent model: only one pair of stereoscopic photographs.

Characteristics of the object:
An object for which it is unnecessary to establish a priori a preset system of coordinates or projection plans.

Data-taking: We shall take two photographs of axes which are parallel or almost parallel and perpendicular to the base (as far as is possible).
We shall take accurate measurements of at least one distance between two well-defined points (D).
We shall take note of the approximate distance to the object and the base (may be done by long paces of approx. 1 m.)

Orientation: As there is no obligation to orientate with respect to a predefined reference system, we can use as such the one defined by the left-hand camera, which is the one referred to by a relative orientation in analytical plotters.
As an introduction we shall mention the approximate distance to the object and the base (b). Orientation is by observation of at least six points to be found along the outer edges of the model, whether on the perimeter or at a proximity or at a distance.

Once this former orientation has been obtained, the next step is to measure the coordinates of the two outer points from the control distance taken in the object. The distance obtained will be

$$d = \sqrt{(x_1-x_2)^2+(y_1-y_2)^2+(z_1-z_2)^2} \qquad [1]$$

the scale of the model will be

$$e = \frac{d}{D} \qquad [2]$$

In order for the model scale to be 1/1 and to allow us to measure true coordinates, we should modify the base initially introduced as approximate data. The true base will be equal to

$$B = \frac{1}{e}\, b = \frac{D}{d}\, b \qquad [3]$$

If on taking the photograph the left-hand camera was placed in both the adequate position and direction, then this procedure may prove to be fast and convenient, especially if the plotting is going to be edited in a CAD programme. If the selection is required of one or more specific projections with respect to planes specified in the object itself, the projected forms may be obtained quite simply through the CAD programme.

*Operating with ADAM MPS2*

*Introduce the approximate values of base and distance on to the object, on card nº 1 (option 2 of the main menu). After introducing the photographs, internal orientation is effected (option 3) and relative orientation (option 4) with at least six points. Once this has been carried out, the orientation is accepted and the next step is then digitalization (option 5). Using option 7 (digitalization), we proceed to measure the coordinates of the outer points of the control measurement taken.*
*Formulas [1] and [3] are used to calculate base B, the value of which is introduced on card 1 with option 2 of the main menu. Next the relative orientation (option 4, option3 and option 4) is re-calculated.*
*The coordinates are re-measured in digitalization, and the distance between the points is checked. If this is correct, plotting may be begun.*

*With the 2.30 version it is possible to introduce onto a type-5 card in the main menu the figure of the distance between two points. On effecting the exterior orientation these points are digitalized with the same name as they were given on card 5. After calculating the relative orientation, the programme automatically calculates the new coordinates of the right-hand camera.*

**2nd case.**

Independent model: only one pair of stereoscopic photographs.
Characteristics of the object:
Object for which the plan of projection is a vertical plane, the alignment of which is determined by two points of the object.

Data-taking: We shall take two photographs of axes which are parallel or almost parallel and perpendicular to the base (as far as is possible). The base will be approximately parallel to the plane of projection. The camera will be set up using a level which controls the two rotations nadir and kappa. This level may be the Cullman type fixed to the hot shoe flash attachment. The accuracy of this level may be considered as ±1°.[1] We shall take a precision measurement of at least one distance between two well-defined points (D). If possible, it will be the points which define the alignment of the projection plane.

The distance to the object and the base will be taken down (they may be measured with long paces of approx. 1 m).

Orientation: In this case it will be necessary to calculate the

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[1] The errors occurring as a result of levelling may be overlooked if only one plotting parallel to the negative plane and with little relief is going to be performed. For a 1° nadir error and for a point 20 m. higher than the camera. the planimetric error will be

$$e = 20 \sin^2 (1°) = .006 \text{ m}$$

The error of kappa will produce a general tilt of the plotting which can be controlled by levelling two points with a topographic or water level.

rotation α of the camera with respect to the plane of reference, using the levelling of the camera itself as a reference for the other rotations. By means of the procedure previously described, we can calculate the actual base, and repeat the relative orientation with this value which has been obtained. We can take simultaneous measurements of coordinates x and y of the two points which define the direction of the projection plane. Rotation α will be (Fig 3)

$$\alpha = \text{arc tg} \frac{y_2 - y_1}{x_2 - x_1} \qquad [4]$$

This value will be introduced as orientation information of the left-hand camera, and a new relative orientation can be compute. It would be appropriate to re-measure the points and check the angle and the base, and adjust accordingly until adequate results are obtained.

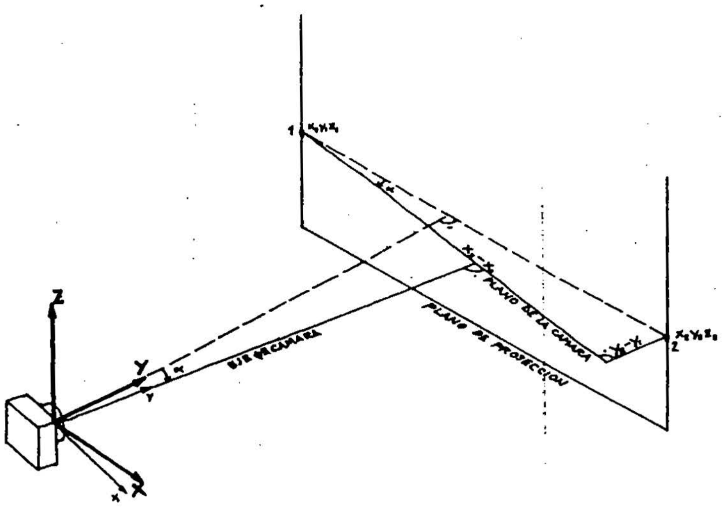

Fig 3, Determination of the α rotation

*Operating with ADAM MPS2:*

*The appropriate values of base and distance are fed onto card nº 1 (option 2 of the main menu). After feeding in the photographs, internal orientation is done (option 3), and relative orientation (option 4) with at least six points. Once this has been completed, the orientation obtained is accepted and option 5 (digitalization) is chosen. With option 7 (digitalization) measurements are taken of the coordinates of the furthest points of the control measurement taken, and those of the two points determining the α direction of the projection plane.*

*Using formulas [1] and [3] the calculation is made of B base, the value of which is fed onto card nº 1 with option 2 of the main menu. Angle α is calculated with formula [4]. To feed this value in, two nº 6 cards must be filled in with option 2 of the main menu. On these cards there must be the coordinates of the left-hand camera, which may be the original values of coordinates (0,0,0 or*

*even 100,100,100), and the orientation angles of this camera which are α,90,0 introduced in gggmmss form*[4]*. On the other card nº 6 there will be the approximate values of the right-hand camera, 100+b, 100, 100 and α,90,0.*[5]*-*
*The relative orientation is then re-calculated (option 4, option 3, option 4). The coordinates are re-measured in digitalization and the distance between the points and angle α is checked. If correct, then restitution may begun. To the contrary, a new adjustment is made.*

3rd case:

Independent model: only one pair of stereoscopic photographs.

Characteristics of the object:
Object for which the plane of projection is a vertical plane, the alignment of which is determined by two points of the object and of which we know two level points, or preferably two points on one vertical.

Data-taking: We shall obtain two photographs of axes which are parallel or nearly so, and perpendicular to the base (as far as is possible). The base will be almost parallel to the plane of projection.
Precision measurements will be taken of at least one distance between two well-defined points (D). If possible, these will be the two points which define the alignment of the plane of projection.
The approximate distance to the object and the base will be noted (may be measured with long paces of approx. 1 m.)
The vertical orientation of a plane or the existence of a vertical line will be checked[6]. In the first case it will also be necessary to have two level points. All of these elements must be on a plane which is parallel to the projection plane.

Orientation: In this case we have to calculate the three rotations α, Θ, K of the left-hand camera with regard to the projection plane. This can be done by calculating these same angles from measurements of the reference elements.
By means of the above-mentioned procedure, the actual base may be calculated and we shall re-calculate the relative orientation with this value which has been obtained. At the same time we shall

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[4] When feeding in this information, the initial value of the FI angle originating from the first relative orientation must be taken into consideration, since the α value which was calculated is the correction that must be applied to this angle. The direction of the angle must also be taken into account, remembering that the angle we use should be that of the plane of the negative with respect to that of the projection.

[5] In a relative orientation, and whenever both cards 6 of left and right-hand cameras are completed, the programme accepts the left-hand camera values to be definite, and the right-hand camera ones as approximate, in order to begin calculations of the relative orientation. As values deriving from orientation, for the left-hand camera there will be those introduced on card 6; and for the right-hand camera those which derive from relative orientation, taking as a base the one introduced on card 1.

[6] A plumb line may be used for this.

measure the coordinates x y of the two points which define the direction of the projection plane, the coordinates y z of two points on a vertical of the plane which defines the vertical, and the coordinates x z of the points which are level or to be found on a vertical line.
Rotation α will be (Fig 5)

$$\alpha = \operatorname{arc\,tg} \frac{y_2 - y_1}{x_2 - x_1} \tag{4}$$

The value of K in the case of points on a vertical line will be (Fig 4)

$$K = \operatorname{arc\,tg} \frac{x_4 - x_3}{z_4 - z_3} \tag{5}$$

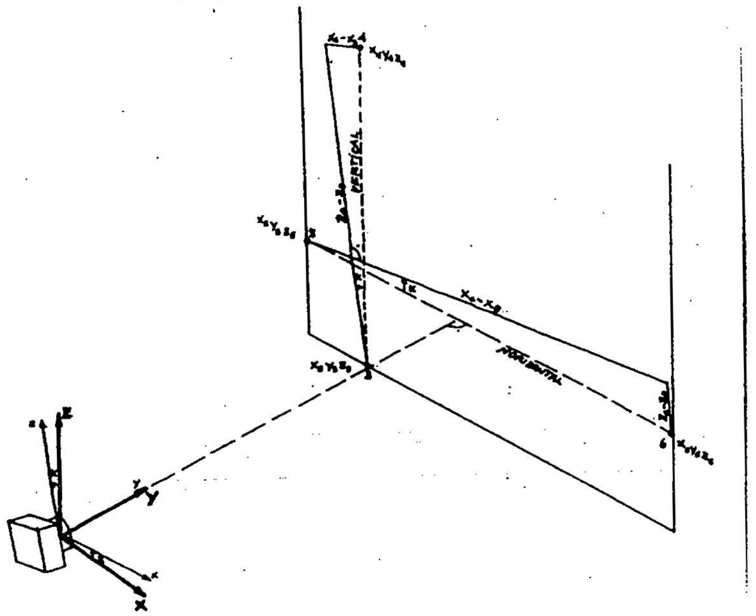


Fig 4, Determination of the K rotation

and for the case of levelled points

$$K = \operatorname{arc\,tg} \frac{z_6 - z_5}{x_6 - x_5} \tag{6}$$

The value of Θ will be (Fig 5)

$$\Theta = \operatorname{arc\,tg} \frac{y_8 - y_7}{z_8 - z_7} \tag{7}$$

These values will be introduced as orientation data of the left camera, and a new relative orientation computed. It is as well to measure the points once more, as well as to check the angles and the base, and re-adjust until desirable results are achieved.

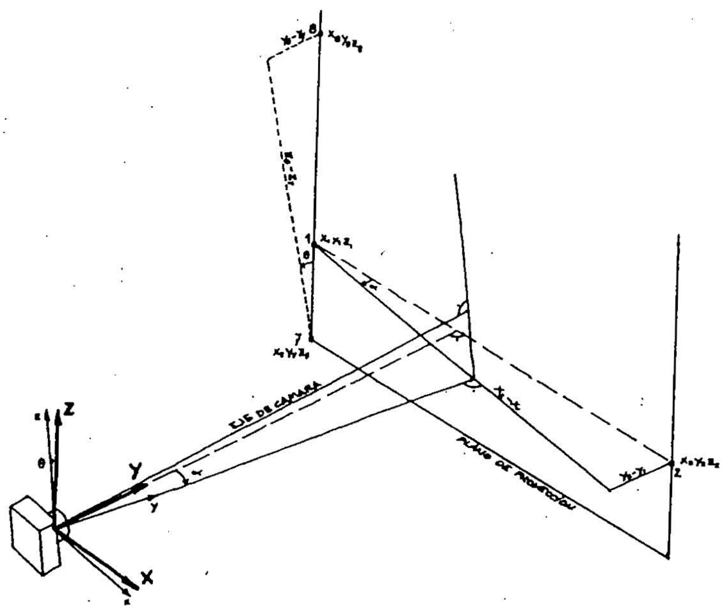

Fig 5, Determination of the α and Θ rotation

*Operating with ADAM MPS2:*

*Introduction of approximate values of the base and distance to the object onto card nº 1 (option 2 of the main menu).*
*After introducing the photographs the internal orientation is done (option 3) and the relative too (option 4) with at least six points. Once this has been done, the orientation is accepted and the next step is digitalization (option 5). With option 7 (digitalization) we measure the coordinates of the outer points of the control measurement taken, and of the points which determine directions α, Θ, K of the plane of projection.*

*Using formulas [1] and [3] B base is calculated and the value introduced onto card 1 with option 2 of the main menu. Formulas [4],[5],[6],[7] are the means for calculating angles α, Θ, K. In order to introduce these values we should fill in two type-6 cards with option 2 of the main menu. On these cards we must introduce the coordinates of the left-hand camera, which may be values of origin of coordinates (0,0,0 or even better 100,100,100), and the orientation angles of this camera, which will be α, Θ, K, introduced in the form gggmmss[7]. On the other card 6 we must introduce the approximate values of the right-hand camera, which will be 100+b,100,100 and α, Θ, K.*
*Immediately afterwards, the relative orientation is calculated (option 4, option 3 and option 4). The coordinates are re-measured in digitalization and the distance between the points and the angles are checked. If they are correct, we can go ahead with plotting. If not, a new adjustment is made.*

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[7] Refer back to note 2.

4th case:

Consecutive models: several pairs of stereoscopic photographs with parts in common (for example, partial consecutive model of the same façade).
Characteristics of the object:
Object for which the plane of projection will be a vertical plane, the alignment of which is determined by a level line which figures in all models (a string with specific points set on it).
Data-taking: We shall take the photographs with a properly levelled camera, and with the axes parallel or almost parallel and perpendicular to the base(as far as is possible). The base will be nearly parallel to the plane of projection which should be the one defined by the line of the object (horizontal string)(Fig 2).
We shall take accurate measurements of the distances between the points defined on the string. At least two of these points should appear in each pair of photos, and where possible on the edges of the part which is common to both photos. The approximate distance to the object and the base for each pair of photographs is noted (may be measured by long paces of approx. 1 m.)

Orientation: We shall orientate the first model as in case 2. Once the model is orientated, we shall measure the coordinates of one of the points on the string which appears in the following model. For orientation of the following model we shall proceed just as in case 2, and once orientated, then measurements will be taken of the coordinates of one of the points of the string. With this coordinates, we can easily calculate the coordinates of all the points of the string which have the same value for the $z_0$ and $y_0$. The coordinate $x_0$ of each point will be these of the previous plus the distance between. The differences between coordinates $(x_0-x_0)$, $(y_0-y_0)$, should be subtracted from the coordinates of the left-hand camera, and the relative orientation re-calculated with the new camera coordinates. By doing this, we shall have performed a general transcription of the second model, adjusting it to the coordinates of the first. We shall continue with the remaining models using the same procedure.

*Operating with ADAM MPS2:*

*Introduction of the new coordinates, once calculated, for the left-hand camera of the second model, is done through card 6 of the left camera. The three coordinates X, Y and Z should be introduced on it. Approximate values, which may initially be X+b, Y, Z, should be introduced into the right-hand camera. Operations are performed in the same way in successive models.*

## A PRACTICAL CASE STUDY. FAÇADE OF "THE HOSPITAL OF THE FIVE SCOURGES", IN SEVILLE. ANALYSIS OF THE RESULTS

In February 1991, during a course on photogrammetry for postgraduate students of the Higher Technical College of Architecture in Seville, we performed an experiment on the façade of a historical building, "The Hospital of the Five Scourges", at that time in the process of being restored and refurbished as the official seat of the Andalusian Parliament.

In order to carry out a more complete study, a somewhat modified lay-out drawing by Hernán Ruíz (Fig 6), the original architect, was made available to us, together with the survey done by the architect Dr Alfonso Jiménez Martín, who used manual means to draw up the plan for restoration (Fig 7).

For the analysis we took two photographs with axes which were almost parallel and perpendicular to the base, using a ROLLEI 6006 METRIC camera with a lens of 40 mm. The camera was mounted on a tripod and a Cullman level fixed to the hot-shoe attachment was used to level it properly. Setting of the camera stations and $\alpha$ orientation of each camera was done visually. The distance to the façade and the base was measured approximately, and found to be 20 m and 40 m respectively. The time taken to do this was about ten minutes. Afterwards the measurement was taken of ten control points by intersection of the lines of sight using a theodolite, from the two theodolite stations, with a required time of one hour for the operation.

We made an orientation with an ADAM MPS2 plotter, using 8 control points plus one pass point on the higher part of the façade. The RMS obtained for each coordinate were .003, .005, .001. From this orientation we were able to draw a simple plotting on general lines.(fig 8, thin line)

Then we took a second orientation of the model using as our only data the horizontal distance between two control points on the lower part of the façade and on one same plane. Taking as reference the system described in case 2, we took an orientation calculating the base and the $\alpha$ rotation from the measurements taken in the plotter. Rotations $\Theta$ and K were adjusted according to the camera level.

An outline and the eight control points were plotted using this new orientation. With the help of an AutoCad, the second plotted drawing was transcribed, adjusting it with the first drawing on the lower left control point. (Fig 8, wide line) In this way the two drawings were superimposed and the errors could be checked.

If we consider the exactitude of the plotting from this orientation with the control points, we may say that the orientation without control points is correct with regard to scale, and we can observe as an error a general rotation, due to the inaccuracy of the levelling of rotation K. If we take advantage of this rotation, the maximum errors which occur are 2 to 3 cms. In the higher part, there is a slight over-elevation caused by the error in the $\Theta$ rotation and a slight excess of base. The sum of all these errors can be considered as $<5$ cm.

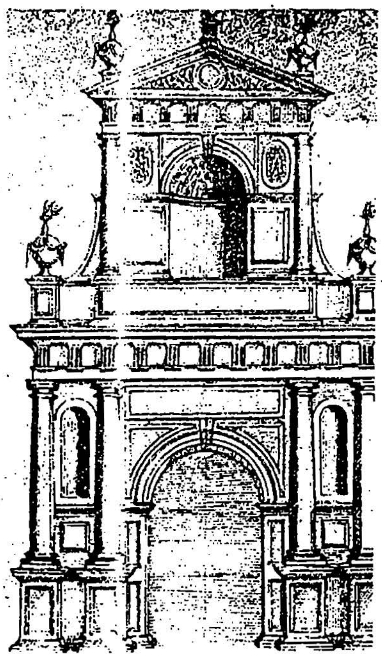

Fig 6, Original disign of the façade

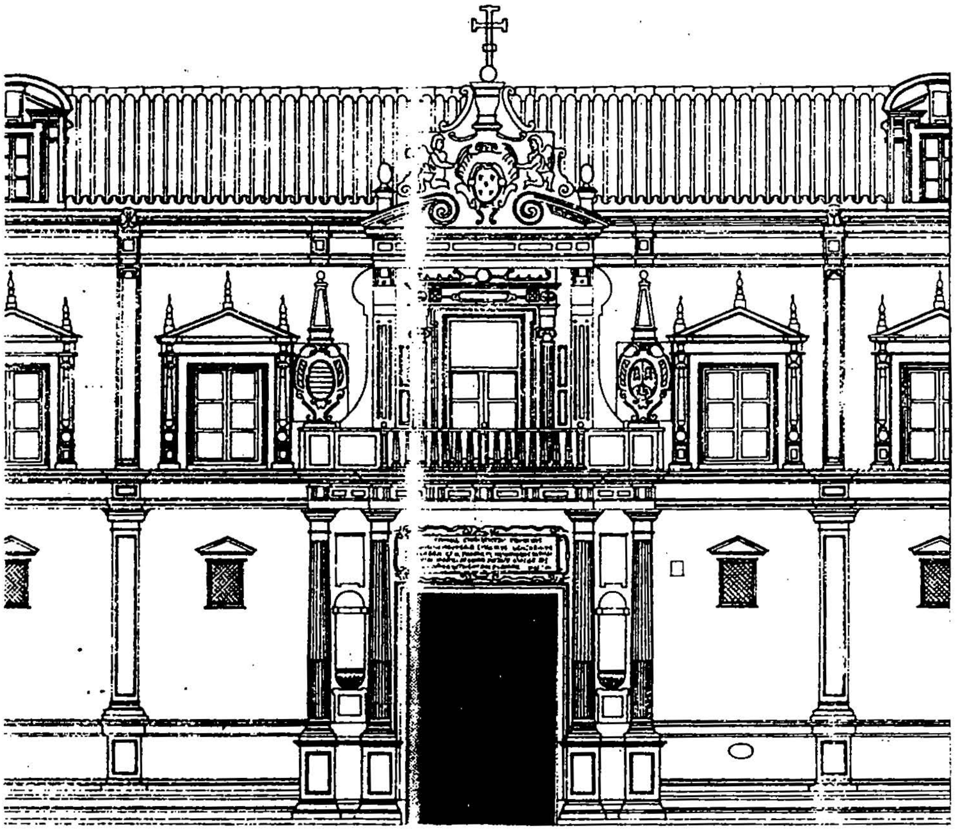

Fig 7, Survey by manual method

When we compare the plotting with the survey carried out manually, we can see that in the parts where it has been possible to measure with a tape measure, the drawings coincide. However, quite considerable errors can be observed in inaccessible areas and in the placing of elements which are on different planes and which have not been related on one level. Generally, errors up to 15 cm. have been observed in the projections of cornices and in the upper part of the façade, which no doubt could not be reached for measurement. Although we are lacking in information, from experience we could estimate the time necessary for this manual data-taking to be at least two hours.

To summarize, there are some conclusions to be drawn. In the first place, the errors resulting from manual measurements, no doubt performed with insufficient accuracy, are too great for a scale of 1/100. In spite of this, the time for data-taking was the longest. Data-taking with a semi-metric camera and complete control from a theodolite reduced the time for data-taking (58% of the previous time), but a greater degree of precision was obtained. Lastly, data-taking with limited control achieved considerable time-saving (12% of the time of manual taking and 20% of the time with complete control) without increasing the errors excessively. At any rate, the accuracy is more than sufficient for a 1/100 scale drawing.

The longer time necessary for orientating in the last case is rarely irrelevant with regard to the overall plotting time. Anyway, we can estimate the plotting time between 50 and 70% of the time required for a finished drawing of a manual measurement.

With instruments costing at a rate of 20% of the price of instruments normally used in photogrammetry (metric cameras, theodolite and precision plotters), and with data-taking times 90% less than what is required when working with metric cameras with theodolite survey, these simplified systems of photogrammetry allow the cost of an elevation to adapt to the necessities of accuracy required in the majority of dealings with cultural resources. Photogrammetry is no longer a sophisticated and costly technique, it is within the scope of any institution or professional person responsible for historical resources. Of course, the system cannot be applied in all cases. It will depend on the size of the buildings and the degree of accuracy required, but a considerable number of buildings and objects can be included in the field of application of the methodology explained in this paper.

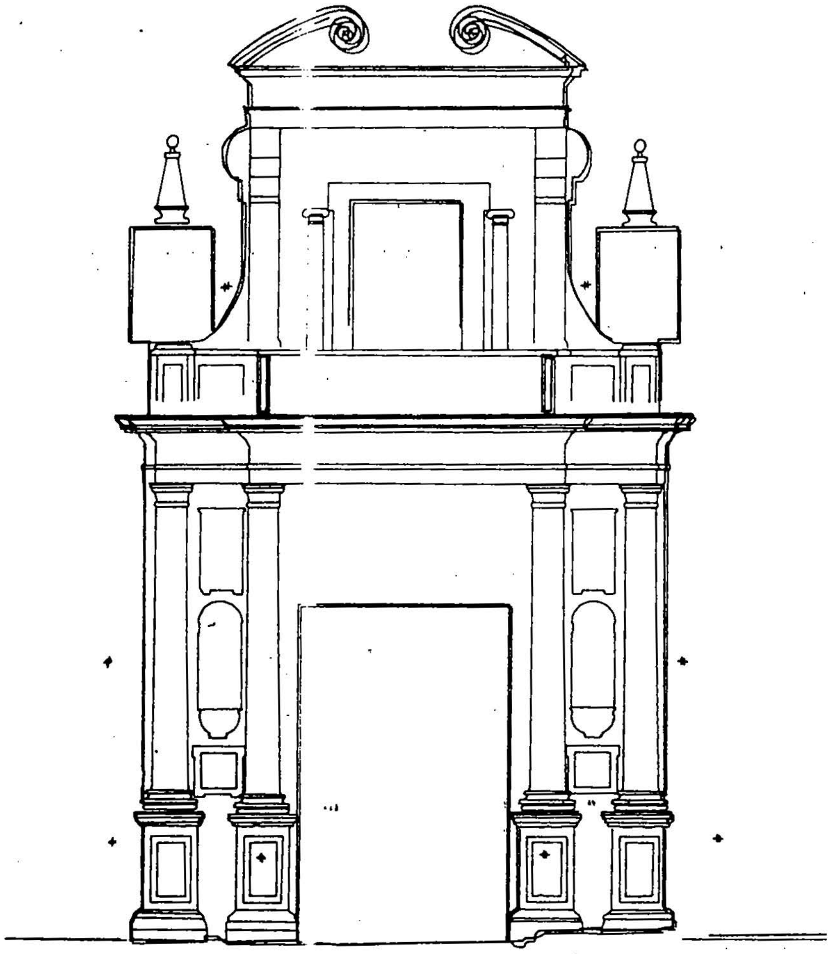

Fig 8, Fotogrammetric survey