

XIV Congress of the International Society for Photogrammetry  
Hamburg 1980

COMMISSION V  
WORKING GROUP V-2

INVITED PAPER

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SOME MEANS TO COST-EFFECTIVE NON-TOPOGRAPHIC PHOTOGRAMMETRY

ABSTRACT

Non-topographic applications of photogrammetry display a great variety of problems and solutions due to the size of the object, accessibility, accuracy, control points and so on. To bring about cost-effective routines is more difficult than for instance in aerial photogrammetry. Nevertheless, many non-topographic photogrammetric projects can be performed in a rather standardized and routinary way. This paper describes routines for photography with a metric stereocamera, 0.4 or 1.2 m base (like the Zeiss SMK 40 and SMK 120) and graphical evaluation in a precision analogic stereoinstrument (like the Wild A7). The routines may be performed with any precision stereocamera or analogic instrument, provided that the described devices are available. One of the devices is a bar with two marks, distant from each other by the length of the photography base. Another device has the purpose to facilitate an accurate adjustment of the photographs in the photograph holder. The bar, the main purpose of which is to reduce the number of control points and to facilitate the relative orientation, could be profitably utilized for these purposes even in stereocomparator work.

## GENERAL ASPECTS

Non-topographic photogrammetry has so many advantages when compared with other measuring methods that it could be expected to have a more frequent use.

Industries which do not include photogrammetry in their measuring routines, probably perform measurements with non-photogrammetric methods, even though photogrammetry would be more profitable. There may be many reasons for this, for instance:

- photogrammetric methods are not sufficiently well known
- the advantages of photogrammetry do not make up for the administrative drawbacks caused by the distance to photogrammetric experts
- there is a desire to utilize ones own resources.

When actually used, non-topographic photogrammetry is often applied to isolated projects with problems which give the application the character of research work rather than routine work. Thus it is difficult to establish standardized procedures to make the technique advantageous and attractive in production.

Nevertheless, non-topographic photogrammetry can be exercised in a rather standardized way. Analytic methods will probably offer excellent possibilities for this in the future, when enough software has been developed to meet practical demands, especially demands on the graphical presentation, like the drawing of contour lines, sections, etc. In analogue non-topographic photogrammetry there are good possibilities to reach efficiency and reduce costs by introducing standardized procedures into the work. This paper deals mainly with practical routines in production using analogue non-topographic photogrammetry.

Along with common rules which have to be observed and exercised in order to reach efficiency and good economy, there are some special facts and principles to consider.

1) To obtain a routine in a procedure, a certain amount of conformity in the technical performance is generally required. In aerial photogrammetry, for instance, most procedures like photography, the processing of the film, the relative and absolute orientation, and so on, are performed in a very standardized way as a result of the conformity from one project to another. In non-topographic photogrammetry a better routine could be obtained by using the same equipment and method through a whole project, and also for different projects, even though other equipment and methods would perhaps be more rational in certain parts of the work. To reach efficiency in the orientation procedures, it is possible to establish a standard like the one in aerial photogrammetry. The routines should allow one model after another to be oriented with no or very small changes of the orientation elements.

2) Cameras and analogue instruments of high precision are favourable for establishing efficient routines. The use of a stable stereocamera, rather than two separate cameras (or the same camera in two stations), is advantageous. The photography can be performed more rapidly. The stable relative orientation between the two cameras can be utilized to reduce the number of control points, and to speed up the relative and absolute orientation. For the same purpose one can utilize a stable relative orientation between the stereocamera and outer orientation devices, for example an accurate spirit level. Using a stereocamera with a well determined base offers the possibility to photograph a bar with two identical targets, distant from each other by the length of the photography base. This will be described in more detail below.

To utilize the inherent accuracy of the camera, the reconstruction of the inner orientation in the analogue instrument should be carefully performed. This can be facilitated by means of a special device for adjusting the photographs in the x- and y-directions after having placed them in the instrument. This will also be described in more detail below.

3) The use of a stereocamera with a limited base (1-2 meters at the longest) reduces the photography distance and increases the number of models needed to cover the object. However, the conformity of photography, control point furnishing, evaluation, etc, obtained when using a stereocamera, often compensates for the increased number of models in practical production.

4) Accuracy should be thoroughly considered and compared, from a realistic and economic point of view, with the capability of alternative methods. The rapid measurements of points in the photogrammetric model is an advantage which can be utilized in different ways to reduce the effect of arbitrary errors. Important points like control points, can be measured many times in the model to increase their reliability. This is of special importance to avoid systematic errors in the relative and absolute orientation. Provided that a model is practically free of systematic errors, fairly large arbitrary errors can be accepted, if their negative effect is reduced for example by

- adjusting the floating mark to a detail many times
- measuring many points in a contour line or a section
- drawing the critical part of the contour line two or more times.

It should be noticed that often the costs of such extra steps in the evaluation is ignorable in comparison with all the initial work (photography, furnishing of control points, laboratory work, orientation, administration ...). Point by point adjustment of the floating mark is favourable for accuracy. The performing of the steps mentioned above to avoid systematic errors and to reduce the negative effect of both systematic and arbitrary errors, is facilitated by using analytic methods. In an analogic instrument this means that model co-ordinates are registered and processed in a computer. Sections, contour lines, etc can be drawn in an automatic plotter. Before that various corrections can be

applied to the co-ordinates.

5) Establishing and measuring of control points is often labourous. The procedures recommended above have the advantages of bringing about a reasonable result without too much control point work. By using the bar mentioned under 2) a stereo model with very small systematic deformations can be obtained without measuring any control points at all. An extreme reduction of the control point work can be reached if such models are connected with photogrammetrically determined points. Often the connection points have to be marked out, but it is not necessary to measure them in the field.

When using a control or connection point it is important to take into consideration where it is situated in the model. If the point is close to the camera, the point error is small and the point can be given a high weight. Points distant from the camera can be expected to have a much larger error and should thus be given a much lower weight. However, if a distant point is situated close to the camera axis it still can have a high weight in the co-ordinates X and Y (if Z is the co-ordinate along the camera axis). This important fact can be utilized not only concerning control and connection points, but also concerning object details which have to be determined with a higher accuracy in a certain direction (for instance, perpendicular to a surface in volume determination). The possibility of increasing the weight of points by measuring them many times, as mentioned under 4), is of the greatest importance for the reduction of systematic errors in the relative and absolute orientation.

The method described is an extreme utilization of the inherent advantages of photogrammetry. For many practical purposes, a sufficient accuracy can be achieved at very low costs. All further measurement of control points will increase the possibility of detecting systematic errors in the orientation and of correcting them. Of course, time consumption and costs will increase as well. In production there is always a need to balance accuracy and costs.



Figure 1

Device for marking a point. The rod can be moved all over the bottom plate without changing its vertical position

6) The marking of control points and connection points should not be time-consuming in production work. A variety of devices should be available to meet this requirement. Figure 1 shows a piece of equipment which allows a point to be marked quickly in a desired position, even on the floor of a building, in an underground chamber, etc. When taken down, about 50 such points can be held in an ordinary size suitcase. It is also very important for the efficiency of work that points are given an identification which can be easily recognized in all the various procedures of a project, not least, in the administrative handling of the photographs.

7) The quality of the photographs is important for the point error and thus affects the possibilities to work according to the principles recommended above. Concerning the geometric quality of the photographs, a control of the fiducial marks should be performed as soon as possible, preferably before control points etc have been removed. The checking of the fiducial marks can be done quickly by noticing that they are sharp in the photograph and also by comparing the photographs, put together in pairs, emulsion to emulsion.

Unfortunately, many analogue instruments do not allow photographs to be evaluated with the original camera constant of the photograph set in the instrument. The enlargement of the photograph necessary for the evaluation will, of course, affect accuracy and economy in a negative way. The possibility of using the negatives by performing an affine evaluation is increased when using a stereocamera with an accurate normal case. The photograph adjusting device mentioned under 2) is of good help for affine evaluation, especially when there are slight deviations from the normal case.

Good exposure of the photographs is important for the interpretation of details and for increasing the accuracy in adjusting the floating mark to points and details. The use of a stereocamera facilitates the exposure, as the two photographs always can be taken simultaneously under the same light conditions.

#### PRACTICAL PROCEDURES

In the following, the evaluation in a precision analogue instrument (Wild A7) of photographs taken with a precision stereocamera (Zeiss StK), will be described. Other instruments of the same quality could, of course, be used as well. It is possible, and profitable, to utilize analytic methods in some procedures, but this will not be dealt with.

Figure 2 shows photography with the Zeiss SMK 120 camera and the bar. The bar can be placed anywhere in the model, preferably close to the camera (enough distant to become sharp in the photographs) and near the camera axis. By means of a directing device and a spirit level, the bar is adjusted to make the two marks define a horizontal line parallel to the photography base. The stereocamera is assumed to be carefully levelled. The bar marks should consist of concentric circles. Two (or more) bars can be used, or the same bar can be placed in two (or more)



Figure 2 The Zeiss SMK 120 and the bar

places in the model. The latter case can be realized by exposing the object two or more times. This, of course, requires that the object is immobile. The method has the advantage that the bar will not conceal part of the object.

Figure 3 shows the device for moving the photographs in the x- and y-directions in the photograph holders of the Wild A7. With the base, all elements and the X- and Y-co-ordinates of the A7 set to zero, the inner orientation of the photographs can be reconstructed with high accuracy, which is an important demand. For a normal case photography, which is assumed, one should be able to adjust the left measuring mark to the left bar target at the same time as the right measuring mark is adjusted to the right bar target. First, the model is made practically free of y-parallaxes through a  $\kappa$ -rotation of the photographs. Notice that the bar, when placed close to the camera, helps to give the photographs a good absolute  $\kappa$ -orientation. The next step is to

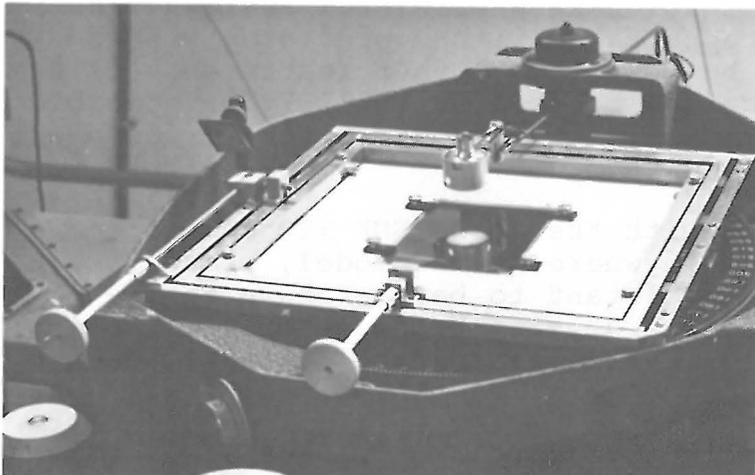


Figure 3

The photograph adjusting device placed in the Wild A7

adjust the measuring marks precisely to the bar targets by screwing  $\phi$  of the one (or both) photograph or by making an x-translation with one (or both) of the photograph adjusting devices. Whether  $\phi$  or x (or both) should be used for this "convergence adjustment" has to be taken into consideration. Often the adjustment is so small that it is indifferent what element is used. As  $\kappa$  is involved in the procedure, one realizes why it is advantageous to have the bar placed not only close to but also at about the same level as the camera. The procedure normally gives a model which is practically free from systematic deformations. This of course, facilitates the absolute orientation, which, actually, is already partly performed with the use of the bar and the accurate spirit level on the stereocamera. Normally nothing more remains than adjusting a sheet of paper on the drawing table to the model, or, if vertical sections are supposed to be drawn, an adjustment of "general  $\phi$ ". Stereoscopic viewing of the bar targets should be utilized in the "convergence adjustment" to increase accuracy.

When the inner, the relative and the absolute orientation of the first pair of photographs in a project is properly accomplished and the model is evaluated, the data of the orientation elements ( $\phi'$ ,  $\phi''$ ,  $w'$ ,  $w''$ ,  $by'$ ,  $by''$ ,  $bz'$ ,  $bz''$ , the projector constants  $c'$  and  $c''$  and the evaluation base  $b$ ) should be recorded for future use. With the z-movement of the base carriage set to a certain value and the evaluation base set to zero, the base carriage is given a position that makes the space rods vertical. When the base carriage has this position, the X- and Y-drums are recorded in both photographs. When the next pair of photographs has been placed in the photograph holders the co-ordinates of the fiducial marks are utilized to adjust the photographs to their correct positions in the holders by means of the photograph adjusting devices. If conditions are such as presupposed, i.e. the equipment has good precision, the camera and the bar have been carefully handled within the photography, the photographs are of good quality, and the absolute orientation case is the same as for the first model, the absolute orientation of the second model will be almost finished, when the adjustment of the two photographs is accomplished. A slight  $\kappa$ -adjustment of the photographs and a slight "convergence adjustment" with the help of the bar targets usually will be necessary to complete the absolute orientation. The same procedure is then performed for all models in the same project and also in other projects with the same equipment and routines involved. To speed up the orientation procedure just one fiducial mark in each photograph can be used, as the relative position of the two photographs is determined through the  $\kappa$ -rotation performed before the translation of the photographs.

It is important that the first model of a project (the "start model") is furnished with enough control points to indicate that the absolute orientation is acceptable. The absence of vertical parallaxes is an important criterium of the quality of the model. When the number of control points is extremely reduced, as described above, the residual vertical parallaxes are the only indicator of the model quality until the next model has been evaluated. Therefore the  $\kappa$ - and the "convergence"-adjustments should

be carefully performed.

Notice that there may be a deviation from the normal case. The important requirement is the mechanical stability of the equipment which guarantees that the deviation is the same for all models.

The described method, involving an accurate stereocamera and an accurate analogue instrument, can be used with good economy for various projects in practical production. With the use of the bases .4 and 1.2 meters, as is the case with the Zeiss SMK cameras, the ideal size of objects is from 1-2 meters to 30-40 meters. The corresponding point errors in the camera axis direction are about  $\pm 1$  mm to  $\pm 200-300$  mm.



Figure 4

Camera holder for taking stereo photographs according to an accurate and stable normal case with a single camera

For smaller objects, the stereocamera and the control points can form a common system of good mechanical stability, offering the possibility of continual photography with no other steps involved than the exposure of a new object. Figure 4 shows a camera holder admitting stereo photographs to be taken with a stable relative orientation using a single camera (a Hasselblad El Data camera). The camera is placed unsymmetrically on a frame with four legs, fitting accurately into four holes in a stable bottom plate. To take the second photograph in the stereo-pair the frame with the camera and the four legs is swung a half circle, and the legs are fit into the holes again. The bottom plate holds a 5 cm grid of control points in which pillars, also holding control points, can be placed. Thus a threedimensional control system suited to the size and position of the object, can be created. As the control point distances are exactly the same as the photography base, the bar method, as described above, can be used for the relative orientation.

For larger objects, there is, naturally a practical and economic limit for the use of a stereocamera with a limited base. If the increase of the photography distance, compensated by an increased base to meet the accuracy requirement, means that one model substitutes 3-4 models taken with a stereocamera, the latter will probably not be competitive. However, even when using two separate cameras, or the same camera in two stations, most of the principles recommended above for use in non-topographic photogrammetric production will be advantageous.