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Detection of Horizontal Crustal Movements by Photogrammetric Methods

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The photogrammetric methods can be applied only if the horizontal displacements of the ground are of the order of several centimeters, because the standard error of the points so determined cannot, at the present time, be smaller than two centimeters.

The procedure to be adopted, which has already been applied with satisfactory results for the densification of geodetic nets, is the aerial analytical triangulation; therefore we shall here deal only about this method.

The taking can be executed with wide-angle cameras (f = 15 cm), or normal-angle cameras (f = = 30 cm) and format 23 x 23 cm. Since the average scale of photos must be chosen in relation with the desired accuracy and then is independent of the principal distance of the cameras, the number of photos is constant, whereas the flying height varies according to the focal length. We believe it advisable to use normal-angle cameras, because the lens have less distortion, better definition and are less influenced by the atmospheric refraction. Furthermore the small value of the ratio b/H does not remarkably influence the planimetric accuracy.

The scale of photograms must be large, because the measure error of the comparator is practically constant. However, an upper limit to the scale is given by the image motion (I.M.) which, at present, is not corrected and reaches sensible values if the photos are taken at low altitude.

Let us take into consideration the scales 1:3300 and 1:5000 which correspond to flying heights of 1000 m and 1500 m with f = 30 cm (or 500 m and 750 m with f = 15 cm) and let us compute the values of the I.M.

If the plane speed is 250 km/h which corresponds to about 70 m/sec and the exposure time is 0.0014 sec, the I.M. is 30 μ m for the lower flying height and is therefore larger than that generally accepted. At the higher height it reduces down to 20 μ m. This simple computation, together with the reduced number of the photos to be examined suggest, in our opinion, a flight 1500 m high, with focal length of 30 cm. At this height the effect of the atmospheric refraction is of a few μ m in the image plane and therefore the errors due to its approximate evaluation are neglectable.

It is advisable to execute the strips with a minimum 60% forward and side overlap. The 60% side overlap is extremely useful in these types of high precision photogrammetry even when only the planimetric position is wanted because, by doing so, the image of the same point appears on several photograms.

It is also strongly advisable to plan two different sets of strips in two perpendicular directions both because the number of images of the same point is still increasing and because it looks like that some systematic errors depend on the direction of the flight.

If we consider a 5 x 5 km^2 block, photo-scale 1:5000 and 60% forward and side overlap, we will require 10 strips of 10 photograms each, that is to say a total of 200 photos, 100 in each flying direction.

We are therefore dealing with a small block which does not entail any computational difficulty. Even if the linear dimensions of the block become twice as much, the photograms to be measured go up to 800, which is still a relatively moderate number.

The control net must consist of a series of points, whose three coordinates have to be known, located along the block perimeter, at a distance from each other not larger than four times the base length, that is to say that in a flight taken from an altitude of 1500 m with a normal-angle camera, they must not be farther than 1.8 km. However, in the case of smaller blocks (i.e. 5 x x 5 km^2) it is better to choose the ground points nearer to each other so that their number will be sufficient for the adjustment. It is not required, but advisable, to determine some extra points in the central part of the block, provided they are situated in areas that are not liable to move, just as the control points in the perimetral zone should be.

The ground control net should be determined with the utmost accuracy, but it is hard to make the standard error of the coordinates go lower than the error of the points determined by means of the analytical triangulation. However, this is not very important because the successive computations will make use of the same points and of the same set of weights. The most important fact is that the ground known points be located in stable positions.

The signalization is on the contrary quite important. All the ground points, that is control and new points, must be signalized. It is generally accepted that the best type of signal is a light disk, yellow for instance, surrounded with a black square tar paper. The size of the disk has to be chosen in relation to the size of the

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comparator measuring mark; if the diameter of the latter is 40 μm, the disk image can be about 50 μm so that, in the above mentioned hypothesis of 1:5000 scale photos, the actual diameter can be 25 ÷ 30 cm wide.

The measures will have to be executed with a high precision monocomparator such as, for instance, the Ascorecord by Zeiss Jena, the PK-1 by Zeiss Oberkochen, the Mann, and will have to be repeated in two perpendicular directions. Furthermore it is advisable to repeat each reading from two to four times.

The machine coordinates are transformed in the plate coordinate system by means of a rototranslation and a scale variation computed on the basis of the measured coordinates of the fiducials of the camera. We can remark in this instance, that it would be possible to use a grid camera, but recent experiments have shown that the increase in precision is very small.

Furthermore, the transformed coordinates are corrected for lens distorsion and comparator errors; as far as the latter is concerned, it must be noticed that the Ascorecord and the PK-1 have errors not larger than 1 μm. The refraction correction can be given to the plate coordinates or during the triangulation computations. In any case, it doesn't go beyond 3 μm.

The best method for the adjustment of block triangulation is no doubt the bundle method which, in the scheme we have here proposed, is very rigid, since each point can be measured on several photos.

Nowadays it is certain that the adjustment by the method of least squares is not completely satisfactory since it doesn't take into account the small systematic errors that are extremely harmful in the error propagation. The most extensively applied procedure for their correction consists in giving the plate coordinates some further corrections in form of polynomial functions of the coordinates themselves with constant coefficients (additional parameters) for all the strips or, at least, for those having the same direction. The conditions those parameters must satisfy are essentially two: to be significant and uncorrelated, both among themselves and the parameters of external orientation.

Some researches have been carried out in this direction and some expressions have been proposed; we can mention, among those which have proved successful, the ones given by Brown and by Ebner.

In the most recent experimental essays the standard error that can be obtained in each of the planimetric coordinates is not larger than 4 μm at the photo scale. If the photos have a 1:5000 scale, this figure corresponds to an error of 2 cm in the ground. This is a result that only few years ago no one would have dared to dream of.

Of course the standard error of the difference between coordinates referring to different times goes up to 2.8 cm, so that displacements of the order of 5 cm that groups of points have undergone in time, can be detected. However the most important thing is that the displacements be similar in value and direction; in other words a judgement cannot be made on the displacement of a single point, but one the average displacement of groups of suitably chosen points.

References

Slama, C.C., High precision analytical Photogrammetry using a special reseau geodetic lens cone, Presented paper to the Symposium of ISP, Commission III, Moscow, 1978

Brown, D.C., Accuracies of analytical triangulation in applications to cadastral surveying, Surveying and Mapping, 3, 281-302, 1973

Ebner, H., Self calibration block adjustment, Invited paper to the XIII Congress of the ISP, Commission III, Helsinki, 1976

Abstract. The use of analytical aerial triangulation is suggested, by particular rules, to determine horizontal displacements of soil. This method is suitable provided the coordinate variations be higher than 5 cm.