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THE ELECTRONIC CAMPUTER AS AN AUXILIARY INSTRUMENT FOR THE PHOTOGRAMMETRIC PLOTTER

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Introduction

The subject we are to deal with is included in the much vaster one of the electronic computer in the service of Photogrammetry. Since we are going te examine the use of the electronic computer in the limited field of application for a plotter, I will necessary have to neglect the argument concerning stereocomparators, analytical aerotriangulation, the block and strip adjustment and, briefly, all the photogrammetric techniques which absolutely need the use of an electronic computer.

The plotter, considered as a mapping instrument, is actually a self-sufficient unit, and doesn't necessarily need the support of an electronic computer, but it is necessary to observe that recently the plotter, and mainly the one without the base-bridge, has been commonly used and has been called upon to perform tasks which go beyond the simple mapping.

Within the frame of this extension of its duties, at first for usefulness and later for necessity, the electronic computer has been strictly connected to the work of the plotter.

In order to follow a regular pattern, we will first point out three different techniques by which this relationship has taken place, and which we shall later examine in greater details one at a time:

a) instrumental control and calibration technique; a set of operations concerned with the calibration, the control and the determination of instrumental parameters have been transformed into analytical operations and therefore require the use of a computer;

b) aero-triangulation techniques; some new aero-triangulation methods called semi-analytical have been recently developed; but while some may be performed without using the electronic computer and employ the computer just for convenience, others on the contrary absoutely need to make use of a computer;

c) techniques connected with civil engineering projects and with cadastre applications; we may mention road designs, land reclamation works, hydrological beds determinations, earth-dams designs as well as the operations of the numerical cadastre, of re-allotment and so on. One might object that in the last case I've named we should not strictly speak of the computer in terms of an aid for the plotter, something which is on the contrary perfectly possible in cases a) and b), but is it not necessary to remark that in this last case the plotter and the plotter and the computer together determine an organized unit; in fact the requirements of civil engineering projects or of the cadastre, affect the working rules of the plotter, and viceversa the data furnished by the plotter couldn't be used without the electronic computer.

I. *Planimetric projection of grids*

Let us now go back to examine the first point and let us take into consideration the operation of grids planimetric projection; the operations which are to be performed are well known and setting aside some differences due to the instruments, they consist to the positioning of a grid in a camera in a nadir-position, and then to read the coordinates of the points projected with a certain enlargement, to graphically draw the result obtained, to correct the camera position, to reproject the grid and so on, until a projection satisfactorily close to the theoretical one is obtained. Analytically the process is, on the contrary, as follows. The grid is put in a more-less nadiral position of the camera, the coordinates of the points projected are read on the coordinatometer and the electronic computer has to process the data.

The input of the calculation program is essentially formed by the plate coordinates of the grid and the coordinates of the projected points read on the coordinatometer. The calculation program is actually the calculation of a space resection; therefore, it furnishes the coordinates of the instrumental perspective center and the angular parameters of the camera and, furthermore, after calculating these data, using the plate coordinates of the grid, it performs an analytical projection of the points, which is then compared with the one actually made. As generally the points taken into consideration are more than the three strictly necessary to solve the space resection, discrepancies will be found out which represent the minimum possible discrepancies in the projection of a grid. Therefore, we only have a really efficient tool to determine the correction and the calibration status of a plotter. The duty of the operator is reduced to a correct collimation and the time required for the operation is around 15 minutes.

In this way two possible application methods of this technique come out.

A plotter being operated can from time to time be controlled without any remarkable loss of time; the operator, at regular intervals of time, performs the projection of a grid for each camera; every time the operation is executed different orientation parameters may be imposed to the cameras, thus eliminating a possible, even though unintentional, tendency of the operator to obtain results which may be foreseen.

The elaboration of the data obtained can be separately made in a calculation service; therefore you have the documentation on the condition of the instrument, you can control its stability, the worsening in the calibration conditions and the eventual wear and tear of single parts.

The second possibility concerns the use of such a technique in the instrument calibration phase, but it is obtainable only if the calculation service is immediately available, and the data can therefore be elaborated without waste of time.

The planimetric analytical projection of the grids can in fact be made with several enlargements or with different values of the camera orientation parameters.

The examination and the elaboration of the discrepancies obtained on the projected points furnish much informations on the instrumental conditions such as: perpendicularity errors in the axis of the coordinatometer, straightness of the rods in the various positions, eccentricity of the rotation axis in the gimbal axes, stability in the instrumental zeros and in the instrumental parameters, straightness in the rails, and so forth.

Lastly is to be noticed that in the operation described above the operator limits himself to aim at the points of the grid and has no means of foreseing which are the correct results; consequently the instrumental situation analytically determined is as objective as possible.

But it is necessary to notice that the situation given by the calculation is deduced averaging all the effects of residual instrumental errors and that such a situation cannot really be obtained; it follows that the judging criteria must be stricter than the ones to be adopted in normal practice.

2. *Altimetric projection of grids*

Similarly to what I have described for the projection of grids in planimetry, we can make analytical the formation of an altimetric model with a couple of grids. The operations are as follows.

A grid is located in each camera put more-less in a nadiral position; a relative approximate orientation is made in order to reduce the parallax between homologous rays below half a millimeter; every point of the model to be formed is stereoscopically collimated after eliminating the parallax in the point with a *by* movement of the camera; the three instrumental coordinates X, Y, Z for each point and the value of the *by* component are then registered.

These data together with the instrumental coordinates of the perspective centers, furnished by the above mentioned program, constitute the input of a calculation program. This program, which is really the calculation program of the semi-analytical triangulation (see par. n. 4), calculates five rotations to impose to the two bundles of projecting rays, in order to reduce at a minimum the parallax between homologous rays and calculate the instrumental coordinates of the model which has so been formed. With no disturbing cause the model formed should come out flat; a plane is then formed (it doesn't matter if it isn't horizontal) to reduce to the minimum the altimetric differences among the points of the model and it comes out a situation which shows the inner precision of the instrument.

The above described operations can be applied successfully when testing instruments, Since the operator's contribution is limited to make a good collimation, and since the calculation programs are impartial and furnish average meaning results, we have the most objective basis for a judgement of the instrument.

3. *Independent models triangulation*

This technique is already well known and it's not necessary to present its characteristics now. We shall only mention that the models are formed independently one at a time, being careful not to move the two perspective centers of the plotter, the instrumental coordinates of which are determined according to the rules described in par. I. The duty to reduce the models as a whole to a single scale and to a single orientation is entrusted to the calculation. The calculations may also be manually performed, but evidently it is much more economical and safe to use the electronic computer. The program is quite simple and it is not necessary a powerful computer. The library for the independent models triangulation allowing the complete cycle of operations includes:

a) the calculation program of the space resection which allows, using the grids, to determine the instrumental coordinates of the perspective centers;

b) the models bridging program; the input of this program includes, besides the general data such as for instance the coordinates of the perspective points, the instrumental coordinates of the transfer points read in each model, and the possible control points. The output gives the strip coordinates referred to the same system to which the first model is referred and, in order to control the accuracy of the measurements made, the differences between the transfer points of two succeeding points. If intolerable differences show up, it is necessary to re-survey two models in order to determine which of the two contains the wrong observation and to repeat the bridging calculation. It is not necessary to re-establish in the instrument the original position of the perspective centers; in fact the program foresees, in any point of the strip, the variation of the coordinates of these points;

c) the absolute orientation program of the strip. This program can belong to the preceedingly described connecting one; it is enough to make the orientation of the first model on known points before connecting the second model to the first one, in order to have the whole strip oriented in relation with the ground. As a consequence, this first model has to contain a sufficient number of known points, which rarely happens. In practice, especially when forming blocks, it is advisable to maintain the two calculations separate. But it is necessary to notice that generally the strips, referred to the instrumental system of the first model, may be disoriented by several degrees; it is therefore necessary that the absolute orientation calculation on known points be made in such a way as not to split the planimetric orientation from the altimetric one, mainly on mountainous grounds;

d) the block compensation program. Generally the absolute orientation program of every strip allows to make the block of strips, that is to refer every strip to a single scale and to a single reference system. The compensation program of the block reduces at a minimum the differences between the strip connecting points and on the control points.

These programs have been mentioned because they belong to the technical equipment which must accompany the plotter on which the independent model triangulation is made. Several applications have already been performed to determine the control points to make maps at the scale of 1:5000 and 1:10000; in order to obtain results likely to be used in cartography at these scales, we have limited ourselves to blocks of 20-25 models based on the points of the national geodetic net. We do not believe it proper to make now technical or economical comparisons between the independent models method and the other analogical methods.

We will only recall that the technique of blocks of strips needs however an electronic computer, and that, therefore, operating in this direction, it is most convenient to employ the computer as an aid also for the other phases of the whole operation, which would not strictly require it.

4. *The semi-analytical triangulation*

It is a variation of the independent models triangulation. The same rules for the independent model triangulation are followed in this technique, with the only difference that each model is not completely formed at the plotter. In fact the operator puts the couple of photograms in the plotter, makes two or three relative orientation operations in order to reduce the parallaxes to one or two tenths of a millimeter; then he observes the points of the model after having eliminated the parallax of each with the *by* movement of one of the cameras; for each point so determined, he then takes note of the three instrumental values and the *by* value (see also chapter 2). The task of improving the model is left to the electronic calculation; in other words one calculates little rotations of the two cameras (three for one camera and two for the other one) in order to reduce as much as possible the parallaxes and according to these small rotations one can correct the coordinates read for each point.

It has the advantage of remarkably reducing the observation time of a model and not to require a special ability by the operator in forming models. One might say it is a generalization of the practice of the instrumental analytical relative orientation; but it allows to use any number of orientation points.

If, instead of reducing the parallaxes to one or two tenths of a millimeter, we leave parallaxes measuring one millimeter, we can, repeating several times the calculations, arrive at the formation of the model. But in this case the amount of calculations is remarkable, and for the process to be economically convenient it is necessary to use a large computer and the plotter is practically limited to supply the same performances of a stereocomparator.

In the succession of calculations presented in the preceeding chapter the calculation for the improvement of the model takes place immediatly before the model bridging calculation. The results of the calculation supply the coordinates of the points of the models, such as it could have been found in the independent models technique, and therefore ready to be employed for bridging. The residual parallaxes are also supplied to allow to evaluate the accuracy of observations made.

5. *Use of the plotter in civil engineering works*

Since we are speaking of the computer as an aid to the plotter, we shall only mention those techniques which allow a complete automation of a cycle of operations, that is those techniques in which the ground representation is no longer graphic but numerical. Valid examples are supplied by road planning, by numerical cadastre, by land reclamation operations, by hydrological beds analysis, by re-allotment and by engineering industry for the production of those elements from which models are constructed.

A common characteristic of these techniques is, as it's already been said, the description of the ground (or of a model), by means of the coordinates of a series of characteristic points. In road planning are to be considered characteristic points those placed in the cross section, in the numerical cadastre the property boundary points, in land reclamation characteristic points of the surface to be reclamed, and so on and so forth. The numerical description of the ground also allows the automation of the designing operations and the computer can therefore supply the final result the designer is looking for.

The techniques applied and the advantages one can obtain have been described in specialized works and it isn't necessary to take them into consideration here too. We will only say that for each of the techniques we have mentioned the library of programs becomes quite complicated and wide. Just to give an example let's give a look to road projects. The minimum number of programs necessary for the entire cycle of operations is represented by the following list:

a) control and plotting program, performed by means of the computer's printing unit, of the instrumental data surveyed in each cross section;
b) absolute orientation program of a model; it is used to calculate the most probable values of the coefficients of transformation of the instrumental coordinates into ground coordinates;
c) calculation program of the longitudinal profile; sometimes the calculation gives, besides the profile on the axis, also other profiles on the right and on the left of the axis to ease the work of the designer in establishing the gradients;
d) designing program; it determines the designed cross sections according to the designer's indications, it finds out the areas, the earth cut and fill volumes, as well as the volumes of works of art, etc.;
e) plotting program, made by means of the computer's printing unit of the designed cross sections;
f) calculation program giving all the topographic elements for staking out the planned road, starting from well known and properly situated points.

Quite simple and unique is on the contrary the program to determine the capacity of hydrological beds.

The ground is described with a net of points which covers the whole area of the bed. The instrumental coordinates of these points are transformed into ground coordinates, taking into consideration the various models covering the area. The calculation program after the water level has been established, determines the correspondent contour line and goes on to calculate the volume included between the ground surface and the established level. In this way it is possible to easily build the capacity scale, by properly changing the water level.

It is necessary to say that both for road planning technique and for the above mentioned one, larger computers are definitely more economical than smaller ones and medium ones. On the other side, the economy of automatic procedures is always better than the traditional systems, regardless of the computer being used.

We cannot finish this brief review without mentioning the instrument which intimately connects the electronic computer with the plotting instrument, and this is the Analytical Plotter AP/C.

In cosideration of what has been said above, it is understandable how such an instrument can allow, if equipped with programs and improved in its capacity, the most advanced automation of all those procedures where the ground is numerically described and a remarkable elaboration of the data is necessary. Operating with the plotter and the computer in different services one can find out that it is necessary to split the work into different phases, each of which needs a staff and data checking. The immediate elaboration of the data can on the contrary allow a reduction of the staff and of the intermediate controls and verifications: a very high productivity can so be accomplished, which is very valuably shown even at the present time by the joint use of plotter and electronic computer.