FURTHER PROBLEMS OF THE AEROTRIANGULATION

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1. Is the Theory of the Aerotriangulation Completed?

Scores of years of the aerotriangulation developement have resulted in fast, accurate and flexible methods. Surveying latest reports on the subject one can even suspect, that further progress on the area is almost impossible.

There is no simpler and more direct method to be invented than simultaneous bundle adjustment. It enables us not only to process primary photogrammetric data /i.e. picture coordinates/, but to construct the network of photographs of any pattern and coverage as well. It permits also to include into common adjustment additional data like distances, angles, coordinate differences and so on.

A reseau camera being available full calibration /pre-mission of the camera and post-mission of a film deformation of pictures is possible. In this case the final accuracy closes the one of photographs measurement. Is there any need to say more after US-colleagues suggestion of standarts and specifications for the photogrammetric geodesy? /see Chapter VIII of [1]/

When the reseau camera is beyond reach self-calibration variant can be applied. Results will be then slightly worse, of course, but still RMS will not exceed a few micrometers.

Modern computation methods allow to utilise any piece of basic or additional data due to its proper confidence level specified by the individual RMS.

It looks than, as if all hopes of photogrammetrists involved in theory and technology of the aerotriangulation, have been fully satisfied. Minor improvements can be expected, of course, but they depend on cooperating branches rather than on curselves. Chemistry can supply us with more powerful emulsions and a better, more deformation-resistant film would be accepted willingly, too. Optics can iprove lenses, but after Slama's idea [3] significant changes are rather doubtful. The precision of machinery producers is so high already, that we can expect almost nothing in the area.

There is still more and more technological care and scrupulosity needed to reach the accuracy of leading projects, of course, but this is another matter.

2. A Pure Photogrammetric or an Integrated Network?

There has been, is and will be a piece of external data in every photogrammetric network. Its nature and sources are varying a bit all the time, but still the same its purposes are:

- tying the photogrammetric network built of any amount of photographs to a reference system,
- strengthening of the internal construction of the network, counteracting its possible deformation and so on.

There are two kinds of such a control available today:
- coordinates of control points,
- another data like distances, angles or coordinate differencies, creating additional consraints for particular points of the network.

Till coordinates only were involved one could consider the aerotriangulation as a pure photogrammetric network of considerably lower order, especially in dark ages, when its accuracy remained far off the one of surveying.

After some time another control has been included into aerotriangulation networks. At first statoscope and later radioprofile data have been inserted. They were, however, of lower than coordinates accuracy, so they could serve as second order constraints for Z-ordinate only. Later on direct results of ground measurements began to flow in. Today, with all the electronic equipement at hand, they are quite easy to be gathered and so comparatively cheap. If they are utilised directly, their accuracy is not deteriorated by a separate adjustment of a ground network. As this adjustment is not necessary, the additional data can be distributed to suit photogrammetric network only, so they can make an excellent guard against its deformation.

It is but not all. Considering connections of the aerotriangulation with surveying and geodesy one is bound to take into account not only their present state but the future one, too.

New electronic instruments have increased flexibility, accuracy and economy of surveying, but very slightly changed the theory and practice of the network construction. Still the same, two-dimensional networks have been adjusted, the only change being continous replacement angle measurements by distance ones.

There is, however, more significant change at hand - dynamic systems and their influence upon the network construction.

First of them are radio positioning systems, initially used as navigation means. Till located on the Earth surface they were of no value for geodesy, but quite interesting for a photogrammetric flight navigation, especially in areas with no map coverage. The recent, satellite-located systems have completely reversed this relation - geodesy and surveying have got totally new, extremely flexible data source of the highest accuracy. Its nature is so different from conventional instruments or systems, that some geodesists expect of them a substantial change of geodesy and surveying methods in a close future. While the satellite positioning systemskeeps hold of the general reference system, the whole needed data of the kind are transmitted

to any surveyor operating the slave station. Where than and what for the ground control comes in in such a case? The positioning slave stations are quite rare and expensive for the present, but this is hardly expected for the future. If but so, the dense reference network can possibly disappear in two-three decades.

And what about the photogrammetry? Are we to be the only surveying branche needing the ground control? Is there no way to utilize positioning system facilities?

There is but second dynamic system considered to be also a very powerful surveying tool - inertial system. It is entering into use just now, so it is difficult to forecast its importance for surveying. It has, however, closer affinity to the photogrammetry than the previous one because of being already used in flying geophysical missions [2].

Taking all mentioned into account it seems that there is just time to cosider a more compleks, really integrated network, consisting of data of any origin.

3. Could the Dynamic Data Really Change the Aerotriangulation?

The traditional control influences upon the photogrammetric network via its lower part, i.e. model of the terrain surface. Dynamic systems seem to be as if cut out to influence on its upper part, i.e. projection centres. There is but a problem - none of them is able to deliver valuable final data today. At the moment they are potential rather than real information sources.

To get ful accuracy of TRANSIT or GPS system one needs a stable point for the slave station and at least a few hours of operation. So an intermediate ground station is indispensable today. It seems that the same refers to on-ground positioning systems like Schoran, Decca, LORAN or their derivatives. The most speedy and fleksible inertial systems have to be calibrated very often. Final results can be significantly improved by common adjustment of mutiple traverse runs with self-calibration [3], but even then accuracy is too low. And so on - there is no visible possibility to get satisfactory exterior orientation elements of any system alone.

Who have told, however, that final results of any system ought to be utilised only? Or - is there any reason for consideration a single system only? Accustomed, as we are today, to adjust data originating from different sources we ought to keep this way with new data, too.

Let us cosider possible advantages of such an approach.

The single inertial run delivers raw data containing significant systematic errors. There is but very strong relationship between adjoining photographs. May be it could serve as a satisfactory constraint for calibration of inertial data. And on the contrary -inertial survey of a whole flight line could possibly counteract a deformation of the strip model. But to

take full benefit of both systems facilities means common adjustment.

The accuracy of instantaneous positioning can not be very high. What about the case, however, when every camera station of the whole project is positioned? Multidirectional relationships amongst the photographs and inertial survey /if included/ can produce quite a stiff network. Multipositial positioning of such a network, even less accurate, can be then utilised for location and orientation of the network, perhaps. Having hundreds of positioning measurements one can find not only seven parameters of absolute orientation, but any possible bias as well.

The other possible approach to the positionig utilisation is, perhaps, returning to on-ground systems. Oving to comparatively high altitudes of the photogrammetric flight there is a very few ground stations needed to cover huge area, for instance that of the country or even continent. In such a way a general control for all the area could replace many ones, being established for separate projects only.

There is but again the only way to get full benefit of all the systems - the common adjustment of the whole data set.

Taking all mentioned into account it seems that photogrammetry can, or even ought to, find its own way of making capital of dynamic systems facilities. In the case we find one - there will be no lack of ground control, no inaccessible area and no extreme climate conditions.

4. Main Problems of the Integrated Network.

The utilisation of dynamic measurements will be possible when a suitable data gathering system is constructed. The traditional camera with a statoscope and a radioprofile system at most has to be than replaced by a photogrammetric total station, consisting of:
- the camera itself,
- a substation of the positioning system,
- an inertial system,
- the statoscope /?/
- the radioprofile system /?/.

Needless to say, data records of all the subsystems ought to be referenced to a common time-record.

All the subsystems mentioned are already operational, so their fusion seems to be quite possible even in a close future.

For getting full benefit from new data a suitable processing method has to be prepared. By the time this can be done, however, we ought to find satisfactory answers to two basic questions:
- Should we go up to raw data of dynamic systems or accept rather some intermediate or even final results of a separate processing?
- Which is the most suitable coordinate system for such a network?

Direct results of surveying have been easily accepted by the three-dimensional photogrammetric network, because they are mutually independent elements of the space. It is not so, however, with dynamic data. For one thing - they are not geometrical elements. For second one - an influence of the system can not be neglected. May be there is a little distortion only in positioning system, but the other one is highly influenced by an atmosphere heterogeneity, a plane drive, a friction of accelerometers and gyroscopes and so on. It seems than essential to find such a stage of their data processing, where a possible bias model is not very complicated yet and results of the processing are already acceptable by the geometric network.

Referring to the second question one feature of the coordinate system is quite clear. As the data has to be gathered along the time also, a four-dimensional time-space system seems to be obligatory. Further its features are not so obvious, however.

The most comfortable cartesian system with similarity transformation rule is excellent for any large scale stereogram. By means of appropriate a priori corrections of the curvilinear data /geodetic coordinates, refraction/ it has been adopted to any scale, area and kind of network, too. New curvilinear data and factors will be, however, far more active in the adjustment process than the previous ones. So we may be obliged to construct the network in a curvilinear coordinate system instead of the familiar, rectangular one. Such a system has but a substantial draw-back - more complicated transformation rule and matching it algebra. Constant transformation factors have to be replaced by variable ones, the matrix algebra - by the tensor one.

If only an exact data of curvilinear origin have to be taken into account, the traditional way of previous to processing transformation would be advisable. If but the whole process of data gathering is to be modelled, the curvilinear system could be more suitable. Its possible advantages can be exemplified even by the refraction problem. Till now we have been satisfied with a priori corrections according to the standard atmosphere parameters. If but the curvilinear system is accepted, the like ray-path could be applied for self-calibration of the refraction model, too.

The future only can verify or deny tendencies presented. They are but so promissing and self-evident, that their discussion even at such an early stage seems to be justified.

5 References.

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