14th Congress of the International Society of Photogrammetry

Hamburg 1980

COMMISSION III

The President's Report

Doctor Antipov I.T.

On the Development in the Field of ISP Commission III during 1976-1980

National Committee of Photogrammetrists of the USSR

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I. The main tasks of the commission

The main problems of Commission III remained the same as in 1972-76 and were defined as mathematical analysis of data. By this definition the general problems common for both topographic and non-topographic practice are meant, namely: aspects of analytical triagulation, software of the analytical plotters and other photogrammetric instruments, the digital terrain model and digital mapping, digital image processing and geometry of remote sensing. Thus the definition "mathematical analysis of data" is at present a favourable foundation for uniting under one commission the scientists and specialists working out theoretical aspects of photogrammetric technique for different applications.

According to the resolutions of the 13th Congress ISP held in Helsinki 4 working groups have been set up for the current period. They are:

- working group III/1 "Metric aspects of remote sensing data" (Chairman Prof. E.Mikhail),
- working group III/2 "Image processing" (Chairman Doctor F. Leberl),
- working group III/3 "Compensation of systematic errors" (Chairman Prof. E. Kilpelä),
- working group III/4 "On-line aerial trangulation (Chairman Doctor T.Blachut).

All the working groups have been conducting intensive studies and holding regular meetings.

Early in August 1978 in Moscow the Symposium of Commission III was held. It was named "The problems of the accuracy improvement of photogrammetric models". This general name allowed all the working groups to take part at the Symposium and to discuss the present status of corresponding branches and further progress. The Symposium was attended by 82 delegates from abroad and some 50 soviet specialists. President of the ISP Mr. J.Cruset, Secretary General Prof. F.Doyle and Congress Director Prof. G.Konecny were the honoured guests of the Symposium.

According to many foreign and soviet specialists the Symposium was quite succesful. 56 papers were offered, most of them for oral representation. Various aspects of analytical triangulation were dealt with in 21 papers, data processing of remote sensing was covered also in 21 papers, 5 papers were devoted to digital terrain models and 3 ones to triangulation with the Moon and planets photographs.

The following review refers essentially to the results of Moscow Symposium and to its state of information.

2. Analytical aerial triangulation

Problems of analytical aerial triangulation are still of importance in the field of mathematical processing of photogrammetric data. Methods of analytical aerial triangulation are widely used including establishment of coordinate system, surveying in small, medium and large scales, solving non-topographic problems and expansion of ground control. The analytical aerial triangulation development is characterized by variety of methods, algorithms and programs available which in turn are due to various possibilities and approaches of re - searchers and users.

Methods adequate to those of analog stereoscopic instruments widely used in the 50-ies and 60-ies have lost their popularity with the development of analytical triangulation. In modern practice two groups of methods are competing on equal rights: the method of independent models and that of independent photographs (bundles).

Their efficiency is based upon the mathematical foundation that perimits to solve rigorously and at the same time simply the problems of random and systematic errors definition, those of blunders detecting and eliminating and those of optimal computation techinque.

A theoretical basis for strip and block adjustment with colliniarity conditions was laid down two decades ago. The practical results however were for some time less accurate than those obtained by means of independent models and differed greatly from theoretical accuracy models.

Introduction of the self-calibration method which allows to determine the systematic image deformation has changed the situation.

2.1. Definition and Compensation of Systematic Errors

Analytical aerial triangulation is based upon a photograph as a central perspective. Inasmuch as factors causing the deformation of the ideal central perspective having been already well known, the measurement results were always corrected beforehand. Owing to the deficiency of our concept about physical nature of deformation the influence of the residial undetectable errors considerably limits the possibilities of photo - grammetric control expansion. That's why the photogrammetrists do their utmost to find out optimal ways of defining and compensating systematic errors.

The methods used at present can be classified as follows:

- correlation of systematic errors a priori based on knowledge of a physical feature of deformation,
- defining of network deformation a posteriori through the residial errors at the control stations and adjustment with polynomials,
- self-calibration,
- field- test calibration.

The two former methods have been widely applied in analycalytical aerial triangulation since its early days and have not lost their importance up to now. But more appreciative now are the latter ones.

Practical value of self-calibration has been well recornized and confirmed. But the questions of additional parameters characterizing systematic image deformation still remain open. Experimental studies confirm that various blocks may have quite different systematic errors. It necessitates the use of different sets of additional parameters and the automatic selection of them. Methods and algorithms for the parameters selection and their criteria are intensively worked out. From the standpoint of the geometry of geodetic and photogrammetric point distribution, block dimension, sideward overlaps etc,the correctness of additional parameters choice is assessed on the basis of correlation among unknowns. As to the physical nature of the problem, that of the correspondence between polynomials and actual image deformation, the expe - diency for including any parameters in the polynomial is tested by the significance of the parameter, i. e. by the ratio of the parameter magnitude and the error of its definition. Combination of two approaches guarantees as a rule fairly good results.

In test-field calibration two-dimensional polynomials of various types are used to describe systematic deformations or the total corrections for certain zones are defined. Methods of field-test calibration and self - calibration have adequate accuracy. In some cases better results are achieved by the field calibration. But the test-field calibration is the whole system calibration and a change of any component (flight altitude, film type etc) will affect the final results. Thes reduces the practical value of this method.

It is established experimentally that whenever the systematic errors can not be truly determined the correlations of measured coordinates within a photograph and between different photographs of an aerial film should be taken into account. But the investigations of practically convenient methods and algorithms for such consideration have not completed yet.

2.2. Detection and Elimination of Blunders

Alongside with the studies of optimal methods of systematic deformation compensation the detection and elemination of blunders caused by carelessness of operators, instrument or puncher failures etc is developing. Most popular until re - cently methods of detecting and eliminating in which the threefold unit weight error serves as a criterion often lead to the wrong outcome. The gross error problems need a profound theory of evaluation of photogrammetric system reliability. It is suggested that dependencies invariant to the coordinate system, e.g. the ratio of distances, angles between intersecting lines, should be put forward as a basis of studies. Investigations on the statictical null hypothesis of observation equation discrepancies for such conditions provide more reliable means for eliminating of erroneous data. But much is still to be done in this field. It is necessary to define more rigorously check strategy, test criteria and their deviation.

2.3. Application of Auxiliary Data

Due to great achievements in the studies of effective methods of systematic errors compensation which considerably increase the accuracy of geodetic network densification the interest to the use of airborne data in aerial triangulation has been lost. Calibration and the internal camera geometry control provide results adequate to those of application measured elements of exterior orientation. New investigations on the application of auxiliary data published in photogrammetric literature are in general connected with the problems of establishing the planetocentric coordinate systems by means of photographs taken from Earth and planets satellites. Stellar images, different types of distances and dynamic equations describing the planet and satellite motion are used in this process.

In non-topographic photogrammetry alongside with the traditional statoscope data and APR profiles, the slope distances measured in the field, vertical and horizontal angles, relative elevations and point coordinates defined in independent rectangular coordinate systems are used as auxiliary data.

2.4. Computational Technique

Computer technique optimization in analytical aerial triangulation helps to save computer time and decrease a memory volume necessary for normal equations and other information. The optimization of an iterative solution consists in obtaining the appropriate initial values as close to adjusted ones as possible, saving the cycle time and reducing the number of imeration cycles. Polynomial pre-adjusment of strips and blocks yields exellent initial values. Reduction of total computing time can be achieved if the coefficient matrix are kept from the previous iteration to the next one and the cycle time can be saved by optimal data sequence providing the quickest data input with the minimal number of accesses to the external memory.

More often preference is given to the direct solution of large systems of normal equations. The reasoning of this is based on possibilities to programme an effective algorithm that takes into account a band or band-edge structure of a normal equations matrix. This reduces the number of arithmetic operations compared with iterative solution. Furthermore, an iterative method is connected with difficulties of determining a reliable convergence criterion. Multi group method of consecutive system conversion for a single strip avoiding the formation of a total system of normal equations is proposed.

The selection of additional self-calibration parameters if the correlation among them are analyzed necessitates the inver sion of the normal equations matrix at least in part. But economical ways of the complete matrix inversion and statistical estimation of aerial triangulation accuracy are not covered in literature yet.

2.5. Accuracy of Analytical Triangulation

The advances in the development of self-calibration and field-test calibration contribute to greater accuracy of analytical triangulation. Self-calibration usually increases accuracy of adjustment 1.1 - 1.5 times in planimetry and up to 2.5 in height depending on a block geometry and a set of additional parameters. The improvement is observed both for dense and sparse geodetic control. In some cases however the accuracy decreases 0.8-0.9 times and this proves once more the necessity of thorough and comprehensive analysis of the additional parameters.

If the sideward overlap is 60% as compared with 20% the improvement factor is approximately 1.5 in planimetry and up to 2.0 in height. The accuracy of a block with two directions strips at 20% side overlap and with single direction strips at 60% overlap is practically the same.

The accuracy level of 5 μm in image coordinates can be achieved at present. There are large potential possibilities for further improvements of the results.

Among them:

- taking photographs by a precise camera with the reseau register on a glass plate which guarantees an effective correction of a film deformation;
- usage of a special lens having the minimum aberration for a narrow zone of the spectrum;
- preliminary camera calibration by stars and test-fields;
- choice of a special emulsion, filter, shutter speed, sizes and shapes of targets on the ground control stations;
- special painting of targets with a colour for which the lens has been designed;
- optimal photogrammetric project as regards a photograph scale, overlap, flight direction, distribution and accuracy of ground control stations;
- repeated measurements of images with thoroughly tested comparators;
- preliminary detecting and correcting of component errors.

The combined usage of the above mentioned factors provides 2 μm accuracy in image coordinates. It is very expensive however and application of these possibilities depends on the economic efficiency in each individual case. If all the precautions have been taken, analytical aerial triangulation can replace triangulation and other methods for expansion of geodetic network on small areas.

As before the scientists are interested in theoretical prediction of aerial triangulation accuracy. Many formulae have been proposed for this purpose. The spline theory closely con nected with the adjustment theory was put forward. The fle - xible grid fixed at the control points physically illustrates the mentioned theory. Discrepancies between the geodetic and photogrammetric coordinates defined at the control stations at equal intervals can predict the mean square residual error after final adjustment. Though experimental data confirm the prediction, the method requires further studies.

More reliable results of aerial triangulation accuracy evaluation can be achieved a priori with the mathematical simulation. For this purpose terrain and photograph models should exactly correspond to actual conditions in the number of and location of strips, overlaps,relief,tilts,the number of and distribution of photogrammetric and geodetic control stations, systematic and random errors. The simulation especially in regard to errors is a complicated process. But it is possible to provide true representation of accuracy and to help in optimizing field and office works.

2.6. On-line Aerial Triangulation

On-line aerial triangulation which reduces processing time and expenses and increases the quality is intensively developed. Now the software of the analytical plotters is an extremely wide library including hundreds of service programs for automatic processing at all steps such as data record input, orientation, calibration, geometric elements calculation, graphical plotting, data store in a general file etc. This provides real-time computation for error detection and localization of common points and calculation of initial values for adjusted coordinates and orientation parameters. The software of plotters performs strip and block densification in planimetry and in height by independent models, self-calibration aerial triangulation, simultaneous adjustment of various geodetic, photogrammetric and auxiliary data. A block can consist of 200-300 photographs to meet most of practical needs. Analytical aerial triangulation by means of minicomputers is also studied on. But minicomputers can compete neither in on-line nor in off-line aerial triangulation.

3. Digital Terrain Model

Among the theoretical aspects of digital terrain model the height interpolation draws most attention. If a model is purposed for orthophotorectification the high-order accuracy is not required. Good results are achieved either by manual scanning of contour lines or profiles or by scanning with automatic epipole correlators. Relief interpolation for automatic contouring puts forward much more problems.

At present many methods of mathematical simulation are known to provide a conversion from arbitrary distributed reference points determined on the topographic surface to this surface description through the heights of the nodes in a regular square grid. The relief approximation by a large number of finite surface elements with continious but not differentiable piecewise linear boundaries defined by the grid point heights is commonly used. However many parameters necessary for practice are not clearly defined, among them the optimal grid pace of a digital relief model and a breakline description.

A structural representation requires to interprete an image and to trace all the breaklines where the surface curvature is changed. The method of finite elements leads to good results for hilly land with even or gentle slopes as well as for low land. But apart from the difficulties of the morphological structure choice which is usually a manual operation, this method needs more or less even initial data distribution.

To give practical recommendations it is necessary to compare different methods of topographic height interpolation for the variours relief types in regard to accuracy, density of initial data and processing time of a computer and an automatic plotting table.

4. Remote Sensing

The modern remote sensing equipment includes photogrammetric, scanner, radiometric and undewater acoustic systems. Processing of images obtained with these means occupies the leading place in Commission III activity.

4.1. Metric Aspects of Remote Sensing

Studies of image projections of different remote sensing systems installed on moving platforms are going on. The exact knowledge of these projections and mathematical properties affords the possibility to recover a time-spatial position of a remote sensing imagery and evaluate its geometric accuracy. Equations describing the relations between image and object coordinates have been already obtained. They provide an accuracy of a point coordinate transformation about 1/3 pixel. They also allow to present a scanner imagery as a unit photography fully defined by conventional elements of interior and exterior orientation. As a result a remote sensing image processing can be reduced to processing of airborne photographs. At present time there are no obstacles to ascertain the geometry of objects by means of every type of remote sensing systems.

4.2. Image Processing

Digital methods of image processing are considered now the most promising ones. The main attention is paid to algorithms for geometric normalization of images and their analytical rectification into a desired map projection. Equations of mathematical transformation have been expanded to the second order polynomials. Results of the experiments and a numerical simulation demonstrate a high accuracy and practical expediency of developed algorithms for digital image transformation.

A side-looking radar is an effective all-weather remote sensing instrument with a high resolution power. But radar imageries as well as those obtained by other non-photographic systems cannot be processed directly with photogrammetric instruments for contouring and topographic map compilation. Two ways have been suggested for stereoscopic perception with remote sensing imageries. The first one is based on preliminary digital rectification of an original image by a computer and following output image processing for map compilation with an ordinary stereoscopic instrument. The second way requires a digital-analog complex consisting of a high-speed computer and a radar stereoinstrument. Such a complex allows to perform real-time calculations for correction and geometric rectification of two images simultaneously with model orientation and map compilation. For the moment a technology of a good capacity can be worked out with the existing equipment along the first approach. But there is a good reason to believe that real-time calculation by a computer combined with a radar stereoinstrument will considerably increase the efficiency of the second way in the nearest future.

4.3. Digital Differential Rectification

Analytical rectification of remote sensing imagery is rather expensive due to complicacy of an equipment and a tremendous amount of information. That's why the emphasis is laid down on the choice of a rectification method providing required accuracy. In the current period investigations aimed to improve the computing technique of input-output of an imagery and its transformation were being in a progress. The studies embraced the functions of geometric transformation, photogrammetric mosaic correction and information exchange with an exterior memory of a computer.

Up-to-date methods of analytical rectification are based upon: 1) utilization of an available information on satellite orbit, 2) polynomials, 3) colliniaity conditions.

Methods avoiding ground control are the cheapest ones. In order to achieve the technological standard of mapping more expensive and precise methods of a polinomial transformation should be used. The second order polynomials with 20-30 control points per image are quite satisfactory for customary practice. Photogrammetric calculations of a super-high accuracy should be done with algorithms based on colliniarity equations.

It is also necessary to mention that alonside with digital image processing orthophotorectification by means of ordinary photogrammetric differential rectifiers is being investigated.

4.4. Application of Digital Image Processing

Digital image processing are widely used now to solve the various problems of topographic photogrammetry, engineering projects, investigation of natural resourses and environment protection. Digital selection of boundaries and lines on colour or black and white imageries is very important for a success of numerical methods. The special procedures have been suggested to separate the homogeneous area boundaries and lines. These procedures can enhance an image quality through corresponding pre-processing, thus contributing to automatic and semi-automatic interpretation. This approach interposes the necessity to define strictly the "boundary" and "line" concepts in order to selest the optimal algorithms. Utilization of an extra information such as a feature and shape of an object is very useful in an automatic interpretation. For this purpose the well- known procedures of a harmonious analysis have been added with algorithms of feature analysis. The latters can be characterized by a simplicity, small magnetic store consumption and moderate computer time requirements.

All the above mentioned contributes to expansion of digital image processing possibilities and the application of photogrammetry and remote sensing is being rapidly advanced now into new fields of the mankind activity.