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REPORT ON THE ACTIVITIES OF WORKING GROUP III/1 DURING 1980 - 1984

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Abstract: The experimental activities of WG III/1 concentrated on performance tests of various methods and computer programs with regard to the detection of gross data errors in aerial triangulation. Based on simulated data tests were carried out by members of WG III/1 and of OEEPE Commission A. The results are summarized and conclusions are drawn.

With regard to the fundamental theoretical questions of the mathematical model of aerial triangulation experimental evidence on the stochastic nature of image errors is available. Based on the 1981 seminar of the WG the general situation is reviewed and experimental procedures are suggested.

1. Introduction

1.1. The Working Group 1 of Commission III was established at the 14th ISP Congress in Hamburg, 1980. It's given name "Identification and Elimination of Gross and Systematic Errors" refers to two main problems of present day aerial triangulation. However, the Working Group III/1 understands its theme to be more general. It is really the general problem of the mathematical model of photogrammetric point determination or of modern analytical photogrammetry, respectively, we are concerned with.

Accordingly, in its initial deliberations, the WG identified 3 main topics which are rather fundamental and which, although interrelated, can be treated quite independently. They are:

- systematic image errors
- gross observation errors
- refinement of the stochastic model.

All 3 topics are part of the general problem of the fundamental mathematical model of photogrammetric point determination. They are also linked together in the evaluation of the total accuracy performance of the analytical method and in the unsolved question of quality control of the results.

1.2. During the period 1980 - 1984 the WG held 4 meetings, usually in connection with other international occasions. It organized a 2 day seminar in Nov. 1981 in Stuttgart on "Mathematical Models of geodetic/photogrammetric point determination with regard to outliers and systematic errors" |1| and took part in the Symposium of Comm. III in Helsinki 1982. Also 2 workshops on the reliability of photogrammetric blocks held in Stuttgart in 1980 |2| may be mentioned here.

The experimental work of the WG concentrated on tests concerning the detection of gross errors in blockadjustment. Up to 15 members took actively part in the experiments. Others observed them closely. Most activities of the WG were done jointly with OEEPE Commission A. We thank here its president, Mr. J. Talts, Sweden, most cordially for his kind support and cooperation.

2. Systematic image errors

2.1. After an initial analysis it was decided that the WG would not go into new experimental tests on systematic image errors and their elimination by self calibration block adjustment methods. The reason was that new experiments could not be expected to lead much beyond the state of information reached by the work of the previous Working Group of E. Kilpelä |3|. The previous experiments have given good insight into the effectiveness of self calibration and the precision level aerial triangulation is capable of.
Also, after more than 10 years of development of additional parameters the method has reached an operational level and is being applied in practice. Thus practical experience is constantly gained, and the method does not need special stimulation any more.

It can be stated that the method of self calibration has seen thorough development within a period of about only 10 years, leading to operational computer programs and practical application. Also the scientific investigations have clarified both capabilities and limitations of the method to the extent that application is relatively safe.

2.2. It is astonishing, nevertheless, that research into selfcalibration seems to have lost interest. Photogrammetrists seem to be satisfied that the additional parameters take sufficiently care of unknown systematic image errors. But to what extent the method is effective at all or how far the success depends on overlap, control, density of points or on the particular set of parameters has not really been worked out. Here, a vast field of investigation remains to be dealt with. We believe, however, that this kind of investigations is at present to be left to individual researchers rather than to be taken up by a working group.

2.3. In spite of remaining questions it can generally be stated that by the application of self calibration methods in block adjustment a consistent precision level of $\sigma_0 < 3$ µm for image coordinates has been reached provided instrumental errors, point measurement errors, and point transfer errors are negligible (by using comparators or analytical plotters and signalized terrain points). Thus, an extremely high performance level has been reached which proves aerial triangulation to be a genuine high precision method for point determination. It should particularly be noted that such precision is being reached more and more in standard practical application and is not confined to special research results only.

It must also be noted, however, that the main contribution for reaching such high precision comes from reducing instrumental errors (by comparator-type instruments) and by avoiding point transfer errors (by using signalized points). In such cases and in connection with sufficient number of control points the further refinement by self calibration is relatively small (about 10 - 30 % only). Bundle adjustments without self calibration and even the independent model method can reach almost the same precision level of 3 µm or better. This indicates the high geometrical quality of modern aerial photographs. An important conclusion is, therefore, that development of high precision point transfer methods, for instance with digital image correlation, is urgently required. Signalized tie-points to which high precision results are limited, so far, remain restricted to special cases of application of block adjustment.

3. Gross error detection

The topic of reliability and blunder detection is not only of great scientific interest but also of highest practical importance in aerial triangulation. Any other progress in the field remains secondary against the successful operational solution of the automatic detection of gross observational errors which are almost always present in large sets of observational data.

3.1 Following the concept of W. Baarda on reliability extensive investigations were carried out by a number of authors on the internal and external reliability of photogrammetric blocks. Conclusions were drawn and rules derived for project planning, see |2| for instance. The reliability of photogrammetric blocks compares very well with geodetic networks. Especially inside a block the detectability of gross observational errors is very good. At border areas either double overlap or double or triple tie points are required in order to ensure sufficient reliability. Unfortunately gross errors can only be poorly detected at ground control points. This means that in addition to asking good reliability from the geodetic survey the photogrammetric identification of ground control points must be ensured by using double or triple points.
In general terms the specifications for project planning are sufficiently known in order to allow algorithms for gross error detection to be effective and successful. It can only be urged that practice will accept such specifications.

3.2. At about 1980 it had been recognized that gross error detection by algorithmic methods is possible and that it is of greatest practical importance. The theoretical insight into the limits of gross error detection (normally only errors larger than 6 σ or more can be identified) had been prepared by the pioneering work of W. Baarda who formulated the statistical "data-snooping" test. On the other hand it was soon realized that the separation of small gross errors from random errors (and systematic errors) by a statistical test constitutes only one part of the problem. In practice a computer program would also have to identify large and very large gross errors, and the algorithm should not break down in the presence of multiple gross errors. For such problems very little theoretical guidelines were available, except for the recommendation that robust estimators would be required. At that time the first computer programs had been developed attempting a solution for automatic blunder detection.

Against that background the WG III/1 decided to go into experimental tests about the practical performance of available gross error detection algorithms. Also, by comparison, the performance of the conventional manual method was to be tested.

3.3. For four different blocks sets of observation data were established by computer simulation and contaminated by random, systematic and gross errors. The participants obtained the data with some general information and were asked to clear the data from gross errors, to do the blockadjustment, and to judge the results obtained. Each participant was free to use any method of error detection available to him. The results were subsequently analyzed with regard to the success rate of gross error detection, to the method applied, and to the number of adjustment runs required.

The experimental test program was carried out in two phases. In phase I the data were particulary contaminated with quite a number of very large gross errors. The aim was to test the ability of methods to remove the large gross errors first before tackling the problem of separating small gross errors from all other random and systematic errors. This set up was deliberately chosen as it reflects the prevailing practical situation. Admittedly the chosen examples were somewhat extreme which was critisized by some participants.

The data sets of phase II of the experiment were established in such a way that the performance of error detection procedures could be evaluated in particular with regard to the separation of multiple small gross errors from random and small systematic errors.

The experiments and their results are described and commented in detail by W. Förstner in |5| and |6| and need not be repeated here. However, the following general statements can be made about the results:

- the methods of error detection applied cover a wide range, also the effectiveness of methods, the success rates, and the degree of experience vary widely
- pre-error detection procedures or robust methods are necessary for the identification of large gross errors
- automatic elimination algorithms are generally more economic than manual or interactive procedures; the total number of runs is considerably less
- in the final stage error detection methods which are based on or are more or less equivalent to a statistical test (data snooping or something similar) give generally best results.

It can also be noted that in the first phase some participants overestimated their results considerably. This attitude changed noticeably in phase II. Thus obviously a learning process took place, and the evaluation of error detection algorithms has become quite realistic.

Evidently, the experiments of the WG have stimulated the further development of gross error detection algorithms and have given deeper insight into the problems. It is now generally recognized that algorithmic solutions are not only possible but that they are most successful in ordinary cases, particularly when the reliability rules for project planning are observed in aerial triangulation. Thus, a highly important stage of development has been reached, and it is expected that such error detection programs will be generally applied in practice.

It has also been confirmed, however, that in extreme cases, when multiple and large gross errors go together with poor geometric stability of blocks, any error detection algorithm, whether automatic or manual, may break down or not find a proper solution.

4. Refinement of the stochastic model

4.1. The successful development in aerial triangulation with regard to the elimination of systematic and gross errors and the related high precision level obtained has opened the view for the general problem of the mathematical model of photogrammetric point determination.

Block adjustment with additional parameters clearly constitutes a refinement of the functional model. Gross observational errors can be considered as relating to the functional model or to the stochastic model, depending on the approach. However, the stochastic properties of aerial photographs and image coordinates have not been investigated thoroughly, so far. And no attempt has been made to take correlation between image coordinates properly into account in block adustment programs.

Previous investigations, |8| for instance, have clearly established that image coordinates are considerably correlated within photographs and between photographs. The magnitude of correlation naturally depends on the extent to which systematic image errors have been taken out.

The general task, however, of establishing a comprehensive stochastic model for photogrammetric point determination still remains to be solved. Related with this general task is the delimitation of the stochastic error properties against systematic image erros and gross observation errors.

It was felt, however, that the problem formulation is not yet clear enough, and that it was too early for the WG to rush into experiments. Instead,the efforts were first to be directed towards a thorough theoretical foundation and preparation. Therefore, the WG decided to organize a seminar (together with OEEPE Commission A) on the basic questions of mathematically modelling the total system of geodetic or photogrammetric point determination. The seminar was held on 26 and 27 November 1981 in Stuttgart. A number of outstanding experts in the fields of statistics, geodesy and photogrammetry were invited to present their views on the problem. The proceedings are published in |1|.

4.2. The 9 papers presented at the seminar concentrate around the concepts of robust etimation, stochastic models including criterion matrices and variance-covariance estimation, evaluation of functional models, gross error detection and sequential procedures.

It can be said in general that on the geodetic side no concepts are ready which would clearly and directly suggest a certain strategy for setting up experiments for the assessment of the stochastic model of photogrammetry. On the other hand, however, the presentations and discussions cleared considerably the theoretical situation. And a number of concepts were emphasized or emerged. These are in particular the concepts of robust adjustment, criterion matrices, the separation of gross and systematic errors, and a concept for assessing the frequency of small gross errors.

In the mean time studies were continued about how the stochastic properties of series of photographs could be described and assessed without requiring unduely large experimental efforts. Here, particular attention is drawn to the approach by R. Schroth |7| who models series of photographs by an autoregressive stochastic process which is defined by relatively few statistical parameters. Their assessment will not require too much experimental effort.

4.3 The WG III/1 did not attempt to set up experimental investigations about the stochastic properties of photographs and series of photographs within the running period. It is suggested, however, that the theoretical and methodical basis for treating photographs as a stochastical process has been sufficiently clarified and that an experimental program might be launched by this or another working group during the next congress period.

It is not expected that a refinement of the stochastic model of photogrammetric point determination will result in spectacular accuracy improvements. Nevertheless it is necessary to establish a complete and realistic mathematical model. It will serve for the evaluation of the accuracy capability of photogrammetry in general. It will also allow performence prediction for special application and promote the further development of computational methods.

Acknowledgement

In closing the activities of WG III/1 I want to express my appreciation and my gratitude to all members and colleagues for their valuable contributions, their active participation, and their friendly cooperation.

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