A GENERAL RIGOROUS METHOD FOR BLOCK ADJUSTMENT WITH MODELS IN MINI AND MICRO COMPUTERS

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Abstract

After more than 20 years from the first appearence of rigorous block adjustments methods, they continue to be out of reach for a large part of the photogrammetric community that cannot afford expensive computer systems.

The program COBLO has had since its presentation at the XIV ISP Congress in Hamburg in 1980, an interesting dissemination in Argentina and in some European countries. Its main advantages are: Small central memory requirements (there is a version that operates efficiently on an inexpensive microcomputer with two Diskettes), acceptance of completely arbitrary blocks as well as very simple data handling. In addition, the program can easily be installed by the user himself.

Following the generous example of Schut from the National Research Council of Canada, COBLO has been made freely available to several universities and state organizations, some of which have introduced very interesting changes, which shows another interesting particularity of COBLO: There is no need to consider it as a black box.

Zusammenfassung

Nach mehr als 20 Jahren seit dem Erscheinen der ersten strengen Blockausgleichungsverfahren bleibt ihre Anwendung einem Großteil der photogrammetrischen Gemeinschaft, die über keine teuren Rechensysteme verfügt, verwehrt.

Das Blockausgleichungsprogramm COBLO hat seit seiner Vorstellung auf dem XIV ISP-Kongreß 1980 in Hamburg eine interessante Verbreitung in Argentinien und einigen europäischen Ländern gefunden. Seine hauptsächlichen Vorteile sind: Geringer Kernspeicherplatzbedarf (es existiert z.B. eine auf einem billigen Mikrorechner mit zwei Disketenlaufwerken effizient laufende Version), Verarbeitung beliebig strukturierter Blöcke sowie eine sehr einfache Datenbehandlung. Darüber hinaus kann das Programm vom Benutzer selbst installiert werden.

Dem großzügigen Beispiel von Schut vom National Research Council of Canada folgend, wurde COBLO inzwischen mehreren Universitäten und Staatsorganisationen frei zur Verfügung gestellt. Von einigen dieser Benutzer sind dabei einige interessante Änderungen vorgenommen worden, was auf eine andere wichtige Eigenheit von COBLO hinweist: Es braucht nicht als "black box" betrachtet zu werden.

1. Introduction

In 1973 two German professors were at our University in Tucumân: Egon Dorrer in May and Gottfried Konecny in October (he was as well in Tucumân in October 1971). They gave us lectures on Analytical Photogrammetry and made us aware of the potentiality of the then new rigorous block adjustment methods.

People of several Argentine universities attended these lectures, and as a result of this the subject was later introduced in some chairs of Photogrammetry.

In 1975 we considered the possibility of installing a program with a rigorous solution in our university. The block adjustment program with models of Stuttgart /1/ was already known, but out of reach for us: high price and requirements of a big computer. The USGS Bundle Block Adjustment Program of Tewinkel /10/ was freely available but it required a big computer, too. We had then an old IBM 1620 computer. The bundle program of DBA System was not for sale.

At that time we asked ourselves, why such programs needed so much central memory storage and why they were so complicated. Was it really impossible to write a program, which could be installed in a small computer? To answer this question there was only one possibility: to write such a program. We knew that this was not an easy task and that some people could not finish it successfully. In /5/ it is said: "We underestimated the difficulties and pitfalls of such an endeavor and the time necessary to complete it". In spite of this discouraging experience we decided to write a rigorous block adjustment program by independent models for our computer.

After some attempts that resulted in not general solutions, we could finish a program in 1978 which could process arbitrary blocks. That program /7/ employed an iterative method (Gauß - Seidel) to solve the reduced normal equations and not the normal equations as in former methods /3/.

A year later in 1979, we could finish lastly a general rigorous method, which was based on a direct solution of the reduced normal equations. The resulting program, named COBLO (for Compensación en Bloque) was the so-called "4-3 solution" (the separated plan-heights adjustments), which was user-friendly and needed only 25 K bytes of central memory storage.

At that time we thought that the program was going to be used only by ourselves in Tucumân. However, the general situation throughout the world market for rigorous block adjustment methods encouraged us to disseminate the program. Besides the iterative methods /2/, which were not efficient, nobody without expensive computer systems could perform block adjustment according to a rigorous solution. The great dissemination of polynomial adjustment methods by Schut was not repeated with the rigorous methods.

This situation is still valid today to a certain extent. Many universities, state organizations and very many private companies have not an efficient and rigorous method to adjust their blocks.

The first COBLO version of 1979 was repeatedly improved and made more efficient. Some of these versions are used in Argentina and some European countries. The users themselves have installed the program, and sometimes modified it to meet the requirements of their "modus operandi".

Since 1982 there is as well a spatial solution (COBLO 7) with simultaneous determination of the 7 absolute orientation parameters for each model.

2. The 4-3 solution

This solution is the well known Anblock method, in which planimetry and height adjustments alternate. For the planimetry the formulation of /6/ is employed. For the heights a similar formulation was developed by the author. The structure of the 4-3 solution is represented in fig. 1.

2.1 Input of data

At the beginning general information (block size, weights, desired number of iterations) is entered. Then there follow the list of ground coordinates and all model lists. Each model originates a list that contains all measured model points. The point numbering and the point sequence in this list are arbitrary. The output of a plotting instrument can be directly fed in. In former versions the models needed to be arranged sequentially forming strips. In newer versions this arrangement may be arbitrary.

2.2 Establishing of model ties

It is well known that the data organization is the real bottle neck in block adjustment methods. In building the reduced normal equations it is necessary to know in which models a point appears and what position it has in the model lists.

To solve this problem, it would be easy, for instance, to use a certain code with this information as point number. This possibility simplifies greatly the programing but the data handling would then be so complicated that it would be no longer possible to speak of "user friendliness". However, this possibility has been employed in the program SBAIM /9/ because "The alternative is a sophisticated search routine to locate tie points in adjoining models...".

In COBLO the determination of ties is carried out by a search routine which compares the point identification numbers. For this reason the point numbering and the point sequence can be completely arbitrary. This search routine consists only of 37 FORTRAN statements and anybody could write with it an user friendly program.

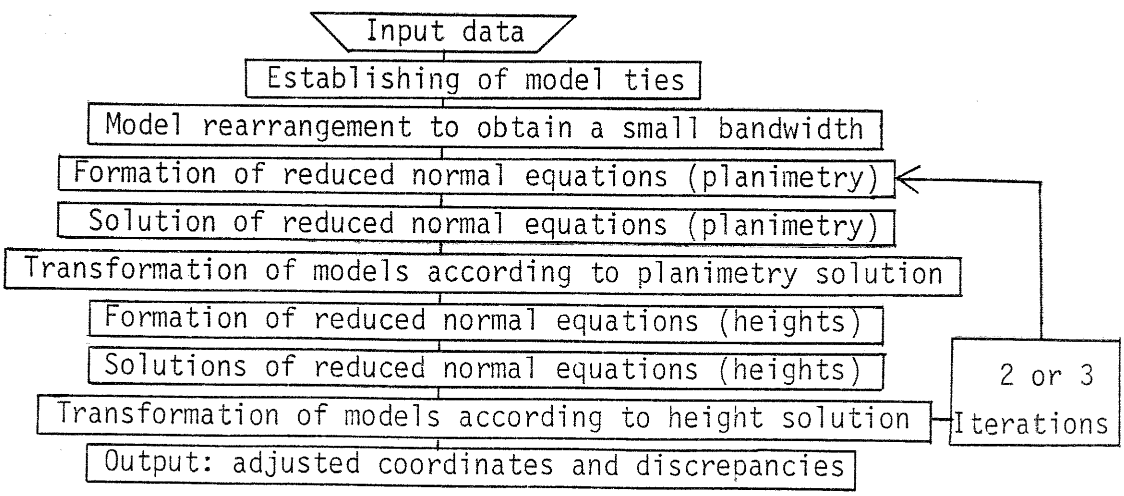

Fig. 1

2.3 Model rearrangement to obtain a small bandwidth

It is known that the numbering of models has a direct influence on the bandwidth of the reduced normal equations. The time to solve the system grows, in turn, with the square of the bandwidth. The new COBLO versions, unlike former ones, have a routine for bandwidth optimization. The program can now change, for instance, the unfavourable model numbering of fig. 2 into the favourable one of fig. 3.

The renumbering routine was obtained as a by-product of the routine to establish model ties, which is a fundamental part of COBLO since the very beginning of its development. With this new feature the efficiency of the program has been greatly improved specially in case of blocks with few and long strips.

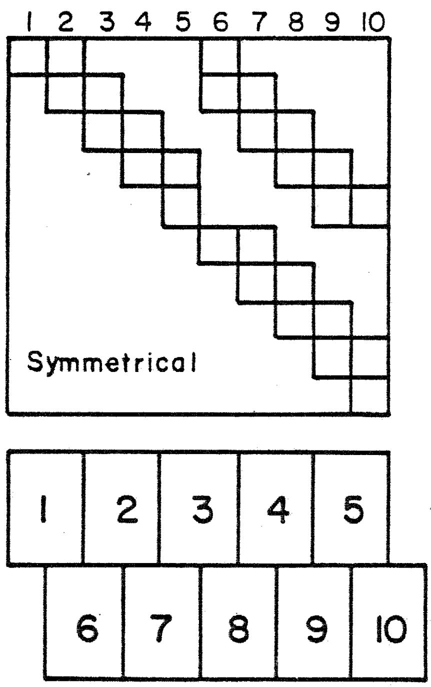

Fig. 2: Numbering along strip axis

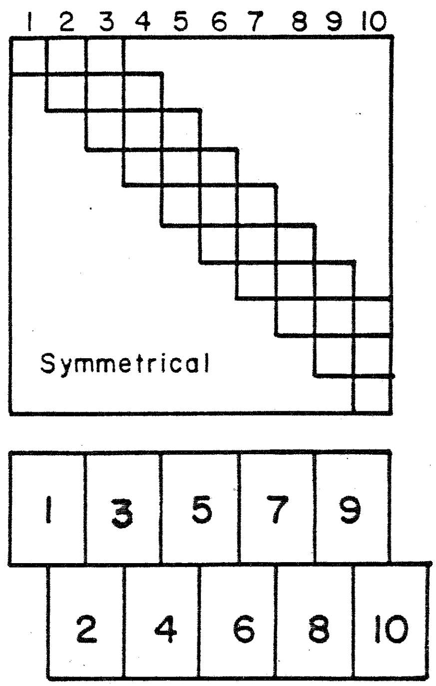

Fig. 3: Numbering perpendicular to strip axis

2.4 Formation and solution of the reduced normal equations

This topic is explained in detail in /8/. Here we resume only the principal features:

1) The reduced normal equations are formed directly.
2) They are stored in external memory (disk or diskette).
3) They are splitted into submatrices (4x4 for the planimetry, 3x3 for the heights and 7x7 for the spatial solution).
4) The solution of the reduced normal equations is the well known Gauß method of elimination and back substitution.

5) The computing elements are, however, submatrices as explained in 3).
6) Only half matrix is processed due to its symmetry.
7) All products having a zero submatrix as a factor will be skipped.

3. The spatial version (COBLO 7)

This version combines planimetry and heights in a common solution. The structure of this program is similar to that of the 4-3 solution. Initially a planimetry iteration is performed to compute good approximate values for the azimuth (Kappa rotation) of all models. All other iterations are in three dimensions. Although the processing of 7x7 submatrices is slower than that of 4x4 submatrices, the total processing time is some 30 % less in the spatial solution, because here the reduced normal equations are formed and solved only once per iteration.

Another important advantage of the spatial solution is the better convergence, specially in case of mountainous terrain.

4. Computer requirements and efficiency

The program COBLO is written in FORTRAN IV and consists of only 830 instructions, thus requiring, together with the working area, which is independent on block size, no more than 25 K bytes of central memory storage without program segmentation. External storage in disk or diskette is necessary.

Some of the computers in which COBLO has been installed are:

IBM 1620, IBM 370/125, IBM 4341, VAX 11/780, Prime 550, PDP 11/34, ICL 2976, ICL 2988, Cray 1 S, HP 1000, Radio Shack TRS-80 Mod. III with two diskettes.

Regarding the processing time, the following information supplied by some users is summarized.

With former COBLO versions (4-3 solution) model numbering along strips (unfavourable) and 3 planimetry height iterations: A block of 70 models took 2 hours (total time) in a PDP 11/34 computer, while in a big computer, the Cray 1 S, a block of 30 models needed only a few seconds (total time with a version modified by the user, which requires no external storage).

With COBLO 7 in a H.P. 1000 computer a block of 60 models with 5 strips (model numbering across strips) needed 53 minutes (total time). In the same computer and under identical conditions a block of 98 models with 7 strips took 2 hours 20 minutes (total time).

5. COBLO in Microcomputers

Two versions of COBLO, the 4-3 solution and the 7 solution have been installed in a Radio Shack TRS 80 Mod. III microcomputer (with two diskettes). The spatial version was faster (30 %) than the 4-3 solution. The following blocks were processed with 1 planimetry iteration and 2 spatial iterations (which is better than 3 planimetry height iterations in the 4-3 solution).

Block	Model numbering	Number of models	Number of strips	Total time
1	along strips	10	2	20 minutes
2	along strips	12	3	32 minutes
3	along strips	20	4	73 minutes
4	along strips	20	2	89 minutes
5	across strips	20	2	47 minutes
6	along strips	30	5	148 minutes

The difference between bad and good model numbering schemes in blocks with few and long strips is evident if blocks 4 and 5 are compared. Larger blocks could not be processed because the available Radio Shack Mod. III microcomputer had only 2 diskettes, of which only one could be used for data storage (178 K bytes). However, it is possible to connect more diskette units so that larger blocks could be processed as well.

In addition to this it should also be considered, that today there are microcomputers somewhat more expensive than the Radio Shack Mod. III, but 4 to 5 times faster. With such facilities a block of 100 models could very well be processed in 4 hours (total time).

6. Gross error detection and elimination

In principle, a robust adjustment could be implemented in COBLO in order to detect and eliminate gross errors (perhaps a COBLO user does it before the author). There are, however, other possibilities which could be implemented without great problems in order to perform an interactive error search during the measuring phase.

After the measurement of a model in a computer assisted plotting instrument, one could form and adjust a small block (subblock) consisting of the current model and of all already measured neighbouring models. This could be done in a block with a large redundancy of ground control points because in this case all so defined subblocks would be sufficiently controlled. If this were not the case, one could proceed as follows:

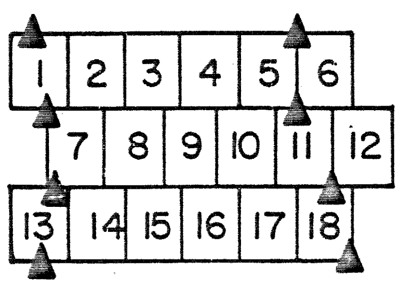

Fig. 4

As soon as the measurement of model 9 is ready, a subblock should be formed consisting of it and the already measured models 1, 2, 3, 4, 7 and 8, because too small a subblock consisting only of the already measured neighbouring models (3,4,8) would not enough be controlled. In this way one could control not only the connection between two adjoining models in a strip, as it is presently done, but the connections between models in neighbouring strips as well.

7. User experience and further developments

The user friendliness of program COBLO does not end with the easiness of its use and the quality of its results. In addition to this, COBLO can be installed by the user himself, and something which is more important: any photogrammetrist familiar with analytical photogrammetry can modify it. One user, e.g., has changed completely the data input in order to keep his previous modus operandi (the point numbering scheme mainly). Another user has extracted from COBLO model orientation data to be used for projector settings in the plotting phase. Another interesting change made by one user resulted in a version for big computers which does not use external storage at all. Of course, this version is extremely fast. Some other users try now to transfer COBLO from FORTRAN to BASIC.

Other important features could be also implemented in COBLO. Some users have shown interest to introduce statoscope and APR data as well as information of shore lines. The preparation of a bundle adjustment would be a very important development, too. This would not be too difficult, because COBLO would not need to be significantly changed in its structure.

The author will try to incorporate this in COBLO, according to his time availabilities, and eventually other developments (for instance additional parameters). At the same time he invites all present and future COBLO users to take part in these developments. He would be happy even in the case of not winning this race.

8. Conclusions

With COBLO we hope not only to offer an efficient tool to "not rich" photogrammetrists, but also to motivate more colleagues for own developments of block adjustment programs. This area of photogrammetric research and development has always been limited to a few leading groups. The photogrammetric community has accepted such programs as black boxes up to now. We do not want to open here a discussion about this topic. In our opinion, the possesion of a good block adjustment program is in many cases not enough. Moreover, the photogrammetrist must understand such program to be able to modify it - if desired - according to his own convenience. This is especially important if research is wanted to be done, for instance, in additional parameters and robust adjustment. The use of the APL language /4/ can be also interesting because it allows the representation of programs in a transparent and concise way.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to "Stiftung Volkswagenwerk" for the financial support of these investigations and to "Deutsche Forschungsgemeinschaft" and "Hochschule der Bundeswehr, München" for the granting of a visiting professorship, and is specially indebted to Professor Egon Dorrer for his many valuable advices.

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