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Interactive adjustment of very large blocks of Independent models with minicomputer and K-Block program

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Abstract: In the first part of the paper the major problems of adjusting blocks of independent models are discussed and, with the emphasis on problems of very large blocks, an efficient program is defined. Then the basic concepts of K-Block, an adjustment program, and some of its features and relative merits are briefly explained.

It is shown that K-Block or similar programs are more efficient in solution of the problems when processing is carried out interactively preferably with minicomputers.

INTERACTIVE ADJUSTMENT OF VERY LARGE BLOCKS OF INDEPENDENT MODELS WITH MINICOMPUTERS AND K-BLOCK PROGRAM

INTRODUCTION

The production techniques used by the survey and mapping industry are constantly under a competitive pressure for increased efficiency. In the industry the motivation for innovation and new developments occasionally differs from that in an academic or scientific environment. This is due, in part, to a lack of a communications system between the three groups. A vivid example of this is the case of the development of computer programs for adjustment of independently triangulated models by people from the different environments.

Since the late 1950's the main burden for the realization of such a program, namely the solution of large systems of linear equations, has been published in mathematical or professional journals. Having this material available, several approaches were pursued in order to present an adjustment program which can function with nearly perfect input data for small blocks. However, in practice, using such programs in large blocks with numerous complex blunders causes disturbing difficulties in obtaining acceptable results.

In view of this situation, this paper discusses the problems, some of the solutions available in the K-Block program and a practical adjustment procedure.

ADJUSTMENT PROBLEMS OF ANALOGUE DATA

It is unlikely any block can be adjusted in the first run, particularly if the block is not small. The problems may occur from a number of sources and the number of trial runs depends, among other parameters, on the geometrical quality of the photogrammetric as well as the field measurements.

Generally, there are two main areas of problems:

1. The input problem which should be tabulated in the results according to their source and nature, such as re-reading the data due to erronous structure, occasional failure of the reading device, etc.

2. What we can call blunder problems, which occur the most frequently of all and can cause repetition of the computations. Many examples of this could be given, but generally they are related to defective

set-up of data, internal unmatchability of different kinds of photogrammetric points and faulty ground control coordinates.

However, depending on the processing environment and the program used, some other undesirable situations might arise, such as computer failure and power interruption, both requiring a repetition of processing. Also, unskilled users of the program are likely to create additional confusion.

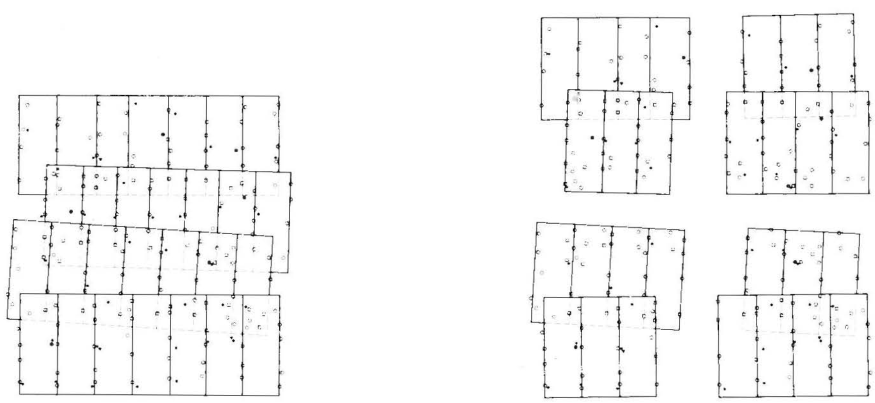
The nature of problems associated with large blocks is proportionally the same as smaller blocks. A problem in a small block can be corrected within a short period. However, a similar problem in a large block becomes critical due to the length of time of the original processing, to which is added further expended time for re-processing the revised data.

The combination of a computer set-up and a specific adjustment program will dictate the practical limits of the number of models which can be adjusted, unless the limits are set by the program itself. In one instance, it could be determined that a large block is one in which the preparation and photogrammetric block size surpasses the practical adjustment limits. Accepting this, a large block for a given program/computer set-up might be a small block for another configuration. It follows that the higher the efficiency of the set-up the larger the allowable size of block for a practical adjustment.

Therefore the conclusion would confirm the intuitively obvious assumption that, under similar conditions, a more efficient multi-purpose program can be defined as one which handles the problems of a large block with less effort and less time.

An efficient block adjustment program should be flexible for use in different computers, correct the systematic errors of ultra-large blocks, automatically and continuously restructure the block to reduce the amount of computation and must have complete pre-computational editing possibility.

A final consideration of some concern in a block adjustment program is the continuity of input/process/output. From an analysis of difficulties in the adjustment of medium to very large size blocks, one should ensure that if the program is not fully and reliably automatic, then it should process the data in different interruptable steps. For example; the four stages could be input, edit, compute and output. Single step programs, in practicality, would only be efficient for small blocks, as it can be an agonizing experience to spend many hours computing a large block to learn that the data structure has been deficient or that the ground control coordinates do not match the photogrammetric measurements or, possibly the worst, when a malfunction occurs in the final stage of printout requiring a reprocessing of the block.



In the figure an example of sub-blocking is shown. A very small block of 28 models is broken into 4 sections. Normal equations are solved for only 4 units instead of 28. This technique at the stage of de-bugging reduces the size of normal equations drastically, especially for very large blocks. Using the K-Block program, the section size can be controlled either automatically by simply defining the size, or manually to obtain sub-blocks of varying size. The latter option is useful only on special cases where there is uneven control density over the block.

K-BLOCK ADJUSTMENT PROGRAM FOR INDEPENDENT MODELS

In 1970 the author wrote and tested a program for large blocks, using the I.B.M. 360/30 computer with 8k words of memory and disk storage. The program was based on least square determination of the parameters of three dimensional similarity transformation for independent models. After putting the program into frequent practical use and gaining experience from numerous difficulties, it was decided to make a complete revision of the program to include the following features:

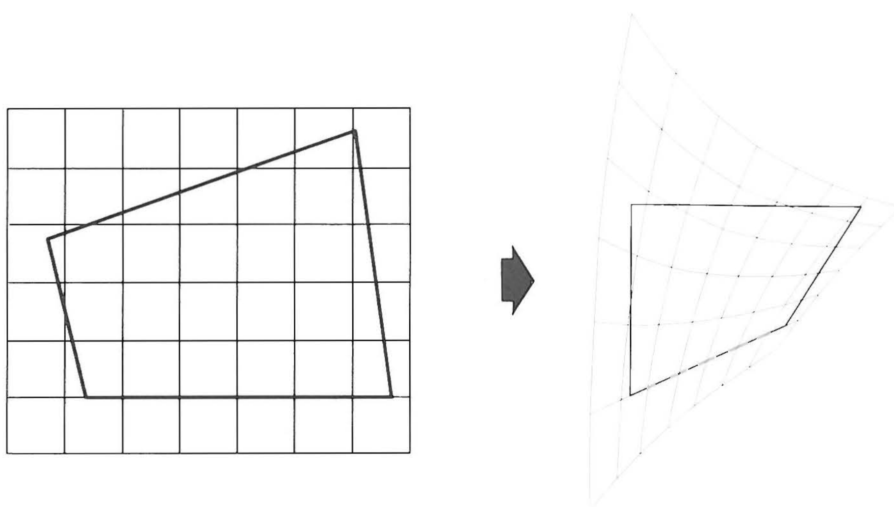
1. Expandability to an automatic system not necessarily requiring skilled operators.

2. Possibility of variable and flexible sub-blocking.

3. Inclusion of corrections for systematic errors.

After many months of development, the resulting multistage program containing most of the above features was operational by the last quarter of 1971.

The table on the next two pages compares the program with two similar programs that are popular in Canada.



A simple example of a transformation developed for correction of systematic errors in deformed films or photogrammetric blocks is shown above. In the figure, a quadrangle is defined by two sets of four straight lines which are called edges. In general, transformation parameters are determined using curved edges and, if available, randomly scattered common points. Application of this transformation to film deformation problems has resulted in an astonishing reduction in the size of the errors which were thought to be uncorrectable due to their complex pattern.

COMPARISON OF THREE INDEPENDENT MODEL BLOCK ADJUSTMENT PROGRAMS - PAT-M43, SPACE-M and K-BLOCK

ITEM	PAT-M43	SPACE-M	K-BLOCK	ADDITIONAL NOTES ON K-BLOCK
Approximate date of publication.	1972	1972-73	1970-71	
Approximate minimum size of memory for the program.	64K	64K	8K	
Independence from specific computer types.	Yes	No	Yes	K-Block is not bound to any specific computer or system, it can be compiled with computers (Mini or Mainframe) which have FORTRAN IV compiler with disk I/O and overlay builder. (When using computers with large memory overlay structure is not essential).
Size of block	No Limit	No Limit	No Limit	By no limit it is meant that only the size of the disk or tape storage limits the size of the block.
Unrestricted coding of photo and control points.	No	No	Yes	In SPACE-M points of different type are specifically coded at preparation stage. For instance the lake points must start with 3. In K-BLOCK there is absolutely no specification for coding. As an example 2015 can be a point of a control, tie, pass, lake, projection center or statoscope type.
Duplicate points allowed.	No	No	Yes	In K-BLOCK different points with identical identification are allowed if they do not occur in adjacent models, adjacent lines or in cross lines.
Automatic or controlled sub-blocking.	No	No	Yes	While running K-BLOCK in "subblock mode" a group of models specified in input (such as 4, 6, 9 ..) are used as a single model, reducing dramatically the size and band width of the normal equations thus making it possible to adjust blocks of ultra large size. The size of subblock can easily be altered at each step of debugging stage enabling the user to control the accuracy of the results. Subblocks of irregular size can also be used for obtaining a stronger block structure or fulfilling specific control requirement.
Precomputation checking and editing of pass points.	No	No	Yes	The pass points can be checked for their geometrical quality and if the computed errors exceed a specified limit depending on the situation either they are edited or computation stops before proceeding to next step.
Gross error detection.	No	No	Yes	In K-BLOCK gross errors are detected to prevent false adjustment. As an example suppose in a block of 5x10=50 models with 4 planimetric control located in the corners of the block, one control point has error of about 250 microns (on plate scale). In PAT-M and SPACE-M programs this error is distributed over the entire block such that the adjustment might look acceptable, while in K-BLOCK the point will be identified as an erroneous point.
Detection of transfer errors of the tie points (PUG error).	No	No	Yes	In most production environments a few percent of the tie points contain a transfer error of 20 microns or more. These points can be singled out in K-BLOCK and if necessary rejected.
Automatic estimation of rotation angles.	Yes	No	Yes	
Simultaneous lake levelling.	Yes	Yes	Yes	
Simultaneous statoscope control.	Yes	No	Yes	
Earth curvature and refraction correction.	Yes	No	Yes	

ITEM	PAT-M43	SPACE-M	K-BLOCK	ADDITIONAL NOTES ON K-BLOCK
Simultaneous systematic error correction.	No	No	Yes	The inclusion of additional parameters for systematic error correction in the normal equations is one of the main features of the K-BLOCK program.
Unique solution for band-width reduction.	Yes	No	Yes	In K-BLOCK the inner band width of normal equations is optimized with a unique solution allowing the projects of large size which have cross lines or two levels of photo be adjusted without an immense increase in the band width.
Automatic identification of points with dubious quality.	No	No	Yes	Depending on weights and quality of different types of measurements, some levels of tolerance are established in K-BLOCK. If a residual (or discrepancy) exceeds its related limit, the point will be flagged (X, Y, or Z). As an example if the block has a point causing errors of about 600 microns in Y of adjacent area, a statistical level such as 563 is computed and all the points having errors in Y larger than this limit are flagged. This process enables the unskilled users of the program to obtain a reliable result, otherwise not easily possible.
Automatic estimation of photo scales and print-out of residuals in units of micron on plate scale.	No	No	Yes	Without the use of any input data, the photo scales of individual models are evaluated such that the computation of errors in units of microns becomes possible. This important uniform scale helps the unexperienced user of the program the easier evaluation of the quality of the block.
Computation of the elements of absolute orientation.	Yes	No	Yes	The elements of absolute orientation are computed for different plotting machines, to reduce the overall set-up time substantially.

From numerous blocks of independent models triangulated with a Wild A-10 and adjusted with K-Block, R.M.S. of about five microns for relative planimetric coordinate residual is achieved. Similar R.M.S. for check points of many blocks has been less than 10 microns.

EPILOGUE

For a specified accuracy, the net density of planimetric control points decreases with the size of the block since only the perimeter of the block has to be controlled. Thus, wherever possible, one should try to form and adjust the largest possible block. On the other hand the average amount of computation increases rapidly and nonlinearly with the size of the block. Also different types of blunders easily removable in a small block might even become difficult to identify in much larger blocks resulting in frequent repetition of more expensive computations.

K-Block program provides a solution to the above problems, as well as offering practically important features which are mentioned in previous pages. The program would produce practically identical accuracies as PAT-M and SPACE-M, except, K-Block is also capable of removing some of the significant systematic errors in a very efficient way. No comparison of the processing speed has been made so far. K-Block is designed for very small memory size

IROQUIOS FALLS 79037 RUN 3 P.S. 8157. #M 28 ,R 1.0

PHOTOGRAMMETRIC POINTS

LOC	TP N	POINT	MOD	LE	RXM	RYM	RZM	
107	3	2042.	406	Z	-3	-2	-25	
211	3	2025.	204	XYZ	-90	-13	52	*R
250	2	2030.	306	XYZ	57	94	-31	*R
336	3	2900.	204	Y	8	16	-3	
372	3	2011.	206	YZ	-12	52	-32	*R

PROJECTION CENTERS

LOC	POINT	MODELS	LE	RXM	RYM	RZM
248	20306.	305 - 306	Y	-4	28	4
298	20202.	201 - 202	X	-35	13	-5

CONTROL POINTS

LOC	POINT	MOD	LE	RXM	RYM	RZM		X	Y	Z	WH	WV
117	460.	406	XY	70	-240		*R	524711.49	5402756.14		0.0	
85	1031.	404	Z			-120	*R			273.44		0.0
131	1027.	407				11	*R			277.77		0.0
146	1036.	301	Z			56	*R			247.63		0.0
194	1017.	303	Z			23				275.92		2.0
235	1013.	305				5	*R			263.39		0.0
403	1001.	101	Z			-49	*R			278.32		0.0

SUMMARY

TYPE	NH	NV	RMSX	RMSY	RMSZ	MAX	IN	POINT	MOD	LOC
PC,S	24	24	15.	13.	7.	35.	X	20202.	201.	298
CONT	7	45	6.	6.	12.	23.	Z	1017.	303.	194
PHOT	300	300	5.	4.	8.	25.	Z	2042.	406.	107

An example of output (or C.R.T. display) of the adjustment of a block of 28 models in the debugging stage is shown above. Instead of many pages of regular output, only the necessary information is printed or displayed. Residual errors are always in units of micron on the plate. In automatic mode the maximum values of the residuals in the summary section could either be used to terminate or to continue the computation. Tolerances are derived for each run from the relevant residuals. Only after terminating the processing the final detailed results are printed out.

This approach of producing the shortest possible output at the debugging stage is especially advantageous for large blocks. In a simulated block of 2,600 models, the average number of pages printed was reduced about 110 times.

and the number of input/output operations might make it less efficient for small blocks. However, for large blocks there is no doubt that, on average, due to the sub-blocking possibility in the K-Block the total amount of computation per model will be much less compared with the other two.

Since a major portion of the program is assigned for checking the structure, the adequacy, and the geometrical qualities of the data, and because many editing possibilities are provided in the program, better efficiency is achieved when the data are processed interactively, specially when dealing with very large blocks.

Experience has shown that with a small minicomputer and K-Block, blocks of thousands of models can be adjusted very efficiently, proving that there is no need for installation of larger mainframe computers in the private mapping environment.

When all or a portion of the hardware cost is amortized, programs such as K-Block can be used more efficiently in an interactive mode with an on-plant mini or even micro computer.

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