MARCH 29-APRIL 3 / BALTIMORE

ASPRS · ACSM / 1987

TECHNOLOGY FOR THE FUTURE,
APPLICATIONS FOR TODAY

TECHNICAL PAPERS

1987 ASPRS-ACSM ANNUAL CONVENTION

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Baltimore, Maryland
March 29 — April 3
ASPRS 53rd Annual Meeting
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COVER PHOTO

Baltimore's Inner Harbor, acquired by the Environmental Protection Agency (EPA) on 22 July 1982 using the EPA-Enviropod camera system.

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FOREWORD

This book is one of seven proceedings volumes of the Technical Sessions of the 1987 Annual Convention of the American Society for Photogrammetry and Remote Sensing and the American Congress on Surveying and Mapping held in Baltimore, Maryland.

These proceedings contain only those papers that were received in time for publication and are listed in the Table of Contents in their order of presentation by Technical Session. Authors are listed in an alphabetical index for the convenience of the reader.

The ASPRS and ACSM Technical Program Committees are grateful to the authors, co-authors, and their typists who contributed their time and talents toward making these volumes possible.

Special thanks go to the ASPRS and ACSM Technical Program Committee members who donated countless hours of their time toward the completion of the proceedings. In addition, the ASPRS and ACSM Technical Program Committees want to thank the society and congress members who assisted in organizing many of the technical sessions by recognizing their participation in this foreword.

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SURVEY DESIGN AND LEAST SQUARES ADJUSTMENTS USING HANDHELD COMPUTERS

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ABSTRACT

Least Squares adjustment methodology allows for an assessment of the accuracy obtainable for a survey project based upon the number, location, types and precision of observations and also on the location of the points. This permits the surveyor to design the field procedures to meet the pre-defined accuracy specification before the survey is undertaken. The paper introduces and discusses the use of this preanalysis methodology currently within the COMPU-LS program.

INTRODUCTION

Within least-squares adjustment methodology there exists a powerful tool for use in the design of a survey. This procedure allow the user to perform a substantiated pre-assessment of the accuracy obtainable for the project prior to field measurements being undertaken. This procedure is commonly known as preanalysis.

The software program COMPU-LS, written at Martin & Company Ltd., contains pranalysis as one of it's basic routines.

This paper gives an overview of preanalysis in an attempt to de-mistify and familiarize the use of this tool.

OVERVIEW OF PREANALYSIS

Pre-analysis refers to the procedure of determining, by propogation of variances, point position accuracies given the geometry of the network, proposed observations and proposed instrument accuracies. By least squares adjustment methodology, these three variables can simulate the desired accuracies and allow for fine tuning of the survey prior to starting any field work.

Geometry is supplied to preanalysis through the input of proposed station coordinates. These coordinates can be derived from the specification of the project, scaled from a map or from the knowledge of what is required for the project.

Once the geometry is defined by the coordinates, the planned observations are used to mathematically connect the survey into a system of equations. The observation types and numbers give the mathematical formulation a base in which to compute whether this system of equations can be solved. In general, the rule is that the number of unknown parameters ie. coordinates must be less than, or equal to the number of observations. This assumes that each coordinate has enough information be to solved for. When the number of observations exceeds the number of unknown coordinates, the true power of least squares is realized. This redundancy of data allows for statistical testing of the adjustment and the ability to check for blunders in the observations.

The traditional observations can be azimuths, distances, directions or angles while other non-conventional observations such as coordinate differences could also be included into the preanalysis formulation.

The last item required for preanalysis is the available instruments with their corresponding accuracies. These accuracies are used to define the uncertainty in the proposed observations and thus lead to the uncertainty of the coordinates being solved for (Mepham, 1983). This is the most important part of any least square calculation as it is the connection that takes the geometrically defined problem into a statistically based system.

OUTPUT FROM PREANALYSIS

The uncertainty in the proposed observations for preanalysis propogate through the mathematical formulation into uncertainties in the results. This uncertainty or accuracy is shown by confidence regions commonly referred to as error ellipses. There are two types of error ellipses within a survey and both are a direct product of preanalysis.

The first type of error ellipse is the relative error ellipse. This shows the relative accuracy between two points with respect to each other. Figure 1 shown below, illustrates how a relative error ellipse may be interpreted.

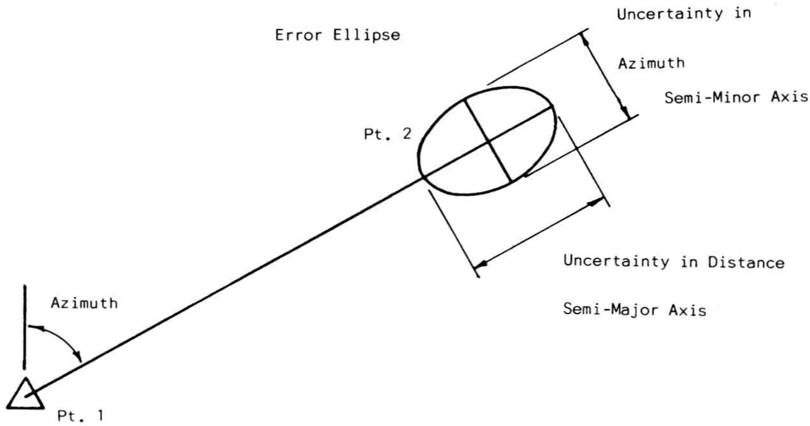

Figure 1. Error Ellipse

Letting Point 1 in Figure 1 be the starting point and measuring a azimuth and distance to Point 2, the associated uncertainties at Point 2 would be as illustrated in Figure 1. If both of these uncertainties were equal, then the resulting circle encompassing their length would be the relative error ellipse. If however, these were not equal, then the resulting figure would be an ellipse (as shown in Figure 1), with the larger of the two uncertainties being the semi-major axis and the other the semi-minor axis. This would be the standard relative error ellipse of Point 1 to Point 2.

One qualification needs to be stated about this example. There are no other points or measurements connected to Point 2. In practice, the relative error ellipses are not always aligned along the direction of Point 1 to Point 2 as Figure 1 illustrates. This results from other network information influencing the coordinates of Point 2 from the Least Squares process.

If we were to take Point 1 in Figure 1 as a fixed point ie. the coordinates are not allowed to change as in a control point, then the resulting error ellipse would be the station error ellipse. This is sometimes referred to as the absolute error ellipse and reflects how accurately the station has been positioned (Mepham, 1983).

Both the relative and absolute error ellipses, when first calculated, have an associated probability level of 39% (ie. there exists a 39% chance or probability that the true position exists within the boundaries of the ellipse) (Mepham, 1983). This is not a sufficient level and thus standard practice is to increase this probability to the 95% level by scaling the error ellipse parameters by expansion factor. (Vanicek & Krakiwsky, 1982).

SURVEY DESIGN USING PREANALYSIS

It should be apparent at this point that the information required to compute the accuracy (error ellipse) parameters can be changed or modified. There exists three general approaches to obtain the required accuracy, (Vanicek & Krakiwsky, 1982). The first approach consists of having the equipment set the accuracies and designing the survey in regards to the geometry number of observations and their type. The second is when the geometry is held fixed and the equipment along with the observations vary. The last case is where all the information ie. geometry equipment accuracies, number of observations and types vary. Modifying the required information leads to the approach whereby the parameters are varied until the preanalysis output meets the desired tolerances.

COMPU-LS

Pre 1985, there existed few Least Squares programs on the market and of the ones that did exist, none were on handheld computers. In the spring of 1985, Martin & Company Ltd. released the COMPU-LS package for the Hewlett Packard 71-B computer. This program with a COGO base front end came with a complete least square adjustment program. This package had the advantage of being very portable for use in the office and the field. This aspect allows the design stage of the survey preanalysis to be easily transferred to the field for on site and reconnaissance updating. New points could now be incorporated or deleted along with changes in the amount, type or location of observations as the terrain dictated. The ability to use preanalysis for an assessment of how these changes will affect the survey before the measurements are undertaken now become possible.

EXAMPLE

The following example illustrates the preanalysis approach to survey design. Figure 2 is a simple traverse of four (4) points from one central monument. The proposed equipment was a 20" theodolite and an EDM accuracy of 5 mm and 5 ppm. Table 1 shows the output from the first run of prenalysis whereby the points are connected by the traverse. As the traverse moves away from the fixed point, the station ellipse parameters clearly demonstrate that the uncertainty is increasing with point 4 being the most uncertain. This is also clearly shown by the relative error ellipse parameters as the relative accuracy between two stations are influenced on the station accuracy.

SCALE=1:15000

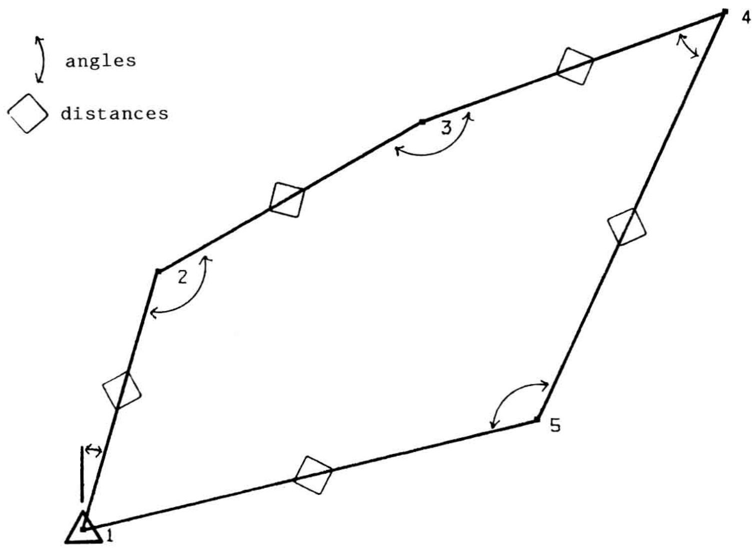

Figure 2

95% RELATIVE ERROR ELLIPSES

POINTS FROM	TO		ELLIPSE AXES SEMI-MAJOR	SEMI-MINOR	SEMI-MAJOR AZIMUTH	DISTANCE	PRECISION	ORDER
ORDER SPEC: USA								
ELLIPSES SCALED: NO								
2	3		.167	.040	148° 23'	806.226	1: 4814	-
2	4	relative error	.320	.054	152° 30'	1655.295	1: 5164	3II
3	4	ellipse	.191	.040	156° 54'	854.400	1: 4464	-
3	5		.139	.091	179° 31'	854.400	1: 6143	3II
4	5		.156	.041	118° 22'	1208.305	1: 7766	3II
2	1	station	.043	.040	105° 56'	728.011	1: 16848	3I
3	1	error	.179	.055	144° 27'	1421.267	1: 7930	3II
4	1	ellipse	.329	.062	150° 5'	2202.272	1: 6699	3II
5	1		.243	.042	166° 59'	1236.932	1: 5085	3II

Table 1

SCALE=1:15000

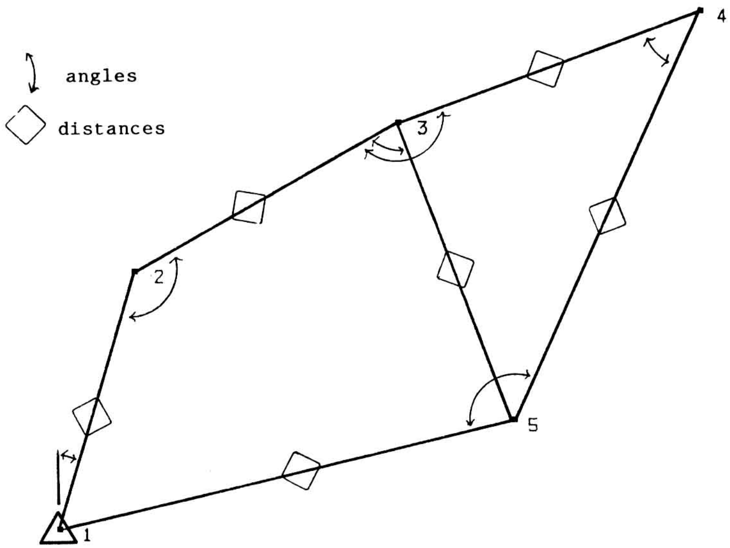

Figure 3

95% RELATIVE ERROR ELLIPSES

ORDER SPEC: USA
ELLIPSES SCALED: NO

POINTS FROM	TO		ELLIPSE AXES SEMI-MAJOR	SEMI-MINOR	SEMI-MAJOR AZIMUTH	DISTANCE	PRECISION	ORDER
2	3		.147	.040	147° 5'	806.226	1: 5497	3II
2	4	relative	.249	.050	149° 44'	1655.295	1: 6655	3II
2	5	error	.157	.053	175° 53'	1077.033	1: 6850	3II
3	4	ellipse	.126	.038	153° 20'	854.400	1: 6785	3II
3	5		.094	.039	67° 5'	854.400	1: 9069	3II
4	5		.151	.039	118° 52'	1208.305	1: 8006	3II
2	1		.043	.040	105° 56'	728.011	1: 16848	3I
3	1	station	.160	.053	142° 12'	1421.267	1: 8865	3II
4	1	error	.261	.056	146° 14'	2202.272	1: 8444	3II
5	1	ellipse	.164	.041	169° 16'	1236.932	1: 7562	3II

Table 2

Table 2 and Figure 3 show how much one cross tie influences the traverse, point 3 is connected to point 4 by an angle and a distance. Point 4 station error ellipse parameters have now been improved, especially the semi-major axis from .329 ft to .261 ft. (an improvement of 20%). On further inspection, it becomes apparent (from the orientation of the error ellipses) that the major contribution to the error ellipse parameters are from the proposed angle measurements. A further reduction in the variance associated with the angles (by doing rounds, etc.) would reduce the size of these error ellipse parameters. The order on Table 2 is now clearly 3rd order, class II. It should also be noted that by using the network of Figure 3, the adjustment must be done by least squares and thus the adjustment in which blunder detection could be used for further preanalysis of the results.

The above example although simple and small in size, illustrates how least squares preanalysis can be used to predict the accuracy of the survey. It also illustrates how cross ties can be incorporated to strengthen a survey.

SUMMARY

Preanalysis can be a useful tool for survey design. It allows for an assessment of the accuracy obtainable given the geometry of the survey, the types and number of observations and lastly the equipment accuracies.

The program COMPU-LS on the Hewlett Packard 71-B computer gives a portable, easy-to-use survey computation system. Both survey design and post adjustment of the data can easily be done on this one-per-desk system.

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EXCEL-ENCE IN SURVEYING COMPUTATIONS

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BIOGRAPHICAL SKETCH

Arthur McLaughlin is an Associate Professor in the Department of Civil Engineering Technology. He is faculty advisor to the Joseph E. Glickman Memorial Student Chapter of the American Congress on Surveying and Mapping, and is a Fellow in ACSM, and its three component groups - NSPS, ACA, and AAGS. He is also a member of ASPRS. He teaches departmental courses including those in surveying and photogrammetry, and is a Professional Engineer in New York, and Florida, and a Land Surveyor in those states as well as Indiana. He received his BCE from Manhattan College, and an MSCE from Rose-Hulman Institute of Technology, and has taught at Alfred for 6+ years. He is active in the New York State Association of Professional Land surveyors, and is a director to two of its regionals. Besides being a computer proponent, he is a member of the Apple Programmer's and Developer's Association.

ABSTRACT

Surveying software for the Apple Macintosh computer is still difficult to acquire, although there are certain programs on the market. In the interim, there is a product which can be used with little or no knowledge of computer language(s) to form sophisticated programs to solve surveying and mapping problems. The product is EXCEL, from the Microsoft Corporation. This paper will demonstrate how the EXCEL environment, complete with macros, can be used to form templates for a variety of computations. Besides being a powerful multifunctional spreadsheet, it includes graphics, database, and a logical print/plot routine. For those surveyors using a Macintosh, there is no need to reinvent the wheel, or wait for menu-driven programs. EXCEL is not just software for business applications - it can be easily mastered, and provide the professional with power, speed, and flexibility in writing programs, again without the drudgery of mastering a computer language. Besides providing a series of examples taken from surveying textbooks, the paper will contain is a list of resources to get the user "up and running". Learning EXCEL takes a while, but the power of the software makes it well worth the effort.

INTRODUCTION

During the past few decades, computers have changed the way surveyors perform their calculations. Many of us have been in practice during this transition, and have traced a circuitous path from log tables to natural functions and rotary calculators, on to battery operated calculators, and finally to programmable calculat ors. TI and HP are examples of this, the former with algebraic notation, and the latter with reverse Polish. Personally, this also included excursions into the nuances of Wang, and Compucorp/Monroe. These experiences led me to a confidence that I could easily "program" most surveying calculations, provided they didn't exceed the memory resident in the machines. Then surveying moved on to bigger and better hardware. No longer was a pocket calculator "state of the art", rather it took a place on the backburner to the computer, this time possibly a mini or micro. As prices came down, the move was from calculators to computers. But lest we totally abandon this technology, remember, if you will, how easy it was to program calculators to perform all sorts of repetitive calculations. There was something almost mystical in being able to control the input and output. Surely there are a number who still fondly remember turning on a calculator, entering in a keystroke sequence, and there you have it - a program. The use of a spreadsheet type of software appears to be a throwback to an earlier, simpler time. But beyond this, they have the capability to support graphics (in the form of charts), and databases, giving the best of the past, present, and future.