

MARK HURD AERIAL SURVEYS, INC.

The technicians of Mark Hurd's Santa Barbara Office are perfecting a "Miniprinter" which will enable a photogrammetrist to print aerial negatives at a 50 per cent reduction. This is planned to save time and space in the indexing phase of photogrammetric practice and the filing of proof prints.

SYRACUSE UNIVERSITY

Syracuse University has completed a study of Photogrammetric Measurements of Dynamic Displacements. The study was sponsored by National Science Foundation and conducted by B. A. Wasil, D. C. Merchant and J. J. Del Vecchio. An analog method has been developed during the investigation in order to reconstruct the bundle of imaging rays from two or more camera stations. The reconstruction is made to generate a three dimensional optical model of the vibrating plate effectively fixed in some selected phase of the oscillatory cycle. The Porro-Koppe principle has been employed. Viewing of the model is accomplished through stereo observation of the processed negatives directly by means of special stereoscope located above the projection camera. The three dimensional model is plotted by introduction of a reference mark into optical model consisting of a point source of light and located under the projection cameras. The instrument is able to provide the evaluation of close-up photographs.

THE BUNKER-RAMO CORPORATION

The Corporation has been engaged in the past with research on automatic map compilation from stereo aerial photograph. Automatic

extraction of altitude data and simultaneous preparation of an orthographic projection photograph as a step in the production of topographic maps was proved feasible with the development of the Automatic Map Compilation System. A second generation system for use in a production environment, the Universal Automatic Map Compilation System equipments (UNAMACE) have passed initial acceptance tests. These systems use hybrid analog and digital techniques to locate corresponding imagery on stereo pairs of aerial photographs to determine attitudes and expose a new photograph on which the image elements appear in correct map relationship with all photographic distortion removed. These instruments besides being fast and accurate compilation instruments, have a 4-micron r.m.s. capability as comparators, and the associated computer has been programmed to perform resection calculations.

WILD HEERBRUGG INSTRUMENTS, INC.

An experiment with super-wide-angle photographs using Wild A9 Plotter has been completed as reported by Prof. Hugo Kasper, Federal Institute of Technology, Zurich. The experiment utilized photographs taken of 2,900, 4,400 and 7,200 feet altitudes over a test area that had previously been surveyed for cadastral purposes. The standard error for the A9 compilation with the lowest altitude found to be ± 23 cm. horizontally and ± 18 cm. vertically. With this investigation it has been pointed out that the users of the A9 and B9 group of instruments in developing countries are able to produce engineering plans or cadastral maps at the scale of 1:2,000.

Recent Research and Development Activities in Aerotriangulation

by H. F. Soehngen

A NUMBER of large photogrammetric organizations have continued research and development programs in aerotriangulation. The major emphasis is on the development of analytical aerotriangulation techniques utilizing medium and large size electronic computers.

A report in detail of the activities of the agencies which answered a questionnaire will indicate the scope of the large effort being exerted to automate this branch of photogrammetry.

U. S. GEOLOGICAL SURVEY

The current investigation of the Topographic Division encompasses two general approaches to the aerotriangulation problem, the analytical and semianalytical. Both systems utilize electronic data processing procedures in conjunction with digital readout equipment.

The *analytical* system derives both vertical and horizontal positions of ground points by a purely mathematical approach of an iterative, simultaneous, least squares adjustment based

on the Herget method. Input for the computer program, written for the Burroughs 220 computer, consists of: x and y photocordinates of control points and pass points measured with a precise comparator, known horizontal and vertical control data; estimates of camera orientations and space positions; and corrections for camera lens distortion, earth curvature and atmospheric refraction. The program will solve aerotriangulation problems in any configuration of up to 22 photograph elements. Successful tests of the system have recently been conducted with data obtained from a specially developed control site near Phoenix, Arizona, and at the present time the system is being applied to a quadrangle mapping project. Initial results of the latter project using 12,000-foot flight height vertical glass-plate photography indicate a vertical RMSE of 1.0 feet and a horizontal RMSE of 4.2 feet for 50 photos, using 25 vertical and 4 horizontal control restraints.

In the *semianalytical* approach the relative horizontal positions of supplemental pass points in each stereomodel are digitized in terms of x and y coordinates and recorded by automatic readout devices. The digitized model data are joined analytically by use of electronic computer programs to form strips which are adjusted to ground control and to each other. The final results are passpoint coordinates that have been determined through a block adjustment.

Several different semianalytical procedures are being studied. One method forms cross strips transverse to the flight strips by linking together sections of adjacent flights before adjusting to ground control. A second method computes the transformation factors between strips, then between the resulting block and known control. In a third method the horizontal projection of the stereomodel is considered the basic unit being adjusted in a simultaneous least squares block solution. The program for this method allows models, sections, strips, or blocks to be adjusted simultaneously. At the present time a test of this third method is being conducted utilizing the same source of input data as described under the analytical system. The results of this test will be compared with the analytical test results with special emphasis regarding the accuracy of the results.

RAYTHEON (AUTOMETRIC OPERATION)

1. A complete system of analytical aerotriangulation for USAE (GIMRADA) has been developed and programmed for operation on the IBM 7090-94. Characteristics of

this system are the ability to solve for the exposure station positions and camera attitudes of up to 100 photographs, simultaneously. The formulation includes the capability of applying weight matrices to the exposure station parameters and to ground points. The solution is carried out either in geocentric or local vertical coordinate systems at the option of the operator. Input and output data are in geographic coordinates. Both partially given and complete ground control points can be incorporated. The program includes inversion of the normal equation matrix and propagation of errors to the pass point coordinates. The system has been tested on both fictitious and real photography.

2. Also under contract to USAE (GIMRADA), a system of analytical triangulation has been developed and programmed in FORTRAN IV which is patterned essentially after that of the National Research Council in Canada. That is to say, the relative orientation of photographs are computed sequentially. This is followed by a strip transformation to ground control. Then the individual strips are adjusted using a procedure similar to that adopted by the U. S. Coast and Geodetic Survey. Finally, the strips are assembled into a block using an iterative solution. This system has also been tested on fictitious and real photography.

3. Another program for analytical aerotriangulation has been developed for Raytheon's own use. In an arbitrary rectangular coordinate system, the position and attitude of a block of up to twelve photographs are computed simultaneously using relative orientation and scale restraint equations. The program steps automatically from one block of twelve photos to the adjacent overlapping block until all photographs in the project are positioned and oriented. The coordinates of all pass points are then computed in the arbitrary coordinate system. A linear transformation of these points to ground control is followed by a polynomial adjustment. The degree of the polynomials can be selected by the operator. The system has been applied to cadastral surveys for the Bureau of Land Management.

4. In anticipation of application to lunar photography, Raytheon has been working on methods of incorporation orbital constraints, stellar attitude data and altimeter data into an extensive triangulation network.

U. S. COAST & GEODETIC SURVEY

1. New computer programs for analytic strip aerotriangulation have been placed in

operation, reducing the cost, time, and human effort, with significant accuracy improvement. The programs are being documented for public use.

The Coast and Geodetic Survey has completed the rewriting of the major portion of its computer programs for analytic aerotriangulation. The new programs incorporate numerous improvements which were uncovered during the past five years experience using the original programs. In addition, the need for human intervention and decision has been eliminated wherever possible. At the same time, the Bureau has undertaken to publish the programs in the Fortran language for the purpose of expediting the application by the public of analytical aerotriangulation methods.

The completed programs include: systematic correction of observed image coordinates, three-photo camera orientation, and horizontal and vertical strip adjustment.

2. A block-type of analytical adjustment by strips has been programmed and tested in various ways to determine error propagation characteristics.

3. Block adjustment itself is in productive use on a limited scale, including Fortran computer programming designed to minimize human operations. Modifications are in process for enlarging the system to adjust 200 photographs simultaneously.

4. Low-altitude, maximum-precision, glass-plate aerotriangulation has been repeated for the detection of earth movement over a fault line. The initial study resulted in an r.m.s. space vector residual of 2.8 microns at the photograph scale *after* the imposition of control data.

5. A spatial triangulation system has been developed in detail and reported.

6. A "single-camera" analytic program has been modified so that it now contains 26 degrees of freedom.

THE OHIO STATE UNIVERSITY

At the present time, research in aerial triangulation is being performed particularly for the Ohio Department of Highways and the U. S. Bureau of Public Roads. This research program deals with the analysis and recommendation of aerial triangulation procedures which are most effective for highway surveying and mapping. For this purpose an inventory on existing ground control in the State of Ohio was made. The analysis (among other phases) covers research, performed at the Wild Autograph A7 of the Department of Geodetic Science and the Analytical Plotter AP/C of the Ohio Department of Highways,

as well as the study of various analytical aerial triangulation methods. The analysis revealed that most of the recent methods should be modified or simplified if analytical aerial triangulation were to become more sufficient than instrumental aerial triangulation. Continuous change of computer models, computer programming techniques, and languages is another reason for a rather unsatisfactory efficiency and economy of analytical aerial triangulation.

In connection with this research program a global adjustment procedure of aerial triangulation was established. This adjustment not only covers orientation elements such as bx , by , bz , ϕ , ω , κ . These adjusted orientation elements are directly introduced into second order stereoinstruments used for map compilation. Tests have shown that in this case the models set-up in the second-order stereoinstruments are nearly ready for plotting. The establishment of small corrections does not take more than 15 minutes and the model is ready for plotting. This time requirement favorably compares with the usual model set-up time of two hours or more when no adjusted orientation elements are used.

Another aerial triangulation research program which is presently performed by the Photogrammetric Research Group of the Department of Geodetic Science is the use of aerial triangulation to measure ice surface movements in the Antarctic. This project is sponsored by the National Science Foundation. A strip triangulation of 375 kilometers has been performed between Byrd Station and the Whitmore Mountains in the Antarctic. For this purpose markers were placed on the snow surface and the method of independent geodetic control was used. This aerial triangulation will be repeated at intervals in the future. In this way horizontal and vertical ice flow vectors are obtained.

Research on super-long aerial triangulation and on aerial triangulation using auxiliary data is also being continued.

THE UNIVERSITY OF ILLINOIS

1. *Mono versus Stereo Analytical Photogrammetry*. This project is sponsored by GIMRADA. The first stage, currently underway, involves a laboratory investigation of the precision of point transfer in each method. A WILD STK-1 Stereocomparator and a WILD PUG Point Transfer Device, equipped with special floating marks and drills, are being used for these experiments. This project is conducted in close coordination with

GIMRADA's in-house research study "Visual Problems in Photogrammetry."

2. *Analytic Aerial Triangulation for Highway Location and Design.* This project is currently conducted as an in-house study, and is fully expected to be sponsored by Illinois Highway Research Council and the U. S. Bureau of Public Roads in the near future. The studies deal with the introduction of the highly developed techniques of analytic aerial triangulation to highway location and design, in an effort to reduce the amount of ground control necessary for photogrammetrically compiling maps and making the precise measurements for such purposes. Experimental research is being conducted to determine the technical and economical feasibility of using stereoscopic and monocu-

lar analytic aerial triangulation for highway surveying and map compilation. Available electronic computer programs will be tested for efficiency, and one will be recommended for adoption.

3. *Studies in Spatial Aerotriangulation.* This is a long-range-in-house project involving the study of the character of errors in spatial aerotriangulation in both its analog and analytic approaches. A major part of the experimental phases of this project has been conducted as integral parts of world-wide experimental research program organized by I.S.P. Some of the findings in earlier stages of this project have been reported in PHOTOGRAMMETRIC ENGINEERING, *Photogrammetria* and *ASCE Proceedings (Journal of the Surveying and Mapping Division)*.

Recent Research and Development Activities in Mapping from Photographs

by Dr. S. K. Ghosh

LETTERS were mailed to twenty organizations in this country who are believed to be handling some research work in the general area of Sub Committee IV (i.e., Mapping from Photographs). Only twelve of them replied. The following is the general impression drawn from the twelve replies:

An increased use of Super-wide-angle photography has been noticed. Research in this area is very extensive.

Increased use of airborne recorded auxiliary data in aerial photography to further reduce ground survey work has also been noticed.

It has been observed that there is a tendency towards increased use of electronic computers in the supply of control to facilitate mapping in Engineering Photogrammetry and in Cadastral work apart from Topographical mapping work.

Generally speaking, almost everyone is doing research in Aerotriangulation and other phases of Analytical Photogrammetry as supplementary aid to Mapping from Photographs.

Several colleagues indicated that the tendency should be towards automation of the measuring and plotting processes through

more compact and more precise instruments.

Particular mention is made of the following organizations and the Research areas significant to this sub committee:

1. *U. S. Army Engineer GIMRADA.* Work on Image Quality and Measuring precision and the relationship between them.
2. *U. S. Coast and Geodetic Survey.* Color photography (aerial) is being used more and more. Constant improvements in the photographic materials and the cameras. Film distortion tests. Analytical Strip Triangulation, Block Adjustment, Study of Ocean currents as important in mapping.
3. *U. S. Geological Survey.* Super-wide angle photography systems development including the testing of special plotters. Experimental color photo mapping. Research on orthophotomapping. Analytical and semi-analytical aerotriangulation for control supply in mapping in general. Developing the system of Digitized Photographic Data Acquisition.