ONLINE DISPLAY OF AEROTRIANGULATION RESULTS

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SUMMARY

A highly desirable attribute of an online triangulation system is the capability to present, on demand, results in various graphic and tabulation formats. This attribute assumes greater importance when dealing with larger photo blocks since it significantly enhances error detection and correction operations. Data base management techniques, computer graphics, and real-time processing were utilized to create an experimental environment for exploring some options in the online display of aerotriangulation results.

BACKGROUND

Two years ago, a research project* was initiated to explore the feasibility of a software system which can provide least-squares computational support to all adjustment programs in the allied fields of photogrammetry, geodesy, and surveying. This effort culminated in the production of a prototype software system named Generalized Adjustment by Least Squares (GALS)[1], Successful testing and evaluations of the prototype of GALS resulted in a decision to proceed with a production-oriented version. This version was completed during the third quarter of 1983.

The implementation of GALS achieved two primary objectives: (a) standardization of least square computation for all network adjustment problems; and (b) creation of a facility by which highly complex network adjustment software can be brought into operation in a very timely fashion and with a great deal of confidence in the accuracy and integrity of the software.

Having completed the GALS least squares module, a planning effort was initiated on the definition of an experimental environment for a typical network adjustment system [2]. Analytical aerotriangulation of frame photography was the selected model for the network.

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* Work described in this paper was conducted while working for the U.S. Geological Survey.

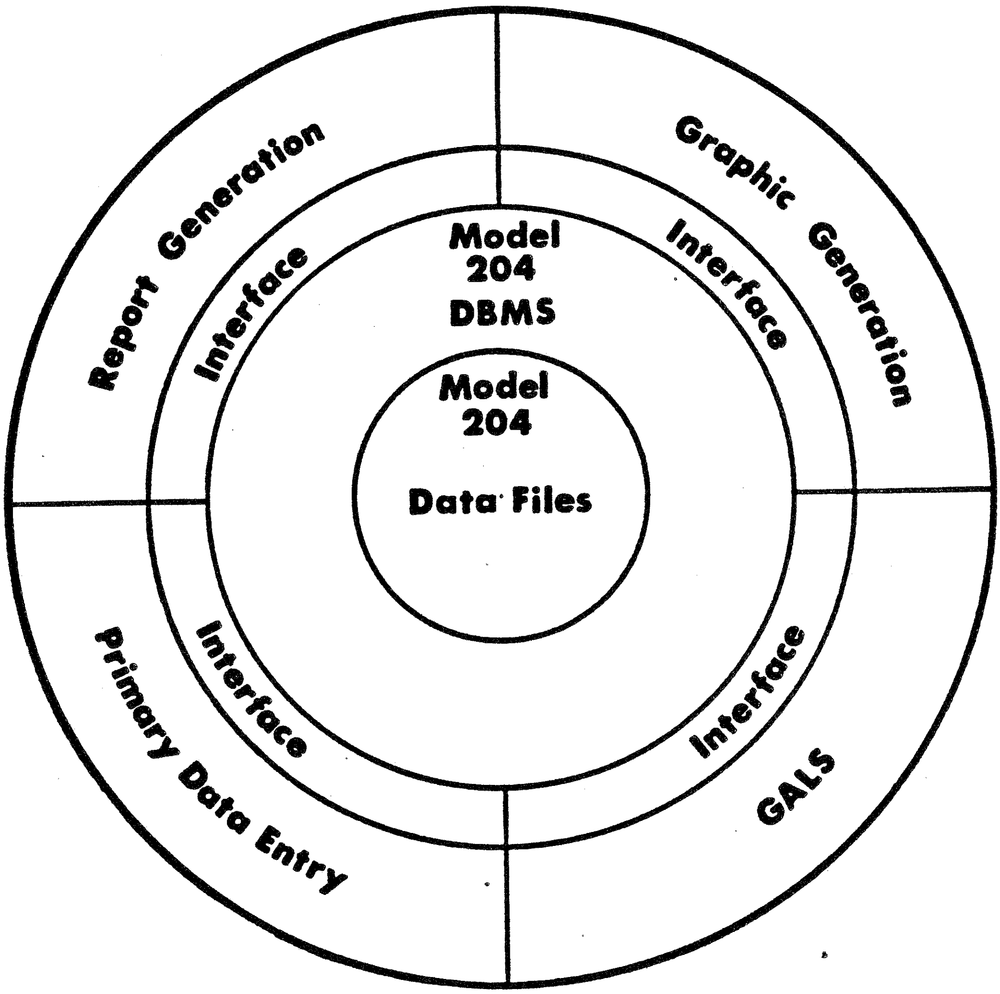

Figure 1. Logical Model of the Network Adjustment Environment

Logical Model of the Operating Environment

The environment chosen to experiment with GALS is schematically depicted in figure 1. At the core of this environment is the data base. Within the data base are related parameters which characterize a typical aerotriangulation problem, for example, camera constants, camera orientations, object point coordinates, and image point coordinates. The data base also contains information which defines the data structure of these parameters and their associated statistics.

The data base management system (DBMS), which was selected for the experiment, is the Model 204 software product of Computer Corporation of America [3]. Model 204 is a generalized DBMS designed to support users of operating systems on IBM or compatible computers. Model 204 provides rapid access to online files and features a user language with considerable selective power. The user language is easy to learn and use, in addition to being capable of composing detailed or complex inquiries or reports. The system also supports a host language interface, thus allowing communications with application programs which are written in COBOL, PL/1, and FORTRAN.

Operating Environment

The operating environment calls for four subsystems which interact with the control DBMS:

1. Primary Data Entry Subsystem - The initial loading of the data base is expected to come from a multitude of sources. The nature of these sources will vary, as will the techniques for data capture, verification, and reporting. The types of equipment and organizational standards will dictate the functional requirements for the components of this subsystem. In the current experimental system, the Primary Data Entry subsystem is simulated rather than implemented. Here a text editor is used to create and modify all primary input files to the DBMS in the designed formats.

2. GALS Subsystem - GALS is responsible for least-squares adjustment of the photogrammetric block or sub-block supplied through the DBMS. GALS requires three data sets for its operations. These three data sets are automatically produced by Model 204 for any selected portion of the data base. The first of these data sets is a network definition data set which informs GALS of the structure of the network that will be subjected to least-squares adjustment (photogrammetric block, geodetic triangulation, leveling network, etc.). The second data set contains all basic observations on the network. In case of photogrammetric aerotriangulation, the basic observations are photo image coordinates and associated statistics. The third

data set contains initial estimates for problem parameters and associated statistical data. For this experiment, photo positions and altitude, camera interior orientations, and spatial coordinates of object points are the problem parameters.

The results of an adjustment are reflected in the form of numerous transformations of the contents of these three data sets. They are formatted in the same basic structure as the input and therefore are used to directly update the contents of the data base.

3. Graphic Generation Subsystem - Graphic portrayals of the adjustment results are produced by this subsystem. In a mature and fully developed system, graphics are expected to provide the primary form of display for network adjustment results. They are also expected to assume an important role in the command and control of system functions. In the current experiment, the role of this subsystem was restricted to the production of graphics representing selected parameters of the aerotriangulation process.

4. Report Generation Subsystem - Reports of triangulation adjustment results and statistics are created by this subsystem. Report generators can operate on all the contents of the data base or on a selected portion of it.

Facilities

The hardware/software facilities that were used in the experiment consist of:

1. The Amdahl model V7 computer at the U.S. Geological Survey National Center in Reston, Virginia, running under an IBM operating system.

2. All programming was done using PL/1 language.

3. Access to the main frame computer was done through a Tektronix model 4114A computer display terminal. This is a high resolution graphics terminal (4096x3120 displayable points) with a 19-inch diagonal screen. The terminal has local intelligence and supports a restricted, flicker- free, refresh display in addition to its standard high resolution storage tube display. Local intelligence allows for the partitioning and local storage of picture segments. Local picture segments (a group of graphic primitives describing a portion of a picture) are redrawn and manipulated locally as one unit. A local segment can contain graphics as well as text. They can be rotated, scaled, or moved around the screen using the local computing capabilities of the terminal.

Operating Mode

Following the initial loading of the data base, using the simulated Primary Data Entry subsystem, complete control over the aerotriangulation process is exercised through the Tektronics terminal. A typical aerotriangulation process will proceed in the following fashion:

1. Instructions are issued to Model 204 DBMS to extract data for the block which will be the subject of the aerotriangulation adjustment. The interactive user language facility is used to achieve this step. A complicated query can be greatly facilitated by using the stored procedure facility of Model 204 [4]. This step results in the creation of all data files required for the operation of GALS.

2. GALS is then invoked to perform the aerotriangulation adjustment of the selected block in the previous step. GALS results are all reflected in modifications of the contents of the input data sets. In this fashion the adjustment results are communicated to the data base through data sets which are identical in structure to those used for data retrieval.

3. Display of the adjustment results can then proceed in the form of graphics and tabulations. These are a preset menu of available output options. As future output components are developed, they can be added to the menu. The user can initiate the creation and subsequent transmission to the terminal for local storage of any graphic component that is available in the menu. It is worthwhile to mention that all display elements (graphs and tabulations) are created as picture segments. They are therefore amenable to display manipulation (scale change, rotation, and translation) using the local terminal intelligence.

The display menu allows for the creation of seven different kinds of graphic elements. Some of the elements pertain to the whole photo block and the others to individual photographs. Block-oriented elements consist of: 1) a plot showing foot prints of all photos in the block; 2) a tabulation of pertinent statistics about the various elements of the block (figure 2).

The photo-oriented elements consist of: 1) a plot of the photo showing image locations, vectors of image residuals, and photo exterior orientation parameters (figure 3); 2) orthographic projection of the photo showing object point positions before and after the adjustment. This plot also shows the projection of photo boundaries before and after adjustment; 3) tabulation of adjusted image and object coordinates as well as photo orientation parameters; 4) tabulation of corrections and residuals of image and object coordinates, and of photo orientation parameters; 5) tabulation of a posteriori estimates of standard

PHOTO STATISTICS

I - POSITION:

Photo (PHOTO 3-1) has Max total correction =			1457.15	
Max component correction	:	1455.09	146.93	73.94
At photos	:	PHOTO 3-1	PHOTO 1-3	PHOTO 3-4

II - ATTITUDE:

Photo (PHOTO 2-4) has Max total correction =			+003 21 58.418	
Max component correction	:	+001 28 09.153	+001 50 20.205	+003 15 18.459
At Photos	:	PHOTO 3-1	PHOTO 1-3	PHOTO 3-4

OBJECT STATISTICS

Point (PT 4053) has Max total correction =			2969.27	
Max component correction	:	1517.38	1449.98	2466.43
At points	:	PT 4051	PT 4053	PT 4053

IMAGE STATISTICS

	Photo	Image Residuals (X,Y,Z)			Image Identifications		
	PHOTO 1-1	8.8	11.0	14.0	PT 4005	PT 4003	PT 4005
	PHOTO 1-2	7.7	10.4	10.4	PT 4005	PT 8000	PT 8000
	PHOTO 1-3	4.6	3.9	5.7	PT 4005	PT 4006	PT 4006
	PHOTO 1-4	3.5	2.8	3.8	PT 4008	PT 4006	PT 4008
	PHOTO 2-1	6.1	9.8	11.6	PT 4036	PT 4036	PT 4036
	PHOTO 2-2	6.7	8.4	9.0	PT 4038	PT 4037	PT 4037
****	PHOTO 2-3	16.4	14.8	22.1	PT 4005	PT 4005	PT 4005
	PHOTO 2-4	8.8	6.8	9.6	PT 8038	PT 4037	PT 8038
	PHOTO 3-1	3.1	10.8	10.9	PT 4036	PT 4054	PT 4054
	PHOTO 3-2	5.8	9.3	9.3	PT 0106	PT 4038	PT 4038
	PHOTO 3-3	7.3	10.8	10.8	PT 8038	PT 2125	PT 2125
	PHOTO 3-4	7.6	11.7	11.7	PT 4042	PT 4056	PT 4056

NOTE: **** = PHOTO with Largest Vector Residuals

Figure 2. Statistical Report Produced by Report Generator Subsystem

Frame : PHOTO 1-4

Camera : CAMERA-A

Position		Attitude	
*X =	266481.32	*Omega =	-000 33 25.125
(	-46.68)		(-000 33 25.125)
*Y =	4318787.57	*Phi =	+000 47 45.726
(	-66.43)		(+000 47 45.726)
*Z =	3852.39	*Kappa =	+001 51 03.682
(	24.39)		(+001 51 03.682)

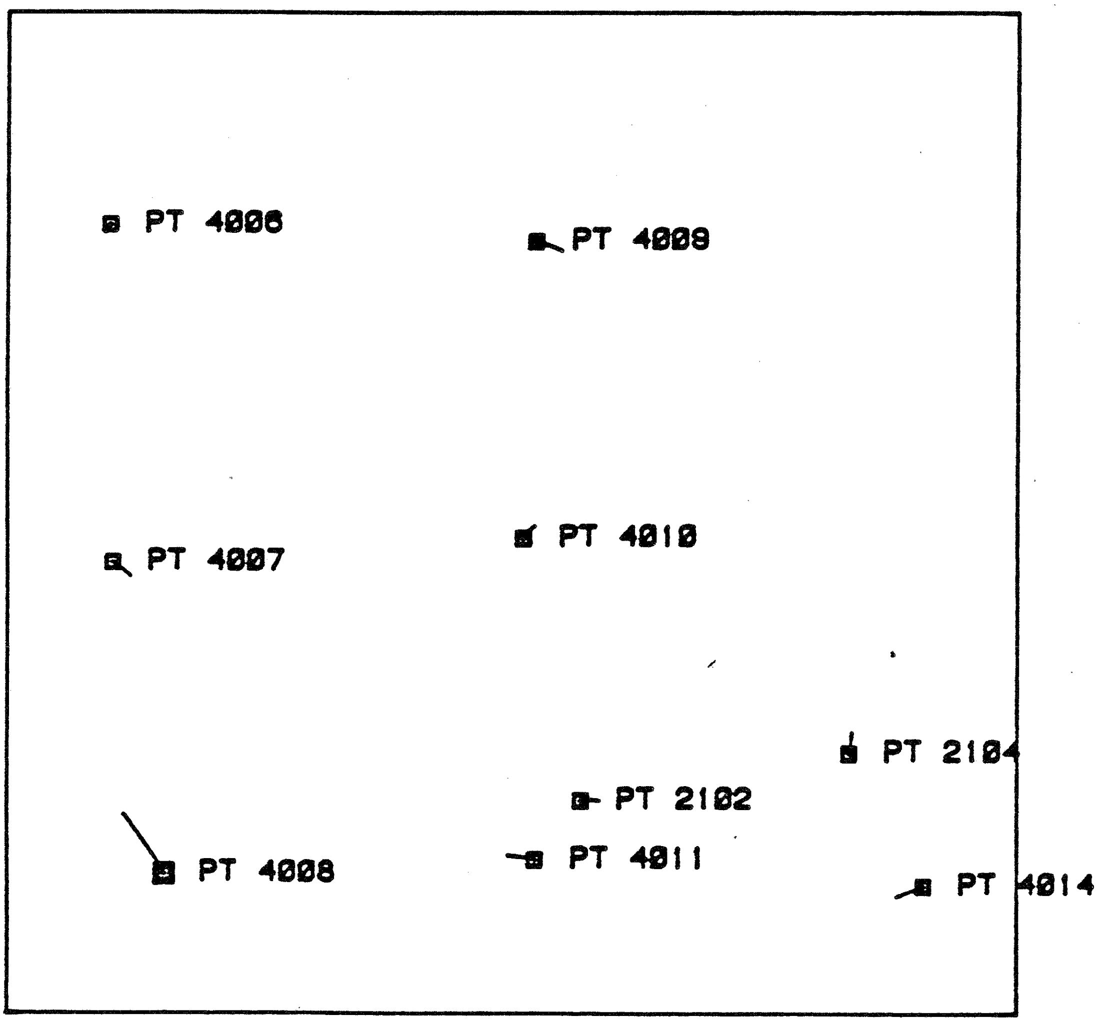

Figure 3. Plot Produced by Graphic Generation Subsystem

deviations of adjusted image and object coordinates and of photo orientation parameters. Any number of these graphic segments can be selected for any component of the photo block and transmitted to the Tektronics terminal on demand. Once in the terminal's memory, the user has the facility to display any selection of these segments on the screen. He can also manipulate their placement, scale, and rotation, to compose a graphic of a selected part of the aerotriangulation adjustment results.

Observation

In the course of building an experimental system for online display of network adjustment results, two state of the art technologies were closely examined. The first of these technologies is data base management systems represented by Model 204 software product. The second is intelligent graphic terminals represented by the Tektronix 4114A product.

There are several remarks that are worth reporting about DBMS: (a) Commercially available DBMS are designed and implemented to serve primarily business-type applications. This usually results in systems which are strongly biased toward optimized handling of character-type data. Searches which are based on numerical values are often cumbersome and performed inefficiently. This fact must be considered when designing the data definition for the data base and when formulating retrieval procedures.
(b) Report-writing capabilities are usually available. Facilities to perform complicated computations in the course of report generation are limited and difficult to implement. In the present experiment, host language interface [4] was used to support the generation of the necessary reports. (c) The efficiency with which Model 204 performs retrievals is remarkable. Naturally this efficiency is closely related to the design of the data base and the selection of the query fields.

Intelligent graphics terminals are very flexible and powerful tools which can provide economical means for obtaining, on demand, graphics of considerable complexity. Local intelligence assists human interaction during the composition of graphics from relatively simple primitives. The range of possible compositions are only limited by the resolution and size of the display area. Programming is considerably simplified due to the availability of human interaction to perform the very hard to anticipate logical decisions.

Conclusions

On demand graphics of network adjustment results are invaluable means to communicate to the user the status of the complicated computational process. The range of graphic elements offered by the system can be expanded without any alteration in the basic system design. A prime candidate for such expansion would be Graphics which depict error propagation results from the whole network. The utilization of intelligent graphics terminals did accommodate nicely the human interaction which is very much needed during the graphic composition process.

REFERENCES

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3. Computer Corporation of America, 1979, "Host Language Interface Manual, Model 204 Data Base Management System."

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