PRACTICAL EXPERIENCE IN INTEGRATING CONVENTIONAL PHOTOGRAMMETRIC COMPILATION AND DIGITAL MAPPING TECHNIQUES

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1. Introduction 1/

Since the mid-1970's, USGS has purchased, developed, or modified various photogrammetric instruments to collect standard map data in digital form. This instrumentation includes automatic image correlation instruments such as the Gestalt Photo Mapper II (GPM-2), as well as analytical stereoplotters and conventional stereoplotters retrofitted with three-axis digitizers. Two of the latest USGS digital mapping support systems are a stereoplotter interfaced with an M&S interactive editing system and the recently acquired Sci-Tex scanning and editing system.

1/ Use of trade names or trademarks in this paper is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

Digital mapping hardware and techniques offer several possibilities for the collection and processing of topographic map data. One method is to collect digital data during stereocompilation. USGS has integrated analog stereocompilation/digitization with interactive editing and automatic drafting techniques for the production of topographic maps (in digital and graphic form).

The integrated system described in this paper has been implemented as a production prototype at the Mid-Continent Mapping Center in Rolla, Missouri.

2. Objectives

There are a variety of reasons for mapping organizations to automate the photogrammetric map compilation and map production processes. Such automation:

- Provides for automatic plotting techniques.
- Accelerates the map production cycle and adds new mapping to the digital cartographic data base.
- Accelerates graphic and digital map revisions.
- Meets the increasing demand for digital data.
- Provides the data base to meet the increasing demand for special types of maps and charts.
- Enables USGS to prepare topographic maps at successively smaller scales, with a selection of features and some generalization of what shall be plotted at each stage.

The great potential for digital data lies in its flexibility either as a production tool in the generation of maps and special graphic products, or as an end product in itself.

3. Concepts

To attain the goal of integrating analog photogrammetric instruments with digital mapping techniques, a variety of offline subsystems is used. The basic input requirements are ground control data and aerial photography, and the outputs are topographic maps and digital files. The total system utilizes equipment, procedures, and a variety of computer programs to perform the following activities:

- Aerotriangulation control information entry
- Compilation/digitization
- Error detection
- Editing -- batch and interactive
- Output -- graphics or digital files

The digital output files contain cartographic features in digital representation. Each feature in the file consists of a unique feature descriptor followed by coordinate data representing the feature's position on the surface of the Earth. In addition to the feature information, the output files contain information relating to the accuracy, resolution, source of the file contents, and the method by which it was compiled.

To ensure meaningful feature identification for data recovery, the compilation subsystem uses a hierarchical classification scheme consisting of three different levels of descriptors: category, feature, and feature type. Each map feature can have up to six descriptive or attribute codes. This hierarchical classification scheme provides for rapid offline verification plots and rapid reviews on the interactive editing subsystem for selected features or categories.

It should be emphasized that the present process relies on the extensive use of offline compilation/digitization and requires operators skilled in digital compilation procedures and capable of applying sound cartographic judgment. Communication between the operator and the stereoplotter system uses appropriate functional spoken words rather than keyed entry codes. Optimum use is made of a voice data entry and response terminal to assist the operator in interfacing with the data acquisition system's various operating modes during a compilation/digitizing session. The operator is led through the operating procedure of the chosen mode, speaking the necessary commands for an appropriate action when prompted by the voice terminal.

4. Hardware

The integrated system is built around the following hardware components:

- o Analog photogrammetric data acquisition system, consisting of a Kern PG2 or Wild B8 stereoplotter, Altek AC189 digitizer, Interstate voice data entry and response terminal, and online Hewlett-Packard xy plotter.
- o M&S Computing, Inc., interactive editing system--with DEC PDP-11/70 computer (128K).
- o Gerber 4477 automatic plotter.
- o Systems Engineering Laboratories, Inc., model 86 computer (384K).

4.1 Photogrammetric digitizers

Altek AC189 data acquisition systems are activated through encoders mounted on the axial shafts of the PG2 and B8 stereoplotters. The AC189 features operator control of point and stream recording, independent scaling and translation of each axis, and both thumbwheel and keyboard entry of identification information.

4.2 Voice data entry and response terminal

The voice data entry and response terminal consists of a Data General Nova 2 minicomputer, a LINC Tape binary loader, a Votrax voice synthesizer, an output speaker, and an input microphone. The heart of the voice data entry system is the application program which allows the user to control the input and output for each specific task. The program, written in Data General machine language, permits the user to specify the vocabulary and the type of action to be taken in response to each verbal input. The program written for this application also prompts the stereocompiler, through the voice response unit, to enter the attribute codes and perform the digitizing functions in a prescribed sequence.

In operation, the stereocompiler stores his speech patterns in computer memory by voicing each word in the program vocabulary three times. The system digitizes the patterns and stores the digital representation for future reference. After training the system, the voice patterns are stored on tape so they can be read in each day rather than retraining.

During a map data digitizing session, each spoken direction is converted to digital code by the computer and compared with the stored vocabulary code for a match. When the system finds a match, it is repeated by a voice synthesizer for verification before the system responds with the appropriate output actions specified in the application program.

5. Software

The software is designed as several modular tasks, depending on the processes involved and on input and output characteristics. Basically, it can be divided into:

- Software for data collection from the stereoplotter with appropriate descriptor code assignment.

- Software for batch processing and editing: transformation of digitized xy coordinates from model-to-ground coordinate system; filtering; determination of quadrangle boundaries and fitting the cartographic features within these neat lines; partial and full-line deletions; generation of plot tapes; and model, sheet, or feature joining.

- Software for interactive graphic file design, display, and editing purposes.

6. Operational Procedures

Relative and absolute orientation of the stereomodel are performed conventionally on the stereoplotter. The xy model coordinates of aerotriangulation-established control points are then measured so that the parameters of model-to-ground transformation can be established for the recorded data. Control points are digitized in point mode. Lines are digitized in stream mode by switching the pencil switch of the stereoplotter to the down position (this switch was wired to activate the stream mode) and then the desired features are traced with the reference floating mark. Raising the pencil deactivates the stream mode. Discrete points along a line, such as the beginning and ending of straight lines, can be entered point by point with the footswitch. This facility allows considerable acceleration in operation where many straight lines and smooth curves, such as transportation systems, are digitized. To collect error-free digital data, two basic tasks are involved: the digitizing process and the editing process. Extreme care is taken to ensure that digitization from the stereoplotter follows a strict sequence. This is accomplished by the implementation of a programed menu via the voice data entry and response terminal. If the operator makes a mistake in either the descriptors or coordinate data, the data are flagged for deletion, and the computer will not process these data.

Error detection is provided during data collection via an inexpensive online coordinate plotter. Editing is performed by a combination of batch and interactive modes. Although it is possible to make all the necessary corrections at the interactive editing stage, this is a laborious and time-consuming operation. Software routines have been developed whereby most of the corrections and related processing on the photogrammetric manuscript can be performed in a batch mode. Interactive editing methods are essential for adjusting improper cartographic clearances of symbolized features to produce the final color separates.

By using the various plot specifications of the offline Gerber plotter in conjunction with the attribute codes in the data, the photogrammetric manuscript and subsequent color separates can be automatically produced with various lineweights, symbols, and text sizes. To date, no attempt has been made to automatically produce the complete map--corrections and additions made by hand play an important part in the process. In order to finish a map, it is necessary for a draftsman to place stickup type for legend and names; to perform minor additions and corrections such as depression and fill ticks, and to adjust contours for proper cartographic clearances where needed.

7. Conclusions

The integration of digital techniques into analog photogrammetric operations has the following primary advantages:

- Provides the capability to convert new map data to digital form as directly and quickly as possible for supporting requirements for digital products.

- Provides for automatic drafting techniques, which speeds up the mapmaking process.

- Eliminates separate digitization of map manuscripts.

- Coordinate data obtained directly from the stereomodel are of a higher accuracy than those obtained from the graphics.

The last point is particularly important when the ultimate objective is to create a digital cartographic data base.

Much has been learned from this production experience. First, it is a difficult task to introduce automation and new technology into a process which has been done manually, so successfully, for many years. When developing a photogrammetric digitizing system, a fundamental requirement is that the new system must be similar to and retain the ease of operation current in photogrammetric practice so that the changeover will be as easy as possible. Second, interactive editing of offline stereomodel map data is a time-consuming operation unless rigid sequential digitizing procedures are developed to minimize errors. Furthermore, many edits and related processing are semi-automatable through batch processes. Third, there are considerable time savings and increased reliability when classification codes are entered by voice for the hands-and-eyes-busy operation of stereocompilation.

On the basis of this limited experience we have been encouraged to continue the development of stereomodel digitizing as one of the primary sources of data for the digital cartographic data base. We believe that even greater success will be realized when some level of interactive data edit capability is available at the stereoplotter work station.