

SEMIAUTOMATED LARGE-SCALE MAPPING

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A semiautomated map-making system has been devised. It consists of placing an information-bearing magnetic tape into a computer system to produce two-dimensional representations of terrain via an automatic drafting machine. Stages in map production and coding, data processing, and drafting procedures are described. The system has been operating successfully for more than 3 years.

•IN 1969, the photogrammetry office of the Department of Highways, Ontario [now the Ministry of Transportation and Communications (MTC)], prepared an engineering report that advocated the Department's entry into automated techniques and therein recommended the purchase of an automatic drafting machine (ADM). The Department accepted the recommendations of that brief after cost-benefit and computer feasibility studies. In April 1970, a Gerber 1232 ADM system was installed. It took 1 month to get this system installed and tested and an additional month to get the input from the stereoplotting instruments oriented toward the standard drafting software provided by the Gerber Scientific Instrument Co. At this point, the system was in an initial production stage.

This initial production stage lasted for 1 year, during which time the programmers wrote the necessary editing software to implement what is considered to be a fully production-oriented automated system.

In the past, a map was generally considered as being a two-dimensional representation of the terrain presented on paper. We suggest that the magnetic tape, which contains all of the necessary x, y, and z coordinate data along with related topographic codings, can also be considered as a map. As a matter of fact, the magnetic tape becomes the map. Our semiautomated system then places this map (magnetic tape) into a computer system to produce any number of by-products, some of which could be conventional two-dimensional representations of the terrain on paper, i.e., via an automatic drafting machine. Each of these by-products can be produced in the scale, content, density, symbol, area, medium, and state requested by the map user.

Economic and technical considerations dictated the development of a semiautomated system that would replace certain human activities by machines. In particular, the system utilizes minicomputer hardware and software to replace much of the more mundane work previously included in the conventionally oriented mapping systems. However, by using the appropriate computer software, it is possible to retain some of the cartographic "license" that is necessarily removed by full automation.

The system was developed within a highway authority, which has a large and continuing demand for large-scale mapping at scales ranging from 480:1 to 12,000:1 (40 ft to 1 in. to 1,000 ft to 1 in.). However, experience with the system and some experimental studies demonstrate that most of the concepts can be equally applied to the areas of small- or medium-scale mapping.

In producing large-scale maps through semiautomated techniques, the main objective was to produce a plan that was equal to or better than the plan that was produced through the traditional manual drafting techniques. Of course, this dictated that the drafting be performed on stable base materials, that there be the capability of drawing many shapes or symbols, that a certain amount of cartographic "license" be incorporated into the plan, and that there be the capability of editing and completing topographic features. A second objective was the production of a digital "picture" of the terrain on the magnetic tape, which subsequently can be "eaten and digested" by computers.

DESCRIPTION OF THE SYSTEM

The present semiautomated cartographic system contains the following hardware elements: four stereoplotters (Zeiss Planimats), four digitizers (two Wang 2300 and two Instronics Gradicon), minicomputer (Hewlett Packard 2116B with 16K 16-bit words), magnetic tape read unit (Gerber M12 to read seven-track tape, 200 or 556 bpi), punched paper tape reader (Gerber), teletype (ASR 33), magnetic tape I/O (HP 7970 to I/O 800 bpi EBCDIC code, IBM compatible), computer disk unit (HP disk, 1,200K words), drafting table (Gerber 32 table, having screw gear drive in both axes), and light-beam drafting head (Gerber optical exposure head OEH-B). The interrelations among all these hardware elements are shown in Figure 1.

EQUIPMENT SELECTION

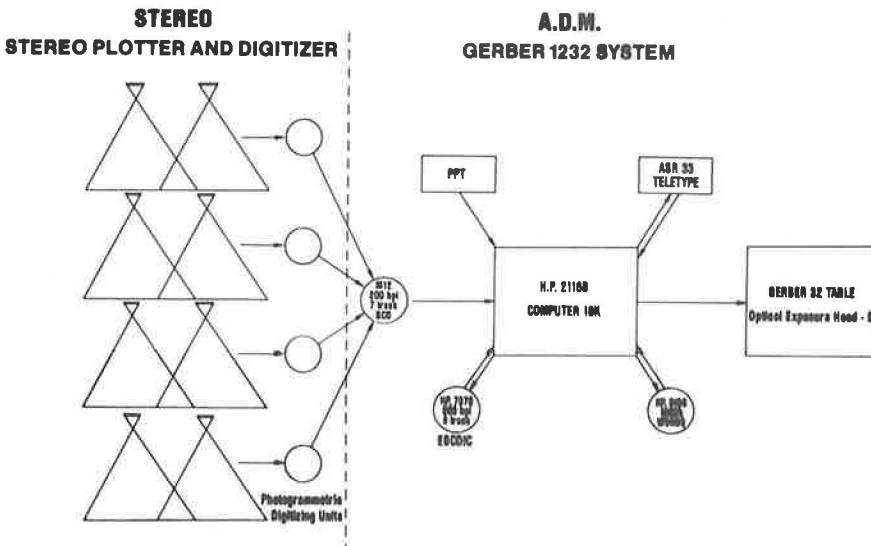
Stereoplotters

The selection of the Zeiss Planimat stereoplotter as the instrument for use in this system followed a complete investigation of the available instruments. The search was conducted to identify an instrument satisfying all the following requirements. The Zeiss Planimat was found to be the only instrument satisfying all requirements and was accordingly selected. Optimum requirements of the system stereoplotter are that it accommodate the range of focal lengths from 300 to 85 mm; be designed as a large-scale plotter (i.e., 2X to 3X enlargement from photo scale to model scale); accommodate a pencil manuscript immediately in front of the stereo-operator (this pencil manuscript being used as a control document, an edit document, and an aid to interpolation); and accommodate the absolute orientation element kappa (K) inherent in its design.

Automatic Drafting Machine

The selection of the Gerber 1232 automatic drafting system followed a similar period of careful product evaluation. Three factors were considered paramount in any acceptable drafting system: It must be fully developed and tested in a production environment, rather than being a new system's prototype model; it must have a minicomputer controlling unit to allow addition of specialized software; and it must have the capability of producing cartographic products having a "strength of presentation" and accuracy that exceed manually drafted products.

Figure 1. MTC mapping system (hardware configuration).



These considerations led to the selection of the Gerber 1232 system because it consisted of a Hewlett Packard 2116B computer as the control unit; the "32 model" drafting table with an accuracy of better than 0.001 in., good operation speed, and a 48- by 60-in. usable area; and the OEH-B optical exposure head that is capable of supplying up to 24 apertures or special symbols or both.

The optical exposure head was deemed critical because only by this method can high-quality plotted products be produced reliably at high speeds. The optical exposure system, also called "light-beam drafting" causes lines to be produced on photosensitized materials by exposing them to a light beam of appropriate width. The subsequent development of the completed plot produces the black lines. The method requires that the drafting table be placed in a photographic darkroom.

The computer control unit was also important because data manipulation is necessary in addition to controlling the drafting machine's functions.

SYSTEM OPERATION

Photogrammetric Procedures

The first three stages in map production with the system are the same as with conventional photogrammetry: Overlapping aerial photographs are taken of the area to be mapped; the aerial photographs are developed by standard techniques; and a stereoscopic model, utilizing those photographs, is created with a stereoplotter/digitizer.

At this point, however, instead of producing graphical information from the stereoplot, digital information is output to a magnetic tape recorder. This output consists of x, y, and z coordinate values, plus topographic codes (for features such as roads, contours, or buildings), subcodes (designating individual topographic features), and accuracy codes (scale of photograph). The completed digital tape recording constitutes, in effect, the entire map and contains all the information that the stereomodel is capable of yielding.

Methods of Data Coding

The coding procedure was developed by the MTC engineers and programmers. It is central to the successful operation of the system. Two types of data recording are possible: a time-mode recording, in which the x, y, and z coordinate values and associated data are continuously placed on the tape automatically at a sequence of equally spaced time intervals for as long as the stereoplotter operator depresses his "record" pedal; and a point-mode recording, in which one set of x, y, and z coordinate values and associated data are placed on the tape each time the stereoplotter operator depresses his "record" pedal. The time-mode method is used to record most natural-made features such as contour lines, forest outlines, and streams, whereas the point-mode method is used for most man-made features.

Additional data are required for feature specifications and identification. These numeric codes are entered by a fixed-address facility incorporated in the digitizing equipment. The following sequence is automatically recorded for every topographic feature record: end of data block [an asterisk (*) is used], code value of three digits, subcode value of four digits, an accuracy code value of one digit, and the corresponding x, y, and z data values.

The code defines the type of feature, and the subcode differentiates among the features. For example, one house shown in Figure 2 has the code-subcode combination of 6000001, while the other house has 6000002. The accuracy code defines the relative true placement of the measured data values. It is based on the scale and quality of the photography, level of ground control, etc. The single-digit value is chosen with reference to a hierarchy of data bases.

Data Processing and Drafting Procedures

All the digitized tape data are passed through the ADM system twice. The MTC system includes a computer unit with somewhat larger than minimum memory requirement to facilitate this data processing function. On the first pass through the system, all the hardware shown in Figure 1 is used except the table; on the second pass, all the hardware is used except the magnetic tape read unit (seven-track).

Figure 2. MTC mapping system (topographic-code configuration).



END OF BLOCK	CODE	SUB CODE	ACCURACY CODE	X	Y	Z
*	C	SC	AC			
(1)	(3)	(4)				

**EXAMPLE:
BUILDINGS**

*	600	0001	4	X _{1,1}	Y _{1,1}	Z ₁
*	600	0001	4	X _{1,2}	Y _{1,2}	Z ₁
*	600	0001	4	X _{1,3}	Y _{1,3}	Z ₁
*	600	0001	4	X _{1,4}	Y _{1,4}	Z ₁
*	600	0002	4	X _{2,1}	Y _{2,1}	Z ₂
*	600	0002	4	X _{2,2}	Y _{2,2}	Z ₂

etc.

During the first pass, the following data manipulations are performed:

1. The input data are cleaned up of any stray parity errors caused by dust or other interferences.
2. The human errors are removed. These errors fall into two categories. First, mistakes are errors that the stereo operator makes while he digitizes. He is conscious of these errors, and, having made the error, he puts more information onto the magnetic tape to say that the previous information is erroneous. He then proceeds with valid information. Second, blunders are the unconscious errors that the stereo operator makes during his digitizing process. These blunders are sought out with software programming that puts the input data through certain logic subroutines to ensure its compatibility.
3. The input data are then subjected to software routines to "square up" building outlines.
4. The input data can be "blocked" into predefined geographical areas corresponding to the provincial (Ontario) coordinate grid system.
5. The data are copied onto nine-track magnetic tapes.

The nine-track tape so produced forms the actual data base and in effect constitutes the entire plan.

On the second pass, this information is passed onto the automatic drafting machine. On line with this operation, the punched paper tape unit reads in a program of instructions to the ADM. Apart from plotting commands, directions as to scale, content, density, symbols, orientation, and area are generated at this stage.

The Gerber model 32 high-precision drafting machine with OEH-B optical exposure head operates automatically on the instructions from the computing unit and transfers the information onto photosensitive film. Line width is controlled automatically by selection of the appropriate aperture from a bank of 24 apertures. In addition, a number of standard symbol flashes are available as an alternative to programming the symbol drawing information in its entirety.

A special feature of this machine is automatic exposure compensation to prevent exposure differences due to variations in traveling speed of the optical head. A closed-loop servo feedback system increases or reduces the light intensity proportional to the velocity of the photo head.

CONCLUSIONS

The system has been in production for 3 years and 2 months. It has been most successful as the following statistics indicate:

1. The four stereoplotters have been working two shifts, or $14\frac{1}{2}$ hours per day; and
2. The drafting system has logged more than 11,000 hours (an average of 14 to 15 hours daily), which break down to 17 percent data edit mode, 69 percent drafting mode, 7 to 8 percent research and development, and 6 to 7 percent maintenance and installation.

The preceding statistics are valid for the period ending June 1, 1973.

An economic analysis prior to purchase indicated that such a system would effect the following savings: unit costs (map), 46 percent; expended man-hours, 58 percent; lapsed time for production, 75 to 80 percent; and considerable reduction of resurveying efforts. A detailed check on these figures has not been run. However, a rough review does indicate that they are realistic, perhaps even conservative. The last factor (reduction of resurveying efforts) probably requires additional comment. It was anticipated that the availability of terrain data on magnetic tape would allow rapid reanalysis of the data to produce digital terrain models, design volume calculations, etc., without additional field or photogrammetric surveys. This has begun to occur in practice. Further savings occur when new information is merged with older data to update them.