SECTION 22

AUTOMATIC CARTOGRAPHY TECHNIQUES FOR EARTH RESOURCES RESEARCH

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ABSTRACT

One of the important requirements of the Earth Resources Observation Systems (EROS) program is to provide data users with adequate facilities and equipment for the interpretation and mensuration of photographic images and related graphics. This paper deals with the progress in developing instrumentation and software for the EROS user facilities. Significant progress has been made in developing the USGS binary-mode scanning digitizer which is described in detail. Other instrumentation and processes discussed include profile-generating techniques, a manual digitizer, image correlation systems, and some new photomechanical data-processing techniques.

USER RESEARCH FACILITY

One of the major ongoing efforts in the Earth Resources Observation Systems (EROS) program is the development of a user research facility for studying cartographic applications of remote-sensed data. The equipment which is associated with the facility is presently located at the U.S. Geological Survey offices in Silver Spring, Maryland, and McLean, Virginia. Among the equipment items which are now assembled at these locations are a density slicer with TV output, a three-lens additive viewer, a graphic digitizer, a microdensitometer, and an image correlating and measuring system.

The Geological Survey is also developing a family of equipment for digital processing which will be used in automatic cartography techniques in both the EROS program and the topographic mapping research program. This equipment will include an x-y plotter of extremely high accuracy and resolution for cartographic use and a graphic scanner for converting binary graphic information to digital form. In its initial application, the scanner will be used for digitizing contours.

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For investigator support, a library of space and aircraft film is available with black-and-white photoprocessing facilities and an array of small viewers, enlargers, rectifiers, and other cartographic facilities for transforming imagery in both scale and geometric shape. A color photolab, which will be used for producing high-quality color imagery, is under development.

Figure 1 describes the interrelated functions of equipment being developed. The upper left box signifies a technique for generating profiles[1/] which is being developed now at the research center in McLean, Va. This is an automatic photographic technique for recording terrain profiles from a stereoscopic model. The model is formed in a double-projection plotter with edge-enhanced photographs, one positive and the other negative. The two images counteract on each other at all intersections of corresponding rays and produce neutral-density traces of the profiles, which can be recorded on film. Research is underway to develop a method of extracting (possibly by density slicing) the profile traces from the images of the noncorresponding rays. The profiles, converted to digital form, could then be input to a terrain data base, shown in the upper right corner of figure 1.

The digitizing scanner, which is essentially a high-resolution Vidicon and imaging optical system under extremely fine control, will scan any binary graphic (for example, black and white) and record on magnetic tape the x-y raster address where data is detected. The scanner is being supported by a fairly extensive software project, which is nearly complete. The data resulting from this scanning will be input to the data base, and the data can be used to generate other cartographic material on an automatic coordinate plotter (USGS Cartoplot).

The manual digitizer, the third item on the left in figure 1, will generate auxiliary x-y data which can be superimposed on either the profile data or the scan data. This type of instrument generates a string of x-y coordinates at a high rate of speed as a graphic is traced manually with a cursor. For flexibility, this piece of equipment is being dovetailed into the system so that the data can be directed through two different routes to the graphic plotter. This approach permits the user to go either by way of off-line magnetic tape to the USGS computer, IBM System 360/65, located in Washington, D.C., or by way of paper tape in a teletype terminal to a time-sharing commercial computer. The time-sharing service route permits the user to convert, process, and plot data without any internal computer support and to maintain data files and programs which can be reached by commercial telephone.

PROCESSING TERRAIN DATA

A process to convert existing graphic data to a map data base is being implemented. The first objective in this task is to convert contour information to a three-dimensional terrain model which could then be superimposed on remote-sensed data to aid in analyzing these data. A standard topographic map contour drawing is the first input document. Figure 2 demonstrates the method for reformatting a series of these documents to produce 10 X 10 km map blocks based on the Universal Transverse Mercator (UTM) Projection. It is noteworthy that the UTM has been adopted as the primary reference system for EROS data.

Once the input document is reformatted, it is divided into a 20 X 20 block array for scanning. Each block represents an area 500 X 500 m on the ground. A single block, which is approximately equivalent to an inch square at 1:24,000 scale, is imaged on the face of the photoemissive tube, as shown in figure 3.

A high-resolution Vidicon is used, and the scanning is under digital control. The resolution of this scanning process is over a million resolution points per square inch--1024 lines are scanned, and each line is sampled 1024 times. As the data are scanned, the x-y address of each data point is recorded on magnetic tape. A data point is defined as any resolution element which contains at least 50 percent of a line or other graphic object. Figure 4a is a computer printout with each X showing the x-y location of a data point. The first step in the computer program generates the center of gravity of the data-point array (shown in figure 4b as heavy black dots). The spacing of the rows and columns of x-y points in figure 4b represents 1-mil spacing on the original graphic. The next step, the filtering process, is fairly simple and results in a major reduction in the amount of data. In this process, the complexity of the line is analyzed, and only the information necessary to retain the character of that line is saved (fig. 4c). Only about 5 percent of the original data are finally stored.

The next step in the route from the contour map to the data base is the assignment of elevation numbers to the contours. A manual digitizer is used to assign a feature code or key, which represents an elevation number, to each contour, and the digitized keys are superimposed on the contour-line data. When the contour lines receive their proper identification, the data are then three dimensional (fig. 5). Next, a 10 m grid (ground scale) is superimposed over the data, and the most probable elevation of each grid intersection is generated (fig. 6). The 10 m grid, we feel, is fine enough to retain the accuracy of our most reliable data, and if we want to use contour information from small-scale maps, we can select a grid-cell size of 50 or 100 m, depending on the reliability of the data. As indicated in figure 6, the array of elevations becomes a three-dimensional model that will be stored in the terrain data base by reference to the UTM grid. From this primary data base, users will be able to derive elevations, slopes, and other terrain information as required for analyzing remote-sensed data. Another planned application is the definition of drainage basins and subbasins. This scanner is scheduled to be delivered and should be in operation in May 1971.

Another very important application of this type of scanning is fast and accurate quantizing of any information developed by cartographic or photographic techniques, such as areal features isolated by density slicing. This binary scanning technique can be applied to many kinds of data derived from remote sensors.

IMAGE CORRELATION

The USGS, in cooperation with the BAI Corp., has developed an operational image correlating and measuring system (fig. 7).[2] Photometric and geometric control of the input imagery are major requirements for change detection. We feel that the use of this particular correlator provides the key to maintaining geometric control so that we can eventually superimpose corresponding images from different sensors or from time-variant exposures. We have used this equipment with images from the NASA SO 65 experiment to correlate multispectral frames, and we have obtained excellent results. The correlator has recently been modified so that we can now obtain a more responsive signature and a larger radius of signal acquisition.

MODIFYING GRAPHIC DATA

Finally, but by no means least important, research is being conducted in a field of data processing which incorporates optical, photographic, and mechanical techniques. Much of the existing ground truth is in graphic form, such as published maps and charts. The original manuscript material is on scale-stable films so that dimensional integrity is maintained as much as possible for future application. In digitizing selected graphic materials, many problems associated with sorting out various symbols and assigning symbol codes can be minimized by optically/mechanically separating symbols which appear on a single graphic. The topographic map black plate, for example, contains as many as 20 to 50 different symbol types (fig. 8a). The approach being developed, which is referred to as symbol dropout, employs a technique of controlling line widths in special reproduction processes.

Two results of the application of this technique are illustrated in figures 8b and 8c. In figure 8b all symbols 0.020 inch and larger were isolated from the original plate, and in figure 8c the road symbols were isolated. The kind of graphic in figure 8b can now be scanned, digitized, and assigned a symbol code because the symbols all represent buildings. The line-width control technique has many other cartographic applications, such as the direct generation of slope maps and shaded relief overlays.

REFERENCES

1. Lewis, J. G., and Hughes T. A., Stereoscopic Profiling by Intersection of Ray Traces, paper presented at the ACSM-ASP Fall Technical Conference, Denver, Colo., Oct. 7-10, 1970.

2. Crabtree, J.S., and McLaurin, J. D., The BAI Image Correlator, Photogrammetric Engineering, vol. 36, no. 1, Jan. 1970, p. 70-76.

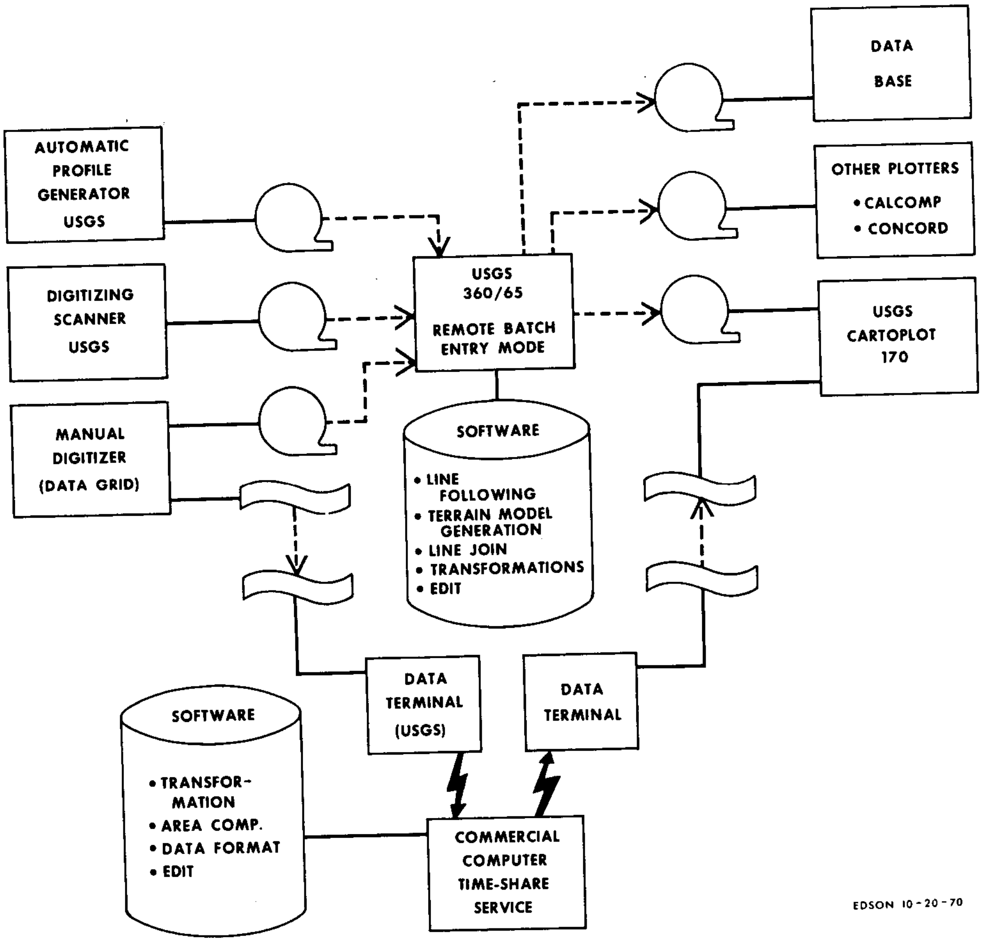


Figure 1.--Digital cartographic systems for earth resources research.

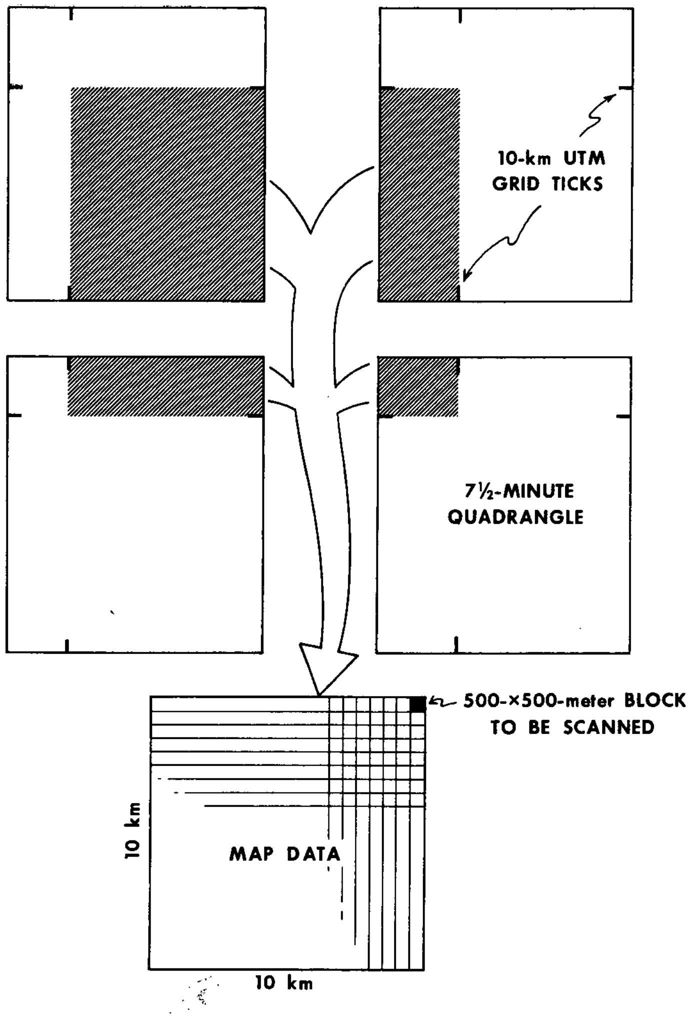


Figure 2.--Reformatting of graphic data.

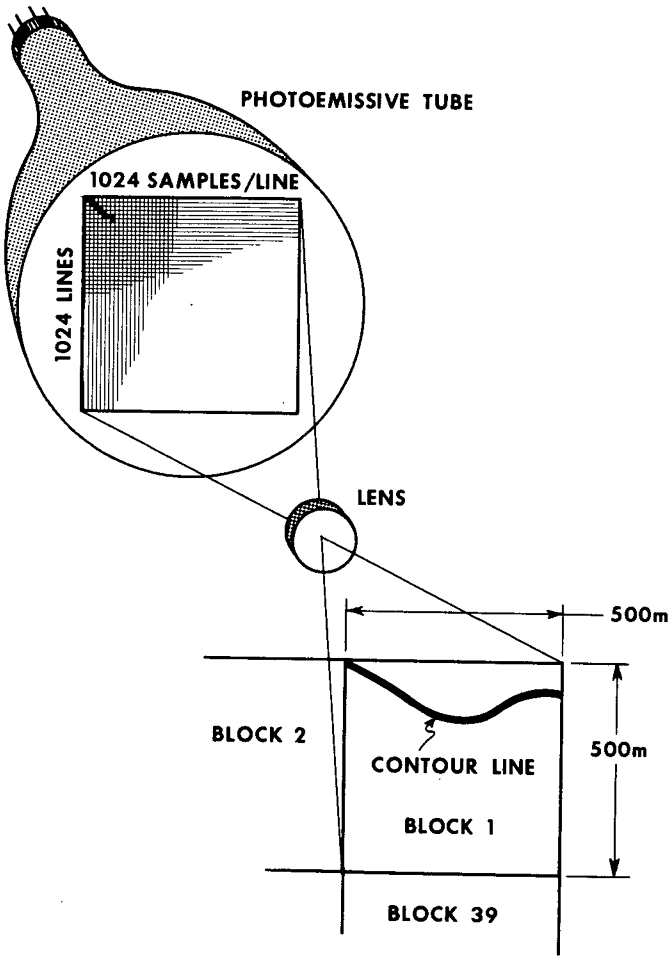
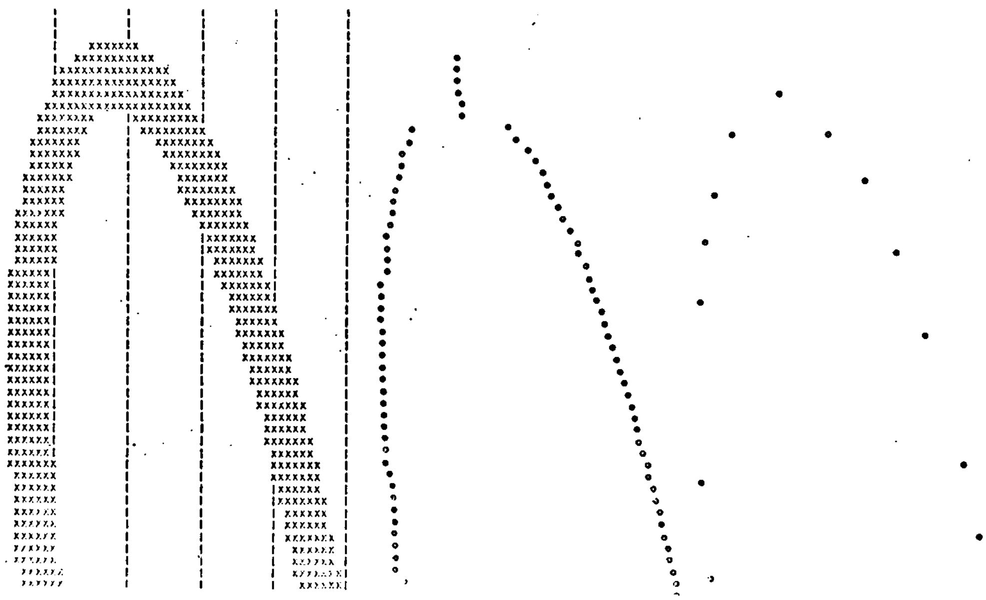


Figure 3.--Scanning the graphic data.



a. Data points resulting from a 0.007-inch line.

b. Processed for center of line.

c. Processed for line data compression.

Figure 4.--Steps in processing of line data.

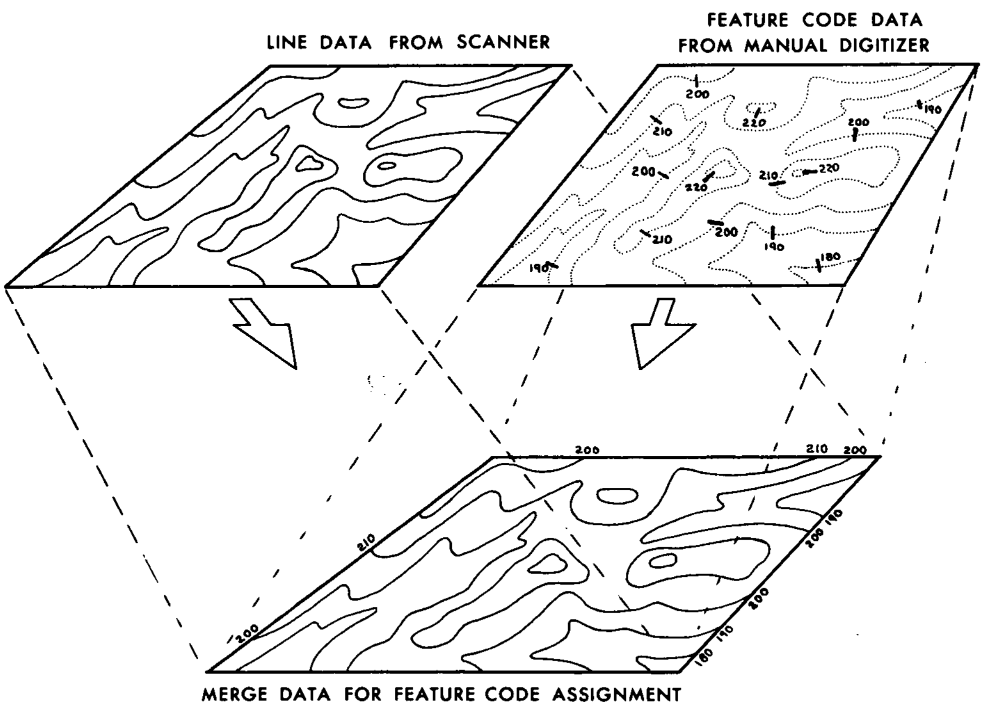


Figure 5.--Feature code assignment.

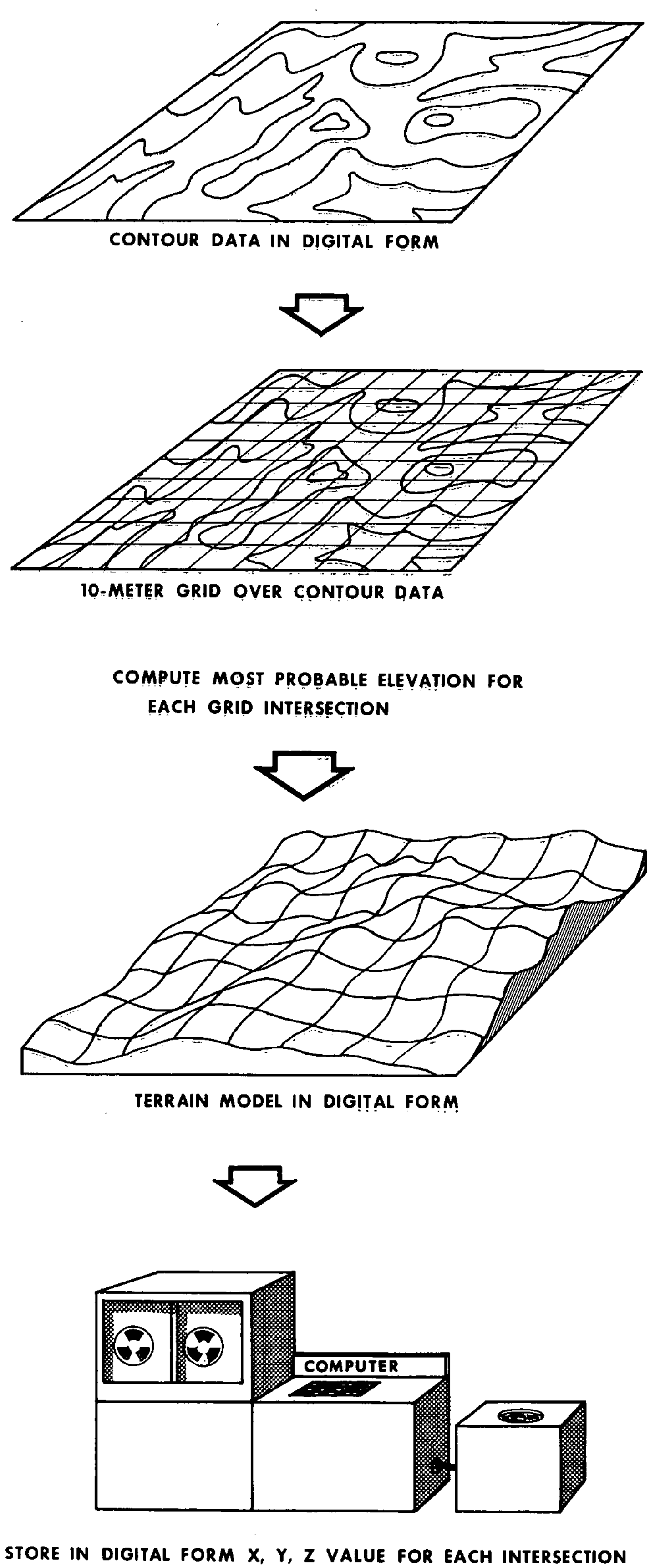


Figure 6.--Terrain model generation.

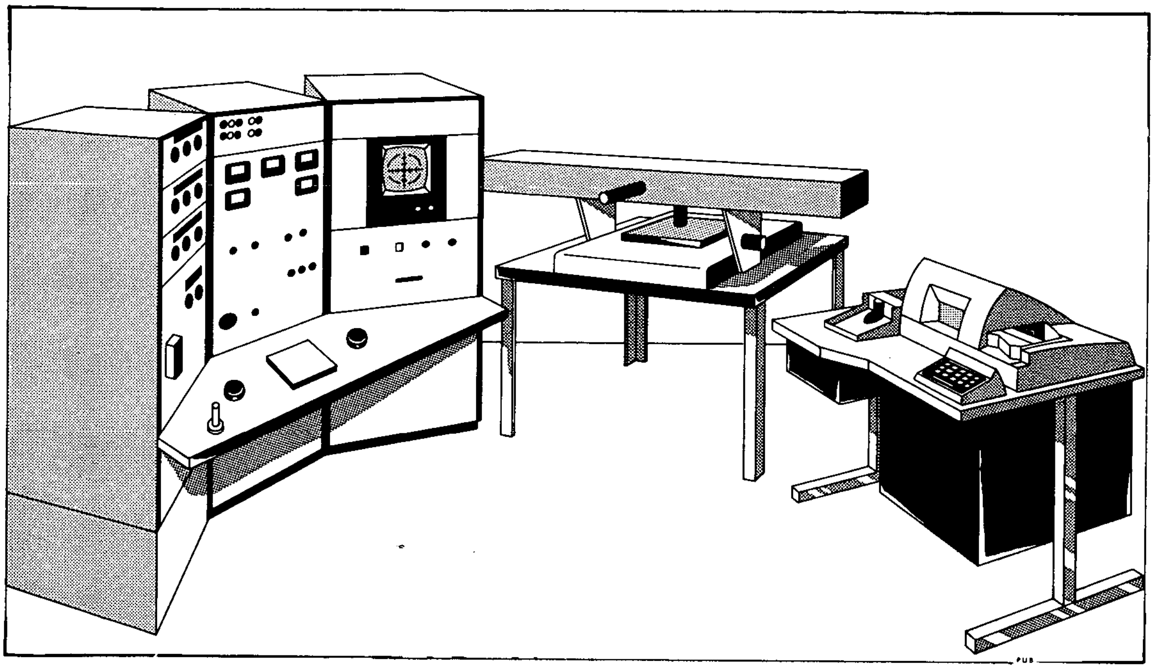
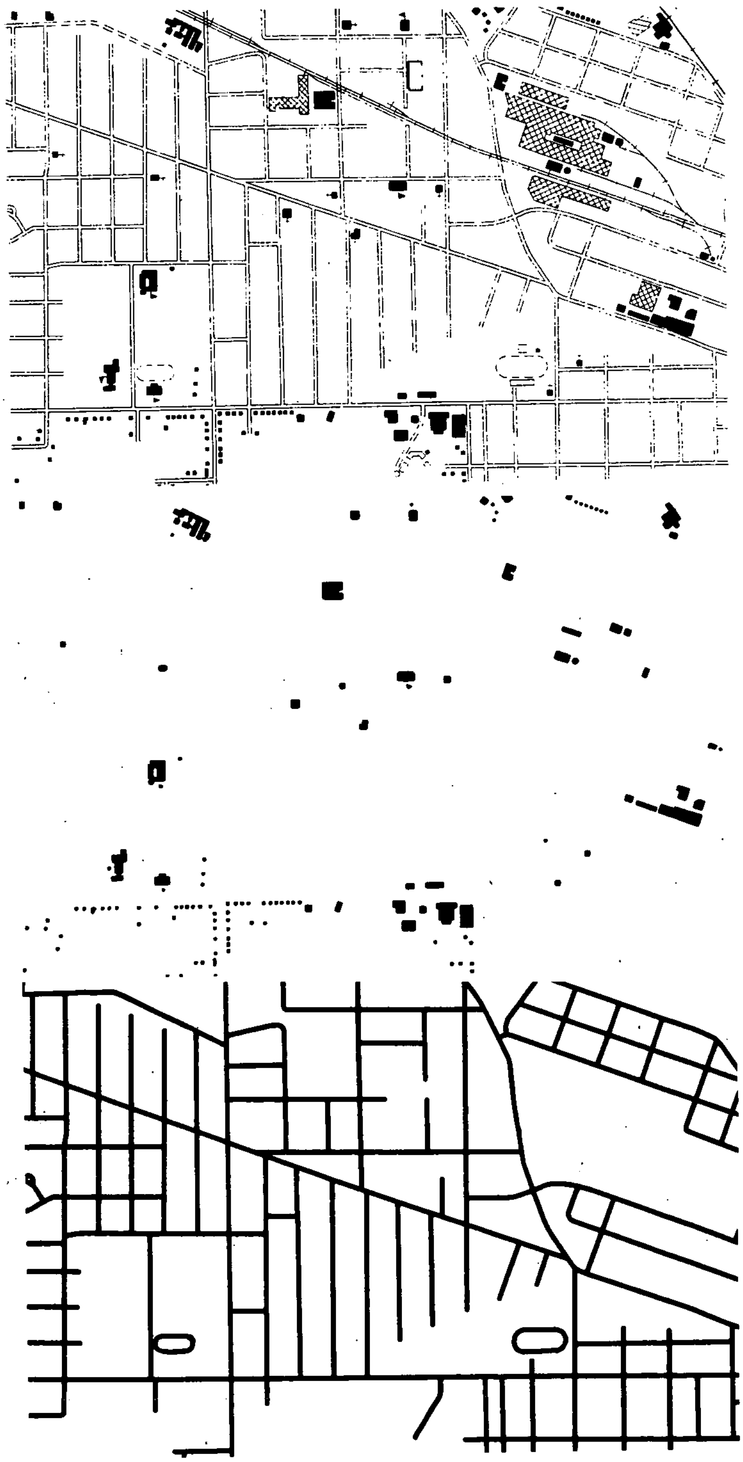


Figure 7.--Image correlator for precise point transfer.



a. Typical planimetric drawing

b. First-class buildings

c. Road pattern

Figure 8.--Photomechanical map symbol separation.