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Roger R. Chamard
Senior Consultant
Systemhouse Inc.
Alexandria, Virginia

AUTOMATED AND DIGITAL MAPPING FOR HIGHWAYS IN THE U.S.A.

ABSTRACT

Location, design, construction, and operation of highways requires data best acquired by photogrammetric methods. Automated photogrammetric and digital mapping processes used by the State Department of Highways in the U.S.A. are discussed, showing that significant changes have taken place with emphasis on changes in the last four years.

AUTOMATED AND DIGITAL MAPPING FOR HIGHWAYS IN THE U.S.A.

Introduction

The photogrammetric and mapping community of the State Highway Departments in the United States of America is an important influencing body on the utilization of large-scale products developed from photogrammetric techniques.

In 1930, the State of Idaho, by contract mapping, completed an 80 kilometer corridor of a highway route at 1:6,000 scale with a 6 meter contour interval. This mapping by photogrammetric methods resulted in the construction of what is now known as the Lolo Pass Road. It is interesting that it was not until after World War II that topographic mapping using aerial surveys and photogrammetry gradually began to be accepted by the highway engineers in general.

One of the most significant occurrences to aid in the use of photogrammetry in highway departments happened with the passing of the Federal Aid Highway Act of 1956. This Act established financing and deadlines for completion of the 72,000 kilometer Interstate Highway System. The Act also established special financing by the Federal Government Highway Trust Fund to support States on a 90 percent basis for highway location, design, and construction costs. The Act allowed these funds to be used to establish basic control networks along highway routes and for research in photogrammetric engineering and other engineering programs related to highways.

Prior to the passage of this Act in 1956, only 13 States were in the process of using photogrammetric mapping. From 1956 through 1958, 10 other States made direct efforts towards involvement in photogrammetric mapping. Many of the others had some photogrammetric mapping done by commercial firms and also started direct "in-house" involvement during this period. In these years through 1960, photogrammetric mapping of routes was done in the classic strip mapping mode. Cross sections for earth work computations were measured from the maps and recorded by manual methods.

In 1956, the Ohio Department of Highways initiated a program to digitize cross section data from the double projection stereoplotter to punched card format. It was not until 1959, that a reasonably acceptable cross section digitizer was developed. This became known as the Autotrol scaler. In the 1960's, most States started using this scaler and began digitizing photogrammetric data -- a start towards today's "state of the art" use of automation and interactive graphics.

Most important in the progress of the use of photogrammetry in highways in the U.S.A. was the establishment in the early 1950's of two organizations -- The National Research Council of the National Academy of Sciences established under the Highway Research Board and The Committee on Photogrammetry and Aerial Surveys. This committee's main function was to promote the research and application of photogrammetric techniques to highway work. The American Society of Photogrammetry, at this time, established a Committee on Transportation Surveys which promoted the use of photogrammetry in highways. Both of these committees were the focal points for technology transfer through publications and presentations at local and national meetings. Through these efforts, there was established a

close association of all those working in the highway photogrammetry community. Today's State Highway photogrammetry community is extensive. In these organizations, over 500 persons are directly involved as photogrammetrists, stereocompilers, drafters, and photographic laboratory technicians. This activity requires over 12 million U.S. dollars in salaries and support activities. The following tables indicate the mix of major equipment directly owned at the State level as of November 1979.

Table I

Aircraft and Aerial Cameras

Metric Camera, 6" Focal Length	30
Metric Camera, Other Focal Length	6
Single Engine Aircraft	12
Multiple Engine Aircraft	18
Rotocraft	2

Table II

Aerial Triangulation Equipment

Mono Comparators	16
Stereo Comparators	4
Analytical Plotter	1
Stereoplanigraph C-8	2
Wild A7	2
Wild A10	1
Total	<u>26</u>

Table III

Stereocompilation Equipment

Double Projection	139
Optical Train	63
Orthophoto Restitutors	4

Table IV

Field Control Equipment

Theodolite	506
EDM - Long-Range	202
EDM - Short-Range	91
High Order Levels	637

Most of the equipment in Tables I through IV represents equipment necessary to do the required conventional mapping. As the States have moved into automation and digitization output, more equipment has been added.

Table V

Automated and Semi-Automated Equipment

Auto Drafting Machines	18 units
Auto Tables to Plotter	11 units
Digitizing X Y Z Equipment	103 units (32 States)
Interactive Graphics	16 units (5 States)

Digitizing

Since the early 1960's with the development of a method of digitizing data directly from the stereoplotter, the State organizations acquired route cross section data directly on punched cards. This data is recorded in ground position and graphically represented by a drawn cross section. This cross section was used by the highway design engineer to make design decisions. By superimposing the roadway templet on the cross section, earth moving quantities were determined. In the early Sixties, most States manually determined the quantities by use of planimeters to determine cross section area and did manual calculations for volumes. During the 1960's, some States developed and used computer-assisted design techniques and started using the cross sections as a digital terrain model for automatically drawing contours along the highway corridor.

In the late 1960's some States started digitizing contours and planimetric information directly from the instrument from the stereo model. This data was then used to draw standard design sheets on the auto drafting tables. The digitizing process was used only as a way of reducing the drafting chore and very little attempt was made to utilize modeling techniques to automatically draw cross sections and make this digital information feed directly into any automated design system. So, even with all the ingredients needed to define the terrain by use of X, Y, and Z coordinates, no real attempt was made to automate interactively the roadway design process by the States. Some other organizations, such as the U. S. Forest Service, were attempting to complete the process into interactive design, but none were entirely successful both in technical or economic completeness.

In the last four years, technological advances in interactive graphics and the availability of more sophisticated software have made an impact on the use of automated photogrammetric techniques in highway works. Combining the technological change, with limits passed on by State Governments on how many personnel each organization could have, provided a good incentive for change. This was especially true in States where work requirements increased without increases in personnel.

Even though only five States have gone through the automated photogrammetric process as of January 1980, they are becoming the models for other States to follow. The information exchange between the States is high and funding for new equipment will be the major limiting factor on how fast other States convert to one of the following systems.

COMPUTER ASSISTED DIGITIZING AND GRAPHIC AUTOMATION

Two basic systems have been developed for gathering data needed to automate the mapping process in the Highway Departments. Neither system is completely automated and should be called computer assisted systems because the human interaction is constant. Both systems utilize the same basic hardware, but the philosophy of operations vary considerably.

The Classic Cartographic System

The basic objective of this system is to describe the mapping process in a manner that the computer can recognize and prepare final maps needed by highway engineers for route selection, design, and for construction monitoring. It makes a basic assumption that highway engineers are the same breed that have existed for the last 50 years and require the typical strip contour map. It has not, as yet, fully recognized that the highway engineer is now computer oriented.

This system utilizes field control and special aerial photography at a scale necessary to meet accuracy requirements. Aerial triangulation is used to supplement field control.

Compilation

The compilation process is accomplished in the traditional manner. The stereoplotter is equipped with X, Y, and Z coordinate encoders and recording is directly stored in computer memory, usually a disk storage device. The stereoplotter operator compiles all of the functions that have always been done starting with drainage, planimetric detail, and topographic detail. The operator works from a completely oriented model and when finished, has in possession a map, but with its data stored in digital format. This map, depending on the stereoplotter used, can be on the coordinograph, on the instrument, or on a CRT.

Editing

Even though the operator has a map drawn, assurance must be made that the data was properly recorded in the digital storage device. The editing process is usually accomplished at a station away from the original compiler. The computer is commanded to draw back the map data onto a CRT screen. The map on the CRT is compared to the compiled map and changes are made on the CRT to the computer stored data by interacting directly. The CRT configuration usually consists of two CRT's -- one which shows the total map and the other which allows for zooming in on parts of the total map at larger scales. In this way, the editor can check for line joining, clear out overlays, and correct any abnormalities that occurred by the digitizing process.

Plotting (Auto Drafting)

After the editor is satisfied that computer data is correct, data is transferred from disk storage to another media. Usually, this is magnetic tape. This tape is then taken to another computer--a large mainframe for formatting as needed to drive an autoplotting device. Autoplotting is usually accomplished as one plot. Plotting is not done in a color separation mode because the need is for a one color map like has always been made by conventional manual operations. The autoplotting compiles the map with all

the border, title, scale, and annotations necessary for that particular requirement. The usual plotter for this operation is a precise autoplotter capable of scribing and or light beam drafting.

Storage and Other Use of Data

The original digitized data is always archived for future use. The data tape to accomplish autoplotting is usually kept for a reasonable period of time.

Organizations are now looking at the original compiled data to use as varying separates for autodrafting of maps at other scales and with varied content. Use of this data is contemplated for revision of existing smaller scaled maps such as countywide transport system maps.

Autoplot data in some States is available for access by other State organizations so they can make their own work maps on drum-type plotters, directly by accessing the original files.

Little work has been done by States using this system to fully utilize this data file for other than the map compilation. Cross sections for earthwork computations are usually obtained by resetting the original stereomodels and digitizing cross sections after a final route centerline has been selected.

The Digital Approach System

The objectives of the Highway Departments using this system is to gather digital data in the most time effective manner and allow the cartographic rendering and other uses of the digital data to be accomplished via software. This system requires less highly trained stereo operators and reduces the field control requirements. Aerial triangulation techniques are fully utilized and sophisticated, thus reducing costly time consuming field control operations.

Compilation

The compilation process is simplified. All digital data is gathered in space coordinates. Planimetric detail, such as drainage, etc. is digitized as a string of digits of whose density is based on complexity. Buildings, streets, highways, etc. are digitized in the same manner. The operator observes compilation by viewing work on an interactive CRT. Corrections, deletions, etc. are made on the raw data by the operator. Editing, in other words, is made directly by viewing data and the stereomodel. Terrain data is gathered after the planimetric process and is usually gathered in the profile mode with data acquisition spacing varied by the degree of terrain roughness.

Editing

The editing of original data is accomplished by the stereoplotter operator. Editing of the software transformations is done through use of a double CRT. The first step in this process is to use software to convert all the digitized data from space coordinates to ground positions. The compilation process has been performed with safeguards to assure data has been properly gathered within mapping accuracy parameters. After the transformation to

ground coordinates, the digital terrain model is formed and contour plot generated. It is checked on the CRT to edit for normal contour program misinterpretations; changes in the plot are made interactively using cartographic rules, but the original digital terrain model is not disturbed. Various commercially available contour programs are used. The State of Michigan uses the Terra Carta program with success. See Figure I.

The planimetric plots are made and edited on an overlay of the contour plot, with contours taking priority on the edit of the planimetric data. The editor in this phase requires more knowledge of geomorphology, cartographic rules, and of statewide practices.

The final edited process provides with finished plot tapes of drainage, transportation facilities, buildings, and other hardware furniture and topographic detail in the contour map plot. This data will provide final plotting the same as seen on the CRT, Figure II.

Plotting

The finished plot data tapes contain all of the information needed for auto drafting of the final map. Depending on the type of flatbed auto drafting equipment used, these tapes may be reformatted to incorporate light beam drafting instructions, for example. Drafting can be formatted more easily into various requirements for the final manuscript or varied manuscripts. The system offers versatility to satisfy various users in the highway planning and design phase.

Storage and Other Uses of Data

Data is stored in several ways. Archival data consists of the original unedited acquisition tape data. Edited data is also stored for shorter periods of time; at least, until it is fairly sure that this data will not be used by remote entry stations to prepare draft maps with their drum-type plotters or interactive CRT design stations. The favorable aspect of this data gathering system is that it is gathered in a layered format. Cross sections for earthwork computations, for example, can be easily generated from the digital terrain model file derived from the topographic profile information on the tape constructed to produce contours. The Digital Terrain Model is key to many uses for highway planning and is just now becoming recognized as a useful tool by the highway engineer.

Digital Applications

Other than the typical mapping applications used by the Highway Departments, there are other applications that are starting to be used with very tangible benefits.

Cross Sections - Use of the DTM for creation of cross sections to be used in volume computations will continue and increase. The ability to identify a series of points on the map and to command the computer for automatic cross section generation is quick and effective when studying various design alternatives.

Highway Furniture Listing - The digital method identifies different types of furniture along the highway and so codes. Studies for signs, ditch drains, culvert and bridge location, emergency telephones, etc. can be

called for and a report generated identifying location, etc.

Orthophoto Production - The digital terrain model can be used to generate profiles to automatically drive some of the orthophoto projection equipment now available.

Prospective Plots - Use of the DRM allows auto plotting of prospective views along and down the highway locations. This is especially useful in these days when the public is concerned about the esthetics of highway location. Figure III shows a typical prospective plot.

Photomontage - Prospective plots can now be easily married to oblique photographs and overlaid over the photograph to show final highway location.

Special Study Maps - With digital mapping procedures, special maps can be generated directly from the source data without having to recompile stereo-models. Large-scale maps of waterway structure inlet and outlet characteristics, for example, become products that can be available almost instantaneously.

Digital mapping is becoming more important to the Highway Departments. The Departments have only started in this process but I expect to see a large increase in this activity in the next four years. New Departments starting in this activity will achieve production quicker because they will take advantage of existing technology now being used by the States presently in digital and auto plotting production.

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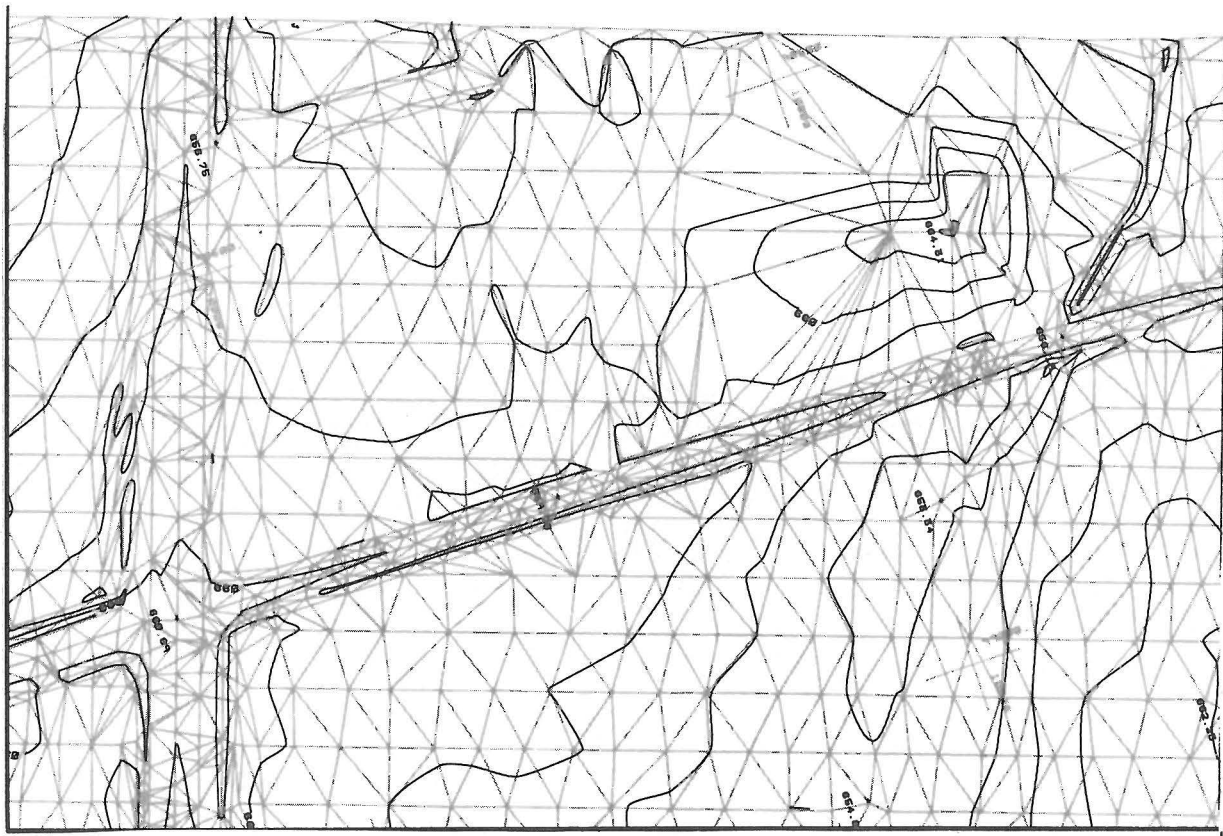


FIGURE I

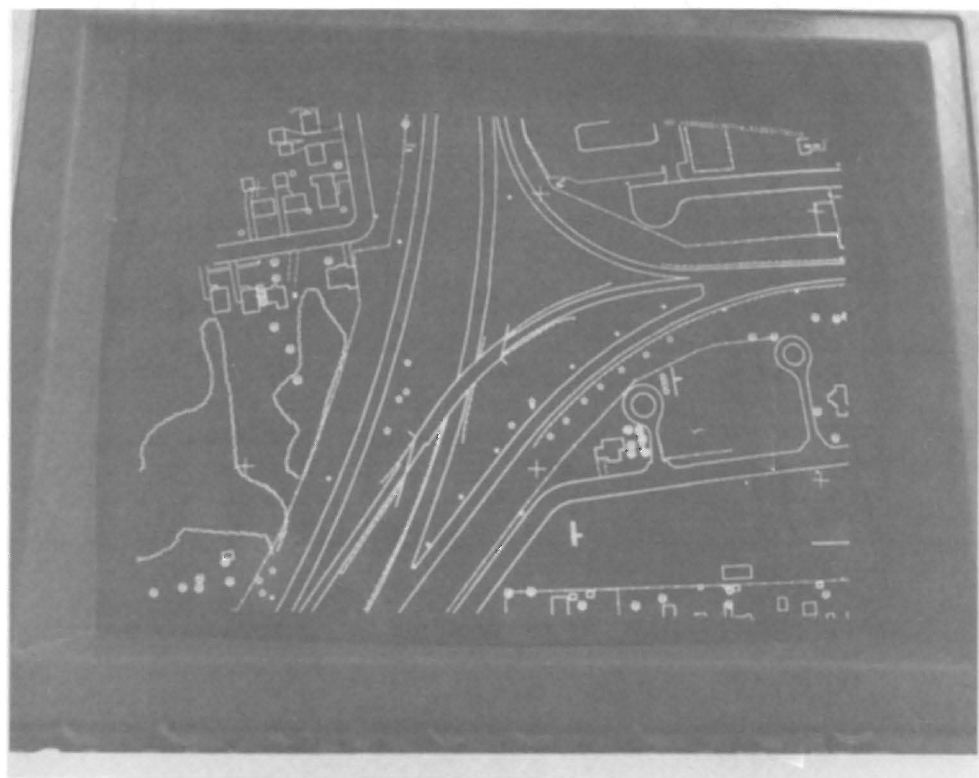


FIGURE II

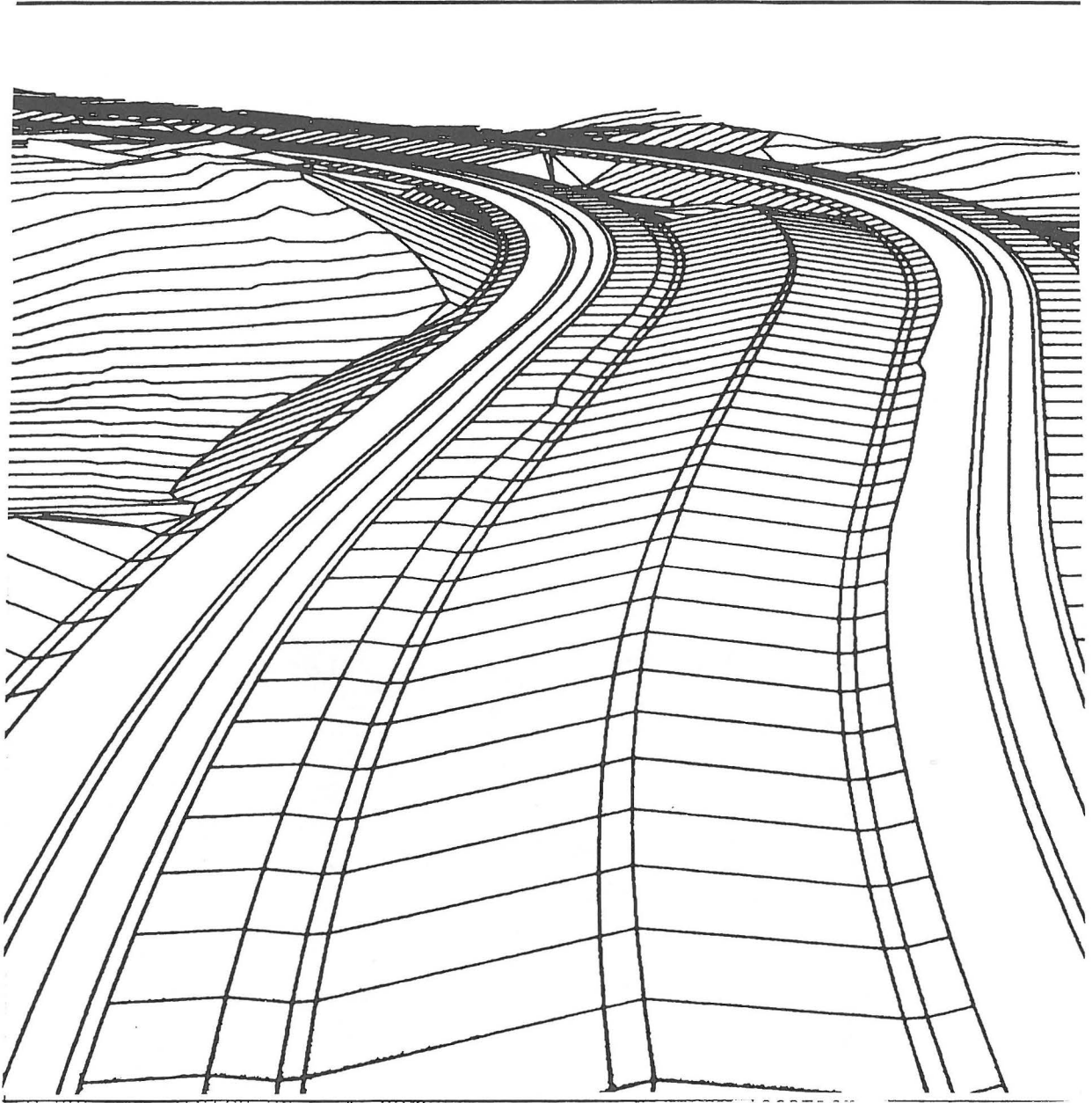


FIGURE III