14 th Congress of the International Society
of Photogrammetry, Hamburg 1980

Commission IV

AN INTERACTIVE DIGITAL PHOTOGRAMMETRIC SYSTEM FOR ENGINEERING DESIGN AND PLANNING

Hugh M^c Donald B.C. Hydro and Power Authority

Abstract

Digital photogrammetric methods can provide new facilities applicable to a much wider range of problems than older methods. A real-time interactive digital photogrammetric system has been developed at the British Columbia Hydro and Power Authority, a major Canadian electric utility, tailored to the requirements of these new problems. One such application, a vegetation maintennance system for transmission-line rights-of-way, can be considered a model for the application of digital photogrammetry to engineering problems. The need for real-time interaction dominates the design philosopy for such systems: the photogrammetrist should be in immediate control of the system at all times. The success of the system can be measured by its growing impact on engineering design and planning practice in the Authority.

Offprint requests to: H. M^c Donald
Photogrammetry Lab. Rm. 1B1
B.C. Hydro and Power Authority
970 Burrard Street
Vancouver, B.C.
Canada

Introduction

The British Columbia Hydro and Power Authority is a major Canadian electric utility with several thousand kilometers of transmission lines of various types. In the past our mapping needs were met entirely by private companies working under contract. Five years ago we began production on an interactive digital photogrammetric system which is continually being enhanced. While the system is in fact quite general, and so can produce all the usual photogrammetric products, it is specifically designed for specialized engineering applications where the final product is not a map of any sort but rather a series of reports representing the application of general engineering criteria to a specific topographic situation. While the particular engineering problem considered in this paper is of only limited interest, the techniques used should be applicable to a wide range of problems.

Hardware

The original system at BCH consisted of a Digital Equipment Corp. PDP-11/40 minicomputer, with 64 Kilobytes of memory, 8 Megabytes of disk storage, a magnetic tape unit and a line printer; a Zeiss Planicart stereoplotter with encoders for the three principal motions; a Cybernex D 1600 digitizer/terminal comprising a character display screen, a keyboard, and counters for the encoders; and a Kern AT-2 automatic table. This system proved quite adequate for initial production and developement, but recently increased production requirements have forced us to expand the system considerably. The hardware currently in use at BCH (Fig.1) consist of two work stations which share both a minicomputer and an automatic table. Each work station consists of an analogue stereoplotter (Zeiss Planicart or Wild Aviomap) and a microcomputer. Each stereoplotter has encoders for the three principal motions and a set of four light visible in the oculars.

Each microcomputer consists of a Z-80 processor with 32 Kilobytes of memory, and has counters for the encoders, a means of controlling the lights, a footswitch, a keyboard, a character display screen, a 9600 Baud port for communication with the minicomputer, and a second such port for the automatic table. The PDP-11/40 minicomputer has been expanded to 256 Kilobytes of semiconductor memory and 140 Megabytes of disk storage, and retains the magnetic tape unit and line printer. In addition there is a Talos digitizing table with its own attached microprocessor, which has 32 Kilobytes of memory, a character display screen, a keyboard, and parallel ports for the table. This processor is currently used mostly off-line, but it can be connected to the minicomputer for data transfer.

Digital Elevation Models

Much of our work at BCH requires the construction of DEM's from small-scale photography in areas of moderate to high relief and moderate to heavy coniferous forest cover. For this we use a program which continuously interpolates the presumed ground elevation from the DEM and indicates by means of the lights whether the floating mark is above, below, or on the modeled surface. The photogrammetrist can enter points into the DEM by depressing the footswitch wherever the interpolated surface differs from the true ground. Since the points entered correspond to real topographic features, and only as many points are entered as are needed for accurate interpolation, this method produces far fewer points than automatic scanning for a given accuracy. In one project we described 120 square kilometres of mostly high-relief terrain to an accuracy of one metre with less than 900 000 points. High quality contour maps were produced from these points without any need for extensive data reduction or editing operations.

Tree Monitor System

Our most important application is the Tree Monitor System (TMS) which was originally developed over ten years ago at the Bonneville Power Authority in Portland, Oregon by Mr. Wally Wilson and Mr. Jim Robinson. It was after a study of this system that the decision was made to develope a digital photogrammetric system at BCH specifically to support this application.

One of the major expenses in transmission line construction and maintennance in wilderness areas is vegitation clearing. The usual proceedure is to clear-cut a swath 50 metres or more wide the length of the right-of-way. This removes many trees which pose no danger to the line while it leaves some behind that are potentially dangerous. The purpose of TMS is to identify those trees which are in fact dangerous and to prepare a clearing-report which gives minimal clearing requirements and a guaranteed margin of safety.

A tree may endanger a transmission line in several ways: it may simply stand too close to the conductor, and so violate a permanent clearance limit, it may fall towards the conductor, or the wind may blow the conductor towards the tree, violating smaller temporary clearance limits (Fig.2). In order to determine if a given tree is dangerous, it is necessary to locate the tree relative to the conductor and to determine its height and expected growth during a clearing cycle, typically five years. Information on line geometry is obtained by digitizing engineering drawings, tree growth is predicted on the basis of height from data supplied by the government forestry service, all other data are obtained photogrammetrically from 1:12 000 scale colourphotography typically flown in a single strip along the transmission line.

In the operation a model is first relatively oriented, then a program is run to determine the model to UTM co-ordinate transform based on photogrammetrically obtained control; the model need not be scaled or leveled.

The TMS program itself is then invoked and an appropriate operating mode chosen. The photogrammetrist usually begins by entering engeneering data at the keyboard, or editing data already present, then he builds a small ground model along the right-of-way, exactly as in the DEM program. When the operator enters the danger tree mode, the program presumes that the floating mark is at the top of a tree. Every 100 milliseconds the program reads the model co-ordinates, transforms them to the UTM system, interpolates in the DEM to determine the ground elevation, subtracts this from the elevation of the mark to determine the tree height, calculates expected growth as a function of height, tests the grown tree to see if it could endanger the line, and sets the lights to reflect the result of this test. When the photogrammetrist sees a red light, indicating a dangerous tree, he may mark the tree by depressing the footswitch which will result in information on the tree appearing in a clearing report used by the field crews. At any time further ground points or engineering data can be entered at the photogrammetrists discretion.

This system has had a dramatic impact on clearing practices at BCH; in regions where it is in full use clearing cost have been reduced by 50%. The impact on design practice has not been as great to date, although the potential benefits are even greater. It is now quite practical to determine clearing costs for both original construction and later maintennance for a number of preliminary designs, and so to include clearing costs as a factor in selecting the final design. Minimal selective clearing has the additional advantage of being much more esthetic, a major consideration when transmission lines must be built through parks, resort areas, or other regions of high visibility.

System Design

During the initial design of the computer system three major requirements were identified. Firstly since there was no other photogrammetric installation at BCH this would have to be a general-purpose photogrammetric system; a turn-key machine devoted to this single application would need continual support from an outside photogrammetric service. Secondly the system must allow for concurrent production and development. An early start to production was a major requirement within the company, but the only way this could be achieved was by writing the simplest minimal software. Continual development could then provide enhanced facilities as the requirements of production dictated. Thirdly the system must provide essentially instant response, that is, the photogrammetrist must never be aware of a delay between a motion of the handwheels and a response in the lights.

The matter of real-time response deserves further comment. It has been our experience that when the response time is 100 milliseconds or less the photogrammetrist can easily develop a feel for the system, which leads to a dramatic improvement in production. With such response rates an operator can enter thirty points per minute into a DEM, whereas if the response period increases to 125 milliseconds only fifteen points per minute can be entered, and the system is noticeably "soft". There appears to be little subjective or objective benefit to response times less than 100 milliseconds.

Current Developments

The major upcoming change to the hardware is the provision of a common high-speed communications link to connect the three microcomputers and the minicomputer. This will allow the digitizing table to be integrated into the system as a third work station, as well as reducing the overhead required for communicating with the work stations.

In order to relieve the computing load on the mini-computer, more of the work will in future be done directly at the work stations. Currently the only real computing done by the work stations is the calculation and display of UTM co-ordinates, based on a transform calculated by the minicomputer.

The system is expected to evolve into a general distributed-processing system in order to meet the expected growth in demand.

We are currently studying two major applications, each of which will require the production of a contour map to be used at the digitizing table. The first is an interactive road design program, which will allow an engineer at the table to trace out a route on a map, and will continually calculate cut and fill volumes, enforce constraints on slope and curvature, and indicate the practicality of the chosen route on a set of lights. The second application, which will be used in much the same way, will produce preliminary transmission line designs as an aid to route selection. Each of these programs is based on a batch program currently in use at BCH, but each will facilitate the examination of many alternate routes, which has not been practical in the past.

Conclusions

It is evident from the success of the current system at BCH that digital photogrammetric methods can be applied to engineering problems only remotely connected to map-making. Many such problems have been ignored in the past for want of any method of solution. Such novel proceedures as these, because they introduce new considerations and new points of view, will require extensive user education and a lengthy period of adjustment before they are completely accepted. In the opinion of the author, much work remains to be done in the field of such "exotic" applications before they can be accepted as a normal part of photogrammetry,and so gain full acceptance in the engineering community.

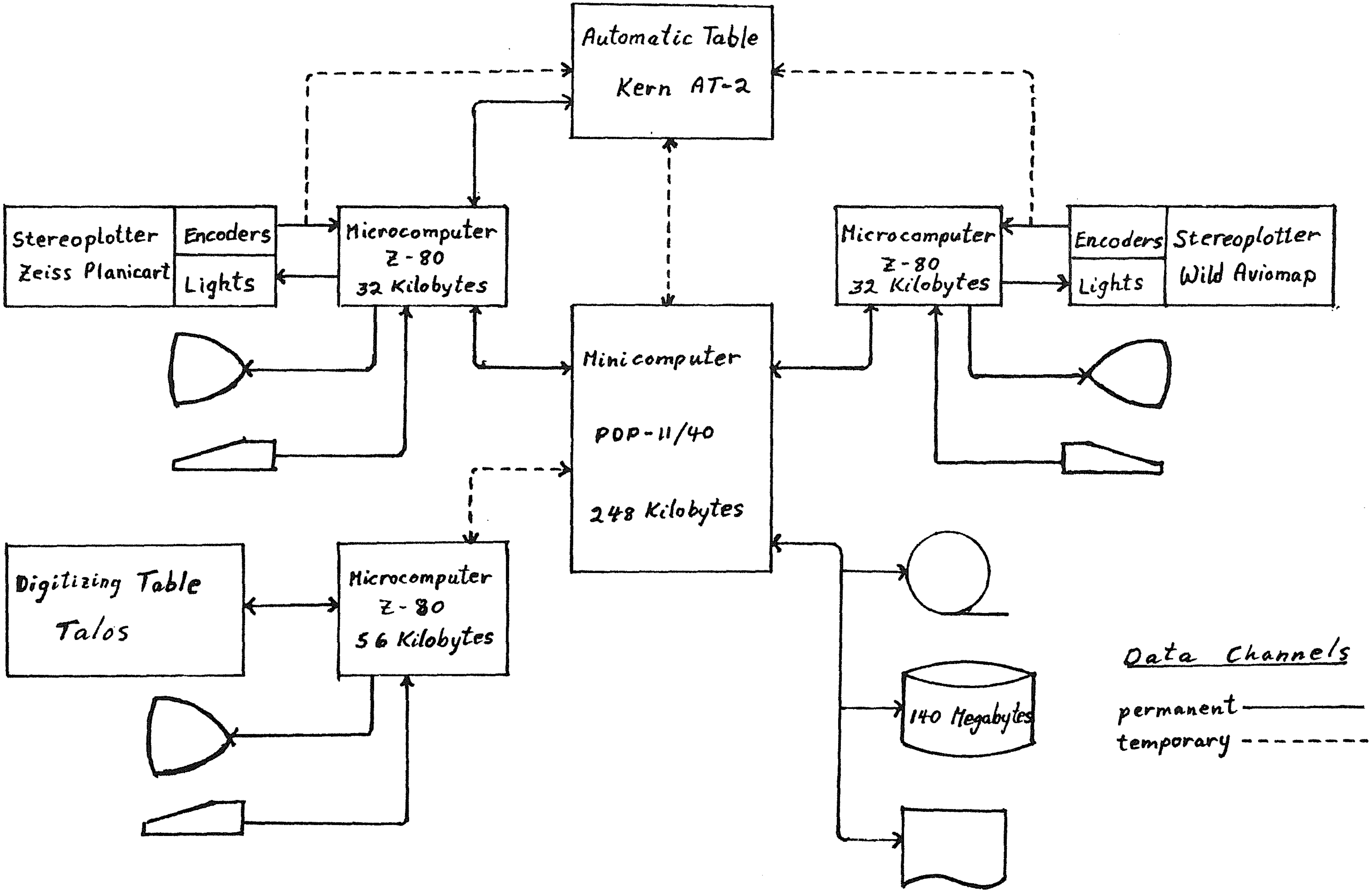

Figure 1 - Hardware

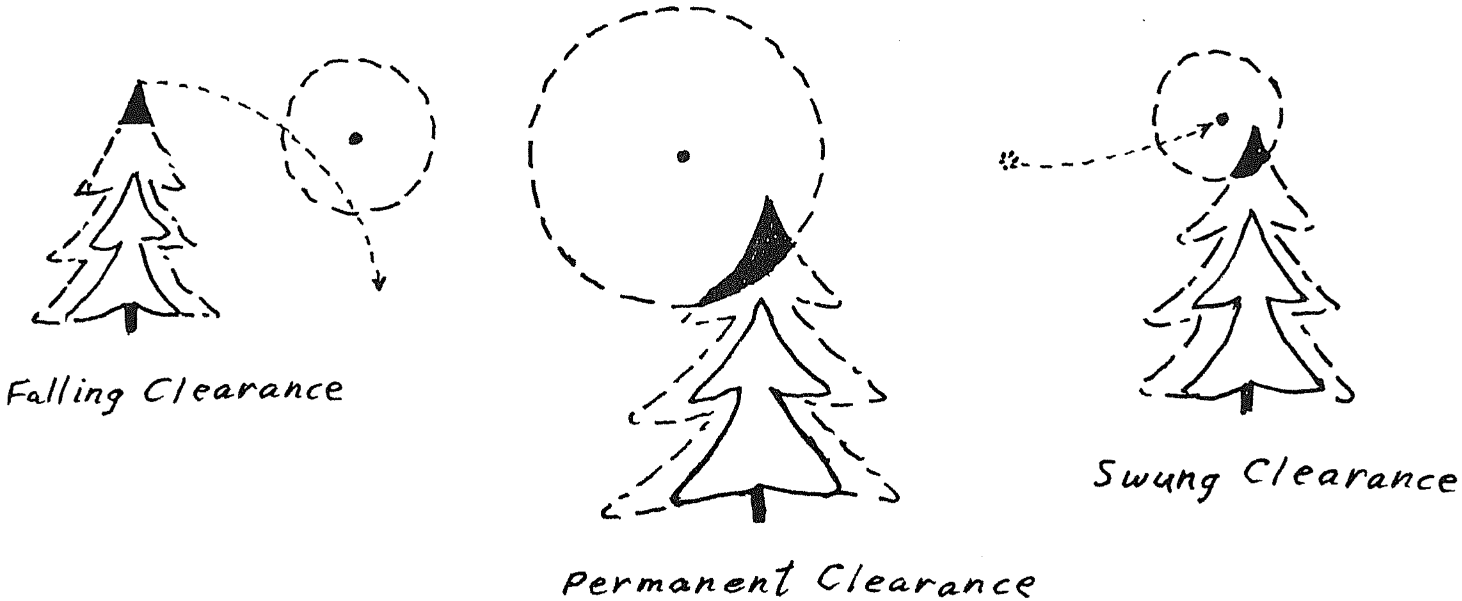

Figure 2 - Transmission Line Cross Section