REAL-TIME PHOTOGRAMMETRIC INPUT VERSUS DIGITISED MAPS: ACCURACY, TIMELINESS AND COST

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Abstract

The introduction of AI techniques into cartography at the current level of object identification and extraction from feature-coded boundaries offers the possibility of transferring these techniques into vision systems. Automated image understanding systems may also replace much of the present-day emphasis on digitisation of map products for both map revision and map generation. However, before this hypothesis may be tested we need to advance our understanding of the difficulties entailed in object recognition from an aerial or satellite image.

One of the key weaknesses of all attempts to automate the photo-interpretation process has been the lack of three-dimensional information about the scene. This deficiency has led to many misinterpretations of line and edge features in images. Another key problem has been associated with the orders-of-magnitude greater storage capabilities of film against digital products. Real-time photogrammetric input systems are now being developed both in the UK and abroad. We report on the results of preliminary experiments to assess the impact of such systems in terms of their accuracy, timeliness and cost compared with existing digitisation of map products. We emphasise the potential of spaceborne systems to provide such photogrammetric input for small-scale mapping which have particular relevance to developing countries.

INTRODUCTION

An essential input to a system for cartography using artificial intelligence (AI) is three dimensional information. Such information has traditionally been provided by digitising contours followed on maps in a grapical form. This operation is tedious, time consuming and prone to errors; it is however faster than photogrammetric compilation of maps using aerial photographs. A necessary pre-requisite, therefore, to an AI system for cartography is the speeding up of the acquisition of height information. Systems of automatic line following are being developed but this paper will concern itself with real time acquisition of data from photogrammetric instruments.

A number of new requirements come together with new technology to create an environment where rapid development can take place. A number of factors are important:

- development of CCD array cameras;
- development of new processing chips and computer architecture;
- acquisition of vast quantities of data in digital form from satellites such as SPOT;
- requirement for automatic operations in industry such as robotics and inspection.

Some of these aspects are discussed in this paper.

CURRENT METHODS

Background

The use of digital correlation for the determination of three dimensional data is not new, it has been used since 1958, but it is only recently that the technique has been brought to a stage where it has economical, practical application. The topic has evolved in several stages. Since 1958 systems have been developed to enable the automatic correlation of images on photographs to produce height information for the production of orthophotographs or digital elevation models (DEMs). These systems have been reviewed by Konecny and Pape (1980), Makarovic (1980) and Dowman (1982). Dowman (1984) has also reviewed some of the problems and the solutions in digital correlation designed for producing digital elevation data. A second stage of development is the recent interest in the use of point by point correlation for the identification of control points and for the measurement of discrete point DEMs. A third stage is the development of algorithms for real time correlation, mainly in the field of artificial intelligence by workers in AI laboratories which include psychologists and robotics engineers. Work in these two latter areas will be reviewed in this paper.

Automatic point measurement

The matching of a pair of similar images is a relatively simple task for digital correlation. A point which needs to be identified and measured in an image can be compared with a similar image stored in digital form. A simple example of this is the identification of reseau crosses on an image (Wolf and Dewitt, 1982). The approximate position of the reseau on the image will be known from camera calibration data and a standard pattern of the image can be stored in binary form. A small area around the image can be digitised and compared with the stored image. The widespread utilisation of analytical stereo plotters which provide a very accurate control and measurement platform for images has led to the use of image correlation for control point measuring and height measurement for DEMs. Forstner (1984) and Ackerman (1984) at Stuttgart have developed these methods which are now incorporated into the software supplied with analytical plotters which have CCD cameras fitted. The work at Stuttgart has broken new ground in that a method of template fitting by least squares has been developed which requires the solution of a single set of equations to give the position of best fit rather than the computation of the coefficient of correlation, at each point, and the selection of the best value as the correct point of correspondence.

Automatic point matching is used by several organisations to identify control points on satellite images. Benny (1981) has described this method applied to Landsat imagery at the National Remote Sensing Centre in the United Kingdom. A reduction in operator time from two weeks using visual methods to half an hour using automatic techniques is reported. Both of these applications achieve very high accuracy at sub-pixel level.

Applications to digital images

The methods discussed above are generally working with small portions of an image at one time. The type of portion includes video images in the Gestalt system, sections along epipolar lines in systems such as Rastar and two dimensional patches obtained from CCD cameras in analytical plotters. The digitisation takes place immediately prior to the correlation. A further stage of development is the digital plotter which can handle complete images, either digitised photographs or originally recorded digitally, and which allows the operator to scan a parallax free image in real time. Such a system has been described by Case (1982) and by Gugan and Dowman (1986). The method of Case is described by Panton (1978) and is essentially a highly efficient development of traditional methods of digital correlation. The system uses fast modular processes operating in parallel and uses adaptive control of the correlation, computing time on a model has been reduced for 20 hours to 35 minutes on the new system.

The artificial intelligence and vision approach to correlation

A global approach to image correlation has come from workers in AI. The methods investigated have combined techniques derived from image processing and the psychophysical studies of the human eye. The basic concept is that primitives such as points or lines are extracted from the image and then with the aid of constraints, derived from a study of human vision, the primitives are matched to obtain a disparity map. The disparity map is, in photogrammetric terms, a set of parallaxes for discrete points. The complete three dimensional model has often been incomplete or relying on statistical or heuristic interpolation. The principle workers in this field have been Baker and Binford (1982) from Stanford University, Grimson (1985) and Pollard, Mayhew and Frisby (1985) from the University of Sheffield in the United Kingdom. Work is now in progress at University College London to combine the AI approach with the geometric approach of photogrammetrists to produce algorithms and a purpose built computer to produce three dimensional models from digital imagery. Some preliminary work (Bell, 1985) has been encouraging.

ACCURACY, TIMELINESS AND COST

Manual data capture

Published figures allow a rough comparison to be made between different methods of recording three dimensional data. Thompson (1984) reports on a Test of Digitising Methods in which contours were digitised from a map of scale 1:10 000 covering an area 3km x 3km of hilly terrain with a range of relief from 110m to 450m. A summary of the results is given in Table 1. These figures do not include the production of a digital elevation model on a grid, which would involve significant amounts of computing time.

Figures can also be quoted for the production of DEMs from photogrammetric instruments, these are reduced to times for the same type of terrain and the same area as in the test quoted above. Figures for DEM measurement using automatic movement to the required points and operator measurement of the height value are quoted from Ackermann (1978) in Table 2. These figures broadly agree with experience at UCL.

Semi auto data capture

It can also be seen from Table 2 that the use of correlation on the Kern DSR and Zeiss Planicomp do not improve speed and in the case of the Kern DSR accuracy is less. Figures are not available for accuracy of DTM products on the Zeiss Planicomp but accuracy for single points is at least as good as manual setting (Ackermann 1984).

Automatic data capture

The use of automatic recording of DEMs is limited. The Gestalt Photo Mapper and UNAMACE have been in operation for many years and

Table 1 Time for digitisation of contour maps. Based on 3km x 3km area of scale 1:10 000 (After Thompson 1984)

		Time for digitising and editng (hrs)
Blind Manual Digitising:	Stream	23
	Point	15
Semi Automatic Line Following		2
Raster Scanning		2

Table 2 Time and accuracy for production of DEM. Based on 3km x 3km area with 20M grid interval

	Time per point (sec)	Time for $9km^2$ (hrs)	Accuracy $^0/_{00}$ H
Kern DSR with correlation	2	22	0.35 (Bethel 1986)
Zeiss Planicomp with correlation	3-4	33-44	- (Ackermann 1984)
Manual setting	2	22	.1 (Ackermann 1978)

their performance is reported by Dowman (1982). At the recent symposium of ISPRS Commission II in Baltimore, USA, Geospectra announced a system called ATOM (Automatic Topographic Mapper) and claim production rates of 800 points per second for every pixel of a model. Taking the example in Tables 1 and 2 to be covered by an image with 0.5m pixels, giving 36 x 10^6 pixels; 12.5 hours computer time would be required to produce the DEM.

Results from AI type solutions are difficult to compare but Grimson (1985) reports less than 5 minutes to correlate a scene 320 x 320 pixels and Baker and Binford (1982) quote 2 minutes for a 256 x 256 scene. Extrapolated to be comparable with the figures above gives rates of 340 points per second and 546 points per second and computer time of 29.4 hours and 18.3 hours.

Costs

Reduction of the quoted figures to costs is difficult because cost of computer time is unknown, and the cost of software is unknown. It can be said though that the semi-automatic photogrammetric approach, whilst reducing human error, involves higher capital costs and no less labour costs as the operator must be available to intervene in case of correlation breakdown.

Comment

The speeds quoted above will not permit the rapid processing of large quantities of data from space in a reasonable time nor the real time processing of small quantities of close range data, hence much faster operation is necessary. The photogrammetric correlation devices relieve the tedium of DEM recording by the operator but do not increase speed.

THE FUTURE

The answer to increased speed must come in the form of purpose built hardware, and algorithms to suit the particular problems. Parallel multi-processor architecture based on transputers may provide the solution. A project funded by the Alvey MMI Directorate in the United Kingdom is under way at University College London to develop such a system and to implement the most appropriate algorithms for various types of data such as SPOT, digitised aerial photography, close range CCD array images and laser based systems for industrial inspection. A key input to this system is the geometry of the sensor and the experience of photogrammetric methods which is available.

A real time system for close range work must be capable of determining the three dimensional information for a 512 x 512 scene in a refresh cycle of the display screen, that is 20 times per second, a rate of 5 x 10^6 points per second. Such a rate would give the same information for a SPOT scene in less than 2 minutes. This is the speed of operation which is aimed at, and for which software and hardware will be designed. The technology is now available and must be harnessed for cartographic applications.

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