The Laser-Scan Fastrak automatic digitising system

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In the field of computer graphics Laser-Scan has several products which use a proprietary laser deflection system either for writing images on films as computer output, or for reading images from films for computer input. This technology is applied in both forms in Fastrak, which is an automatic line-following digitising system, developed primarily for cartographic applications. It is based on the Laser-Scan HRD-1 large screen display/plotter with the addition of the film reading hardware, and is controlled by a DEC PDP 11 computer.

The map to be digitised may be on paper or film and can be digitised in one session unless larger than Al size. Larger maps can be dealt with by simple subdivision. The map is photographed to give a reduced negative (A6 size) which is inserted into the machine. All the lines on the map can then be followed by the machine, with operator help where necessary, to produce digital data on disc storage on the computer. This can then be redrawn on the screen of Fastrak for examination and editing. At this stage any corrections and annotations can be added before a check plot is produced on diazo film, and the final data written to magnetic tape for transfer to another system for use or further processing.

Digitising principles

The hardware of Fastrak involves the use of a finely focused spot of laser light which is used as a probe to detect light and dark areas on the film to be digitised. This probe spot is moved over the film in a local raster-scan pattern by the deflection system and the hardware detects the transitions from light to dark and dark to light. These transitions correspond to the edges of the lines on the map, and are returned by the digitising hardware to the computer where the digitising software will interpret them in order to extract the co-ordinates of the centre of the line being followed.

The main difference between Fastrak and other automatic scanning digitising systems is that the scanning for Fastrak is done over a small area surrounding a particular line being followed. This means that the scan direction, width and pitch can all be changed to suit the direction, width and curvature of the line on the map which is being followed. Another major difference is that the following of lines to give features is done at the same time as the scanning, rather than scanning the whole map and then attempting to vectorize the scanned data into features as an offline process. The advantage of on-line following is that the operator can intervene to guide the following process if the automatic process is misled or unable to determine the correct line.

Operator's viewpoint

A Fastrak digitising session involves the operator at several stages. The first is the initialisation stage in which the map negative is placed in the machine and the

digitising program is loaded and initialised. Part of this initialisation involves registering the film in the machine by digitising four corner marks which must be at known positions at the map scale. This defines the co-ordinate system of the final digital data, which may be millimetres on the map sheet, metres on the ground, latitude and longitude or whatever is required.

The next stage is selecting the feature to be digitised. This is done using a refresh cursor cross on the large screen, whose movement is controlled by a tracker ball. The operator then presses a button to indicate to the program the type of feature, eg straight line, curve, building, single point etc. Also at this stage the operator may enter a feature code to identify the feature as a house, a fence, a road boundary etc. Line following then starts automatically and will continue until the program has captured the whole feature, or until operator help is required.

The operator can stop the automatic following at any time to correct a wrong decision; also the program will call on the operator for help if it cannot see any logical continuation to the line being followed. This may happen at a large break in the line, or if the program can see several possibilities and for some reason is unable to choose between them. In the latter case the operator can examine the available options by means of buttons. In the former case where the program has lost the line altogether then the operator can either indicate a new direction using the tracker ball or simply instruct the program to look further ahead in the direction the line was heading, by pressing a button. The amount of operator help required will be dependent on the complexity and quality of the line being followed and the quantity of obscuring detail. Most contour work can be followed with no interaction while large scale urban mapping requires more than average due to the number of branching lines and the neighbouring detail.

Following will stop when the program reaches the end of an open feature, or returns to the start point of a closed loop feature. The operator can then examine the data points on the small close-up screen if he wishes before accepting or rejecting the digitisation. If it is incorrect for any reason he can reject it and have another try. If the feature is accepted then the feature is painted out from the digital data. This paint out process uses the writing mode of Fastrak to draw a black line superimposed on the clear line on the negative, thus obliterating that line from the map image on the screen. Use of paint out has three main advantages. Firstly it marks the feature as done, eliminating the common errors on manual digitisers of digitising the same feature twice or missing one out. Secondly it gives a first hand check of the accuracy of digitising as it is done from the final digital data. Thirdly it simplifies the rest of the map by removing obscurations and reducing the number of options. Hence following gets easier rather than harder as more of the map is captured.

As soon as the feature has been painted out the operator can select the next feature to be followed in the same way and the three stages of feature selection, possible guidance of following and feature acceptance are repeated until the whole map has been captured. If it is required to break off before the whole map is complete then at the start of the second session the map is re-registered and the features in the first session can be painted out from file up to the point to continue.

The digitiser program can also recognise point feature symbols. These are usually crosses, either x or + where the required digital representation is a single co-ordinate pair representing the centre point of the symbol. In this case the whole of the feature is captured in one scan and the centre point calculated. The point is then displayed and accepted in the same way as a line feature. A similar process is applied

in the case of small area features which are small enough to be captured in a single scan.

The cartographic editor

The output from the digitiser stage of the Fastrak system is a disc file on the computer in Internal Feature Format (IFF file). There are then a variety of programs for handling and modifying IFF files. The main one of these is the cartographic editor program which exploits the unique high resolution large screen display of the Fastrak to provide efficient editing capability for large graphical data files such as maps. The editor can handle a variety of data types including line strings, curves, circle arcs, symbols and texts.

Commands available include ones to find, delete, modify, extend, join and copy existing features as well as ones to create new features and many others. Commands are given via the refreshed cursor cross and tracker ball in conjunction with the 16 function buttons and alphanumeric keyboard. The large screen of Fastrak allows effective editing with the whole map visible, but windowing commands are available to allow magnification of a small part of the map to fill the whole screen for delicate editing operations. The same windowing commands can be used to draw the whole or part of the map on diazo film for a permanent hardcopy check plot at high speed (e.g. 90 seconds for a fully annotated Ordnance Survey 1:1250 urban map sheet). With the addition of high accuracy software which is also available these facilities can be used to produce high quality enlarged output on film or paper by photographic enlargement of the diazo.

The output from the editor program is also in the form of an IFF file, and further programs are available for sorting, merging, splitting and printing IFF files as well as ones for co-ordinate transformation (eg grid metres to latitude/longitude) and clipping of data to defined boundaries. Other programs are used for conversion between data formats for overall input to and output from the Fastrak/IFF system. The usual output form is on magnetic tape for storage or transfer to another system.

Performance and evaluation

As Fastrak digitises from a reduced film negative, the performance figures in terms of the source document will be dependent on the reduction factor used. Typical values have been determined from general usage and these give throughput rates of up to 850 inches per hour (2125 cm/hour) of clean edited line from contour sheets. Rates for the more complex land use maps are lower, and a useful formula has been determined empirically for approximate digitising times on a variety of maps. Assuming a times five reduction, this is:

$$T = L / 12.5 * F / 720$$

Where T is the approximate time in hours,
L is the line length in metres
F is the number of features

This time is subject to variations due to operator skill and assumes the use of simple numeric feature codes only.

Assuming a five times reduction factor Fastrak can measure lines of width 0.15 mm to 1.5 mm on the original (0.006 in to 0.06 in). Accuracy is to + 0.1 mm (+ 0.004 in) with a repeatability for measurements of well defined intersections of +0.05 mm (+ 0.002 in).

A Fastrak system has been running in a production environment at the Mapping and Charting Establishment at Feltham for over a year, and a second system has recently been installed. These systems have been successfully integrated with an existing manual digitising system and production experience at MCE has been very important in the continuing development of the Fastrak system. Development work is now being concentrated on the problems associated with large scale urban mapping.

Reference

The Laser-Scan Automatic Digitising System by C. Howman, Mapping and Charting Establishment RE, and P. A. Woodsford, Laser-Scan Laboratories Limited, Cambridge. ICA 9th International Conference on Cartography, Washington, July 1978. *This paper was presented at a recent joint RICS, North East London Polytechnic land surveyors' seminar on digital mapping and databanks.*