THE LASER-SCAN FASTRAK AUTOMATIC DIGITISING SYSTEM

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BIOGRAPHICAL SKETCH

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ABSTRACT

The FASTRAK system is an automatic line or edge following digitiser with the benefit of being interactive and under operator control at all times. A negative of the source document is projected onto a large console screen (0.7 metre X 1 metre) from which the operator can observe the automatic digitising process. Features to be digitised are selected by positioning a cursor under tracker ball control. After a feature has been digitised and accepted by the operator it is erased from the screen using a unique 'paint-out' facility which acts both as a completeness and accuracy check.

Since 1977 two FASTRAK systems have been used extensively by the British Ministry of Defence Mapping and Charting Establishment for digitising maps for digital radar land mass simulation. The British Ordnance Survey Office installed a FASTRAK system in 1980 and other FASTRAKS are installed in Sweden and Italy. Laser-Scan Laboratories, being the manufacturers of FASTRAK, have been operating a bureau service for a number of years at their premises in Cambridge U.K. and further details of performances achieved are given in this paper.

INTRODUCTION

The Laser-Scan FASTRAK system is an interactive automatic digitising device developed primarily for cartographic applications. Based on inhouse technology, developed over a number of years, it has proved itself to be both reliable and user friendly. In April 1982 Laser-Scan Laboratories

Limited were presented with the Queen's Award for Technological Achievement which was obtained for the development and proven cost effectiveness of FASTRAK.

Being formed in 1969 Laser-Scan has over twelve years experience in the field of computer controlled laser scanning with particular emphasis on cartographic applications. Initial work produced a laser-based line following digitiser SWEEPNIK, for use in high energy physics applications. Experience gained in this field together with that gained in the production of a high-resolution display/plotter, (Street and Woodsford 1975), and the awareness of market requirements lead to the production of FASTRAK. Its main aim being to increase the throughput of data acquisition without the disadvantages of the manual digitising table. As well as being an automatic line digitiser FASTRAK has the following additional facilities.

Interactive Control

The operator is able to intervene during the digitising process at any stage and is able to devote his skills and experience to an interpretive role in responding to particular cartographic problems.

Feature Selection

The operator can select only the features which are required to be digitised and has complete control over the order of selection.

Feature Coding

By means of the control console the operator can classify and code features at the intial capture stage. This is achieved very simply by selecting the appropriate function button at the time of initial alignment. The numbering of features within a particular feature code is done automatically the incremental steps being previously selected by the operator, thus being particularly useful in, for example, the coding of contours.

Erasure of Captured Features

After a feature has been captured the operator has the facility to erase this feature from the console screen. This process is actually controlled by the captured digital information of that feature so that it acts as both an accuracy and completeness check. This process is particularly useful when one is digitising dense data and thus prevents double digitising or feature omissions. The details of this 'paint-out' facility are described in more detail in the next section.

Multiple Data Capture Sessions

Again using the 'paint-out' facility the operator is able to continue jobs which are only partially completed. After initial registration with the source negative all the previously captured data is erased from the screen and the operator continues in the normal fashion.

Hard Copy Plots

Integral to the FASTRAK system is the facility to produce a hard copy plot onto microfiche sized (148 mm x 105 mm) film. Development of these plots is by means of a simple desk-top machine providing permanent hard copy with clear lines on a dark background, ideal for reproduction and check plots.

Editing Facilities

Previously captured data can be drawn directly onto the large console screen and FASTRAK can be operated in its 'HRD1' mode. (Woodsford 1976). The screen has a resolution of some 3500 X 5000 lines with an addressability to within one tenth of a line width. By use of a tracker ball, completely general refresh images can be produced, features selected and erased.

Large Screen

The large console screen allows the operator to view and digitise the source document at actual size or indeed magnified in the majority of cases. When used in the HRD-1 mode the operator is therefore not faced with the continual problem of 'windowing' as presented by smaller displays.

FASTRAK HARDWARE

FASTRAK is based on laser scanning technology which is also incorporated in Laser-Scan's HRD1 display and Microfilm Laser Plotter together with an additional scanning laser and software for performing the automatic line following function.

A film negative is produced from the original source document and is projected at X10 magnification on the large console screen. The source negative itself occupies an area of 98 mm X 68 mm on a 105 mm frame so that a 40 cm X 40 cm original (e.g. a U.K. Ordnance Survey 1:1250 urban map) is reduced by a factor of 6. At this reduction factor a line width range of 0.18 mm to 1.8 mm on the original can be dealt with quite satisfactorily.

The console also houses a small close-up screen and the interactive controls which include a tracker ball, function buttons and keyboard (see Figure 1).

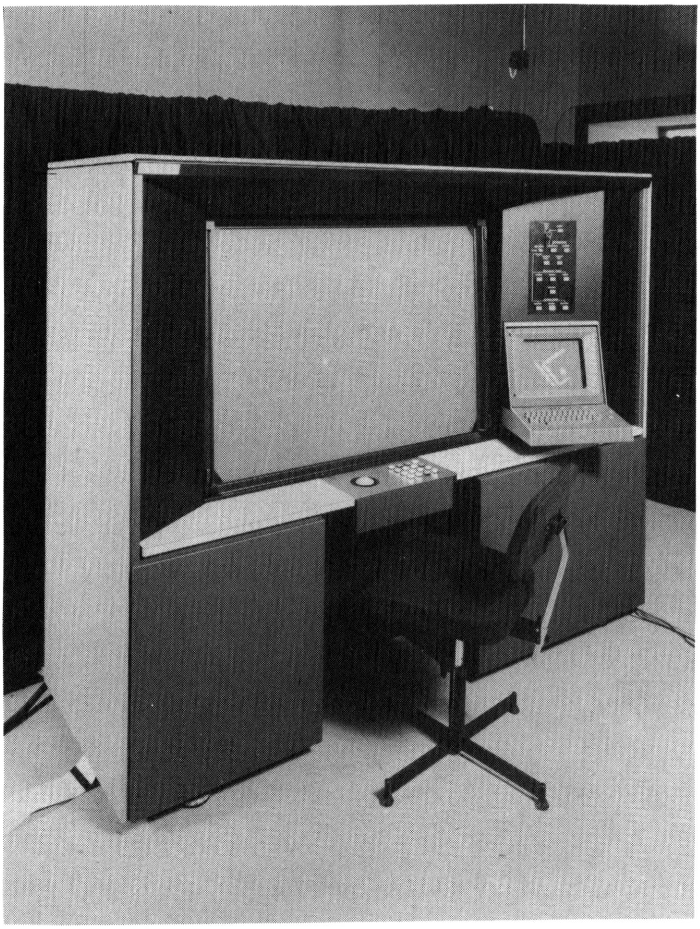

FIGURE 1

FASTRAK utilises two He-Ne lasers, one being used for the interferometric control of the beam steering mirrors and the other for the actual scanning process itself. An Argon-Ion laser is used for the 'paint-out' and plotting facility.

As can be seen from Figure 2, a reel of photochromic blue-sensitive film is sandwiched between a zone plate and the negative of the source document. The purpose of the zone plate is to present the operator with a real time trace of the digitising process by diffracting a small portion of the He-Ne digitising beam onto the screen console. It is also used for diffracting the cursor and other symbols onto the screen.

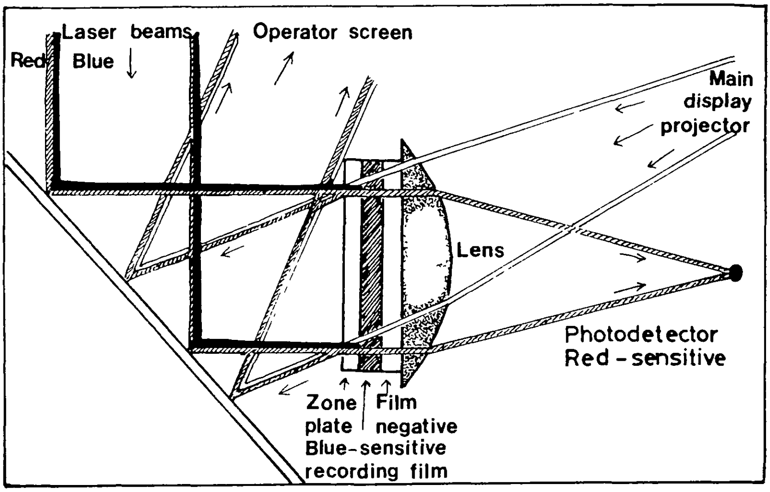

FIGURE 2

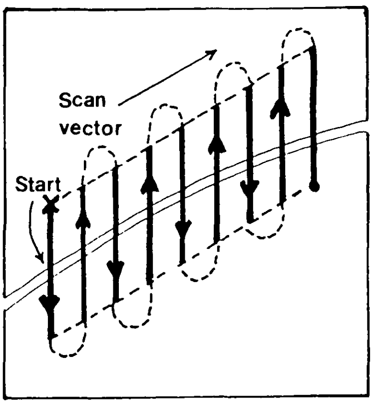

FIGURE 3

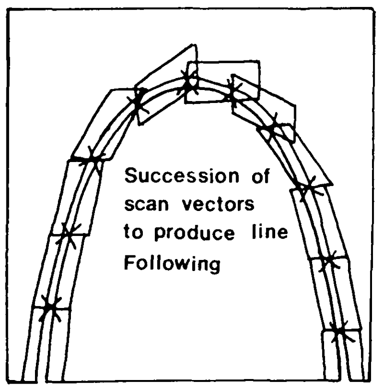

FIGURE 4

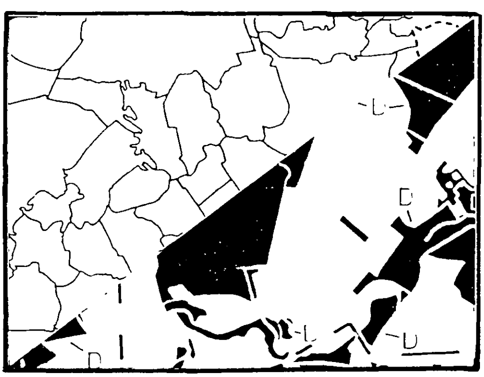

FIGURE 5

The document therefore appears to the operator as orange features on a dark background due to the filtering nature of the photochromic film.

A refresh cursor is aligned, by means of the tracker ball, onto the feature to be digitised and an initial scan vector direction is determined by the operator. Subsequent scan vectors are determined automatically by the controlling software's interpretation of data, captured from the superimposing of a local raster scan, Figure 3.

As this local raster scan traverses a line a photodetector placed behind the source negative detects the transmission of the He-Ne beam and records the width and centre co-ordinates of the line. Each scan vector contains approximately 25 or so traverses of the film at intervals of 10 or 15 microns at a speed of 500 Hertz. This data is then processed to produce a set of line elements which are subsequently compacted and used to provide the next scan vector, Figure 4 (Fulford, 1981).

Thus automatic line following proceeds until the end of the feature has been reached or the operator intervenes to stop the process. 'Paint-out' of this feature is then achieved by writing onto the photochromic film using an Argon-Ion laser which produces dark lines on the photochromic film in contact with the source negative thus erasing this feature from the operators view and preventing double digitising.

SOFTWARE CONSIDERATIONS

Control of the FASTRAK is by means of a PDP 11/45 (or upwards) or VAX 11 series computer operating under the RSX-11M or VMS operating systems respectively. The software is written in FORTRAN with machine dependent parts in assembler

The edge encounters returned by the FASTRAK hardware to the host computer can be followed directly to allow digitising of the boundaries of solid shaded areas (see later section on bureau digitising for the Forestry Commission), but more usually are immediately paired together to give line encounters having centre point and width attributes. For each scan vector the encounters that form continuous line elements are chained together. This may result in chains for lines other than that being followed being eliminated. This is achieved by using considerations of continuity and line width which results in only the chains formed by the line being followed selected. After the last scan encounter has been analysed a prediction is then made for the position and direction of the next scan vector.

Before being written to the data file held on disc the data points, representing the captured line, pass through a data compaction process. This compaction process results in a set of master points which, when joined together by straight lines, represent the line measured to within a prescribed tolerance. This tolerance is determined by a patch file selected by the operator at the commencement of a digitising session. The patch file parameters also determine the maximum distance between consecutive master points.

Feature co-ordinate data is stored in a disc file in an internal feature format (IFF). Each feature is numbered and can be sequentially or operator specified. The feature is also assigned a code defining the type of feature represented (e.g. major building, contour, river etc.) and an optional commentary for arbitrary alphanumeric information can be input by the operator. Within a file, features may be grouped into overlays by the allocation of an overlay code.

Data as captured is stored in the co-ordinate space of the FASTRAK hardware. At the start of each job, registration is achieved by measuring four corner fiducials (or more) and specifying their co-ordinates in the source co-ordinate space. The first stage of post-processing transforms the captured data to this source co-ordinate space, dealing with both distortion correction and registration. Various integrity checks are also performed (closure checks, clipping to boundaries) and statistical summaries generated. The second stage of post-processing involves translation to the required data output format, which may be a plotter drive tape or a data base format. These post-processing phases can run as background jobs whilst data capture is in progress.

An important software implementation, especially when digitising data containing a large number of nodes, is that of junction recognition. When line following the FASTRAK system is able to detect and analyse junctions. The number of arms to the particular junction is determined and a unique junction coordinate point is derived. The operator has the facility to pre-program the exit of the junction, (e.g. straight-ahead, left or right), although this choice of exit can be overridden if desired. The junction coordinates are stored together with the arm coordinates and 'paint-out' is suppressed in the region of the junction to allow 'revisiting'. When required the cursor automatically returns to the junction and the undigitised exits are followed.

FASTRAK also has the software facility for pre-guidance. The coordinates of the start of features are entered on a manual digitiser together with the relevant feature codes. When set-up in FASTRAK in the normal fashion these features are then automatically located and digitised.

It is possible to use FASTRAK to scan an entire map unattended and to post-process the resulting raster data into vector form. This technique is particularly efficient on good quality polygon maps.

SYSTEM PERFORMANCE

Performance in a cartographic production sense is dealt with in other sections of this paper. For completeness the basic parameters are given in terms of the film negative and should be related to a source document by scaling up by the photographic reduction factor.

Readable Area	:	98 mm X 68 mm on a 105 mm frame
Line Weight	:	0.030 mm to 0.3 mm
Point Accuracy	:	± 0.020 mm in either axis
Point Repeatability	:	± 0.010 mm in either axis for repeated measurements of well defined points
Line Following Rates	:	Highly convoluted lines 2.5 mm/sec Average curve 4.5 mm/sec Straight lines 5.5 mm/sec
Plotting Resolution	:	5000 X 7000 lines
Display Resolution (HRD 1 mode)	:	3500 X 5000 lines

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 time in hours, L is the line length in metres on the original and F is the number of features.

BUREAU EXPERIENCE

Laser-Scan operates a bureau service in the U.K. for not only its FASTRAK system but also for a Microfilm Laser Plotter and LITES (Laser-Scan Interactive Editing Station). Bureau work has been carried out on the FASTRAK system for many clients and some of the more well known include:

U.K. Forestry Commission	Woodland Areas
U.K. Electricity Board	Town Maps
U.K. Gas Board	Town Maps
U.K. Experimental Cartography Unit	Contours
U.K. B.K.S. Surveys (for British Rail)	Tunnel Sections
Australian National Mapping Organisation	World Aeronautical Charts
West Germany Rhein Braun Coal Works	Contours
U.K. British Petroleum	Topographic Maps
France Institute Geographique National	Contours
Eire Petroconsultants	Contours
U.K. K Shoes	Shoe Pictures

The U.K. Forestry Commission is presently engaged in producing a Woodlands Census in which data is captured from the green overlay separations of the Ordnance Survey 1:50000 sheets. Each of the 204 sheets is marked up by the Forestry Commission with the county boundaries and woodland areas are given a classification code and may appear as solid polygons on the sheet (see Figure 5). The data is captured on FASTRAK operating in its edge following mode and appropriate coding is performed as previously described in this paper. The final output for each county is on punched card and consists of lists of woodland areas, with classification code, area in hectares and centroids. In addition woodland perimeter data is retained and used to generate check plots, on a per county per sheet basis. The throughput of 4 to 6 maps per week is geared to be in step with the Forestry Commission's programme, although the throughput could be as high as 10 to 15 maps per operator week.

Contracts for digitising 1:1250 scale Ordnance Survey urban area maps have been undertaken on FASTRAK for the Electricity and Gas Boards in the U.K. Whilst the Ordnance Survey is producing digital 1:1250 scale maps, the sheer size of the task has meant that certain areas of the U.K. have a sparse coverage in terms of digital mapping. In fact a FASTRAK system is installed at the Ordnance Survey and is presently undergoing an evaluation program for the possible future integration into their production flowline (Fraser and Woodsford 1981).

A typical map sheet used in this contract is shown in Figure 6. For the purpose of producing a detailed report on this particular contract digitisation on FASTRAK was performed by an operator completely unfamiliar with these types of maps. No particular order of digitising was pre-ordained, but experience showed, that digitising blocks of houses, complete with their fences and surrounding road edges, was the logical approach. Even for the inexperienced operator FASTRAK was obviously very much faster at capturing any form of line detail on these maps than manual digitising. The comparison was made using Laser-Scan LITES system which, although primarily a cartographic edit station, can be used as a manual digitiser. Despite the operator inexperience it was shown that FASTRAK was between 4 and 6 times faster compared to the manual method even for this type of data. Obviously when the same comparison is made for contour type data FASTRAK is very much faster (X15)

House names, numbers and any point features will take a similar time on both systems as they are manually applied. The 'paint-out' feature, described previously in this paper proved to be invaluable for this type of data capture. A typical time taken for digitising a map of this nature is six hours.

1:1,000,000 Aeronautical Charts have been digitised for NATMAP in Australia. FASTRAK was used for contours, water features and roads with point digitising for symbols. Typical times were 5 hours per separation which included edge matching and coding in addition to processing to the customer's required format.

FASTRAK has recently been used to digitise the profiles of tunnels to enable the careful monitoring of any future profile movements. B.K.S. provided 70 mm films of the tunnel using an optical arrangement which produced a pencil beam of light around the tunnel profile. It is this pencil beam which is followed and digitised by FASTRAK and throughput of 1 tunnel section per minute is readily achieved.

The profiles of shoe designs have been digitised using a recently developed raster scan software on the FASTRAK system and is undergoing further trials before general release.

M.C.E. EXPERIENCE

The British Ministry of Defence Mapping and Charting Establishment, Royal Engineers (MCE RE) produces maps and aeronautical charts at a wide variety of scales and in many designs. Involvement in cartographic automation started in the sixties and digitising methods were introduced in the early seventies. It was recognised at an early stage that the heaviest load, on a digital production system, is placed


TQ 1103SE
SUSSEX
WEST SUSSEX ADMIN CO
WORTHING M B & C P
GORING WARD
BARRINGTON ROAD
Westholme
West Park
County Primary School
Clive Court
MELBOURNE ROAD
CLIVE AVENUE
WELLESLEY AVENUE
WALPOLE AVENUE
ELGIN ROAD
MARLBOROUGH ROAD
MARLBOROUGH WAY
GORING ROAD
Charles House
Parklands Court
ALINORA AVENUE
WARNHAM ROAD
PARKLANDS AVENUE
Courtlands Hospital
WORTHING BORO CONST
TQ 1102SE

FIGURE 6

on the initial data capture stage. Due to the proposed loading, on MCE digitising resources in the mid seventies, it became obvious that an improved method of data capture had to be utilised. Increased throughput was required without the basic disadvantages of the manual digitising table. Proposals were made by Laser-Scan to meet MCE's requirement and the acceptance of these proposals lead to the development of the FASTRAK system. There are presently two FASTRAKS installed at MCE both running on PDP computers together with a VAX 11/750 which controls a Laser-Scan LITES system and fix free standing digitising tables.

FASTRAK is used by MCE for two main applications. The first is in the production of maps which has necessitated the data, captured by FASTRAK from compilation manuscripts, to be re-scaled (or otherwise manipulated) for drawing on a plotter in the form of film output. The second application has its final output in digital form for use in, for example, radar flight simulators.

It was a requirement that FASTRAK could be operated by a cartographer with the minimum of specialised training. Experience showed that given a general automation background and expertise an operator can be trained on FASTRAK in approximately four weeks.

The digitising source document in both cases is a single component, this being a map colour separation in the map/chart case and a culture manuscript in the digital product requirement.

Figure 7 shows an example of a contour source document which contains 3556 cms of line, 238 individual features and resulted in 23,242 coordinate pairs captured.

The digitising time for this example was 98 minutes. Full MCE performance and operating procedures was presented in another paper (Howman and Woodsford, 1978).

SUMMARY

Experience has proved FASTRAK to be a versatile and effective automatic line following digitising system whilst still retaining the interactive facility which allows the operator to input cartographic and feature information at the vital data capture stage.

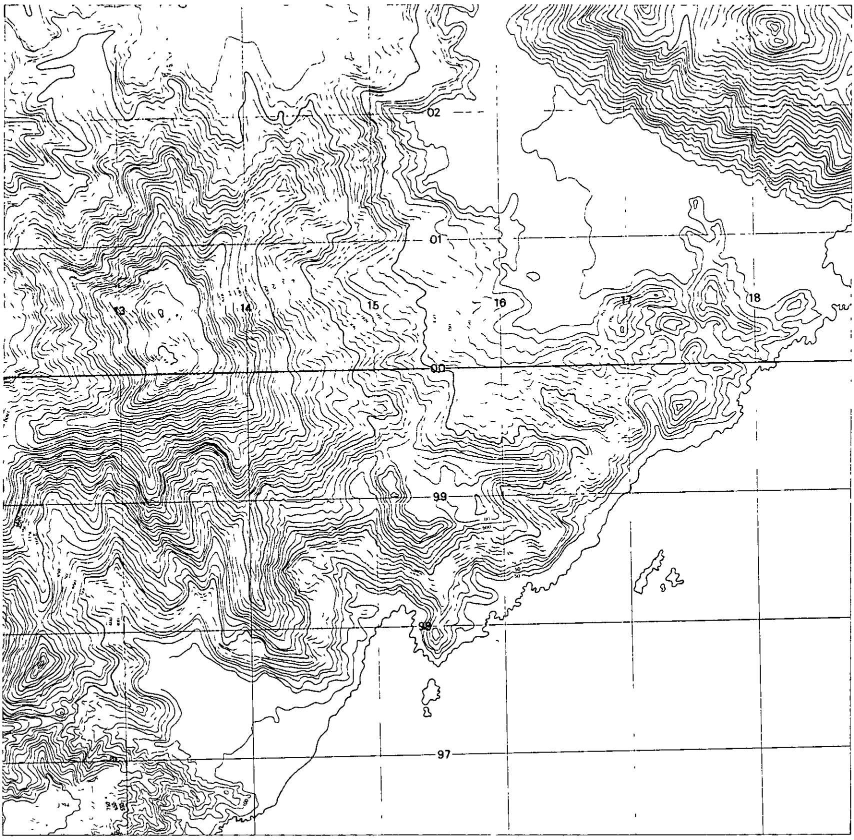

FIGURE 7

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