DATA CONVERSION FOR GIS

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ABSTRACT

Data acquisition for Geographic Information Systems is both time consuming and expensive. Most existing work is undertaken using manual methods which suffer the additional problem of producing results which vary and show inconsistency. A variety of automatic and semi-automatic methods have been developed to try to reduce these difficulties. Unfortunately, many of these technologies fail to work with the noisy, soiled or corrupted material with which bureau companies typically work. The talk describes two solutions designed to lower the cost and increase the reliability of GIS data capture. DIGIST[1] is a product designed to extract lines from paper documents. DIGIST operates with complex or soiled documents and has been shown to significantly reduce the cost of generating a GIS. A second technology tackles the problem of terrain generation. AUTO-Z[2] is a fully automatic system for the generation of terrain surfaces from stereo image pairs captured from aircraft or satellites.

INTRODUCTION

The world GIS market is currently estimated to be worth around $5.6 billion[3]. Of this, at least 7% is directly attributable to data conversion costs. Work by an independent consultant in North America [Har92] has suggested that more than 70% of GIS data conversion is done manually and that this currently represents a serious bottleneck to the wide scale development and uptake of GIS[Web91].

Over the last ten years, a considerable effort has gone into developing technology which is designed to assist or automate the data conversion task. Unfortunately, whilst most of these developments have produced high quality demonstrations with carefully selected data, performance degrades when used with the documents or images commonly used by bureau companies. Much of the data conversion task takes place with paper documents which are stained or have been hand-erased or hand-edited. Photographic records may also be degraded. Although a variety of computer-based products have now entered the market for assisting or automating the data conversion task, many have yet to cross the commercial threshold for solving the bulk of real data conversion.

This paper describes a new product, DIGIST, which is able to track lines and contours on soiled or complex documents and convert the data to a GIS. We also show some results generated by a fast stereo matching algorithm, AUTO-Z, which automatically generates a Digital Elevation Model (DEM) from stereo images.

DIGIST

Most line tracking systems work with binary (only black and white) data in which the thresholding commonly occurs in the scanner itself. Applying a fixed threshold to soiled or complex images of documents may result in a significant loss of image clarity. For complex images, there is no single threshold value that can adequately be applied to the entire image. Therefore, not having to apply a threshold at scanning time is a distinct advantage. The new problem is one of working with grey valued images.

Recent changes in workstation hardware performance now mean that there is no problem in storing large data sets in computer memory. For example, a 1:1250 Ordnance Survey map scanned at 150 dots per inch (dpi), takes up less than 6 magabytes (Mb): workstations are now rarely installed with less than 16 Mb of memory.

To start the process, the document is scanned and loaded into the system. Following an image warping operation to adjust the coordinate frame, the user applies a real-time clipping operation which helps make the lines more visible. Clipping is an operation which filters out grey values outside a particular range. Components are then placed manually onto the document image and their attributes stored. Examples of components could be junction-boxes, manhole covers, transformers, pumps or whatever the application requires[4]. The user points to the line with the mouse and DIGIST then automatically tracks the line and connects to the components. This means that in a single process, the line is automatically tracked, it's connectivity is made explicit and the user can verify the operation via the user interface.

[1] Document Imaging for GIS Technology (DIGIST) is a trademark of The Turing Institute Ltd.

[2] Auto-Z is a trademark of The Turing Institute Ltd.

[3] Source: Daratech Inc, USA

[4] The first fully operational system for mass data conversion is for utility companies involved in the electricity supply industry.

Should the document contain a portion which has a totally different contrast to elsewhere, the user can dynamically alter the clipping value using a simple slider control which is built into the interface. In this way the user has total control of the application via a simple and intuitive interface. The use of grey scale ensures that lines are tracked along their centre and that junction ambiguities are handled correctly. Should the system make a tracking error, the operator can immediately halt the tracking process, cut it back to where the error occurred and then continue along the right track.

The DIGIST technology has recently[5] been released in a commercial product. Over the next 12 months versions will be available to solve various applications including the gas, water and telecommunications utilities as well as handling colour and 3D data.

Figure 3 shows a view of the user interface with a grey-scale image loaded loaded in. The image has been processed by the system and a coloured graphical overlay is used to map the lines back over the original image.

AUTO-Z

For many GIS applications, 3D information is required. A common approach is to capture stereo pairs of aerial images. These are then subjected to photogrammetric conversion and scaling followed by a matching process which identifies common points in the two images. The vast bulk of this work is carried out by hand.

The automatic discovery of left-right matches in stereo-pair images, *stereo correspondence* [Jul71, MF81, PP84] is an intensively researched problem. Correct matches are those which project to the same points in the scene.

Marr and Grimson (see [Gri81]) built their matching algorithm on the zero-crossings of a number of $\nabla^2 G$ filtered images. The behaviour of zero-crossings derived from filters of different size (varying σ) has culminated in the finger-print theorem which states that zero-crossings will not occur abruptly in the (x-σ) scale space [Wit83]. This is of great heuristic value and laid a solid mathematical foundation for token tracing over a variety of scales.

An alternative approach to the token-based methods is to perform matching on the complete gray-level image or on its convolutions. Witkin *et al's* [WTK86] approach is representative of such methods. Here, the system traces down the scale space continuously as the fingerprint theorem indicates. The approach avoids the problem of linking tokens of neighbouring scales by producing a dense (pixel-by-pixel) estimate of the disparity map as well as implicitly maintaining a continuity constraint inherent in the nature of continuous blur functions.

[5] Product release date for Europe and North America; 26th October 1992.

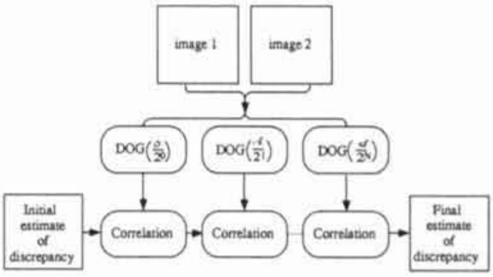

Figure 1: Multiple Scale Signal Matching.

The matching process used here is a multi-scale signal matcher (*MSSM*) [JM89]. Its input is an image pair and its output is a pixel-by-pixel, continuous measure of all image discrepancies. Discrepancies are represented by two images, one which depicts all horizontal discrepancies and the other which depicts all vertical discrepancies.

Figure 1 shows the software architecture for the multi-scale signal matching algorithm. Each of the two input images is blurred using a large $\nabla^2 G$ filter whose size is determined by σ. For each pixel in one image, the matching pixel in the other image is searched for, using a cross-correlation function. The cross-correlation searches the neighbourhood of a pixel rather than a single pixel to provide the matching score. The search starts from the initial discrepancy estimate, *e.g.*, $(0,0)$ and ends at a local optimum around that initial discrepancy estimate. For the coarsest filter, the displacement of the pixel in the image is the initial discrepancy estimate for the algorithm. The output discrepancy maps (vertical and horizontal) are used as the initial discrepancy estimates for the input images convolved with a smaller $\nabla^2 G$ filter of $\sigma/2$. The process is repeated and so past through to finer scale filters following a coarse-to-fine regime. The output from the smallest filter is the final estimate of the image discrepancies.

Figure 2 shows a stereo pair of images of Irish Canyon in the United States. The stereo pair was input to MSSM and each point in the two images was matched. Following photogrammetric scaling, a Digital Elevation model was constructed and the original image elastically stretched back over the surface. Because the model was constructed directly from the stereo images, the image texture is guaranteed to be in perfect correspondence with the terrain. The 3D view at the bottom of figure 2 is one from a sequence 'fly through'.

AUTO-Z is a C program which requires no set-up parameters and guarantees an optimal match which is accurate to approximately one eighth of a pixel. When running on a Sun IPX workstation with no special hardware accelerators, the algorithm produces approximately four thousand height estimates per second.

Acknowledgements

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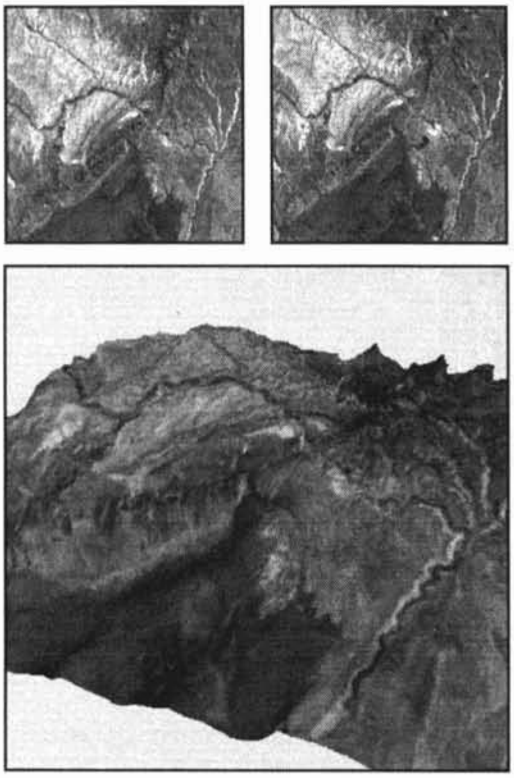

Figure 2: The top two images are from a satellite. The lower view is of a 3D model built following fully automatic stereo matching.

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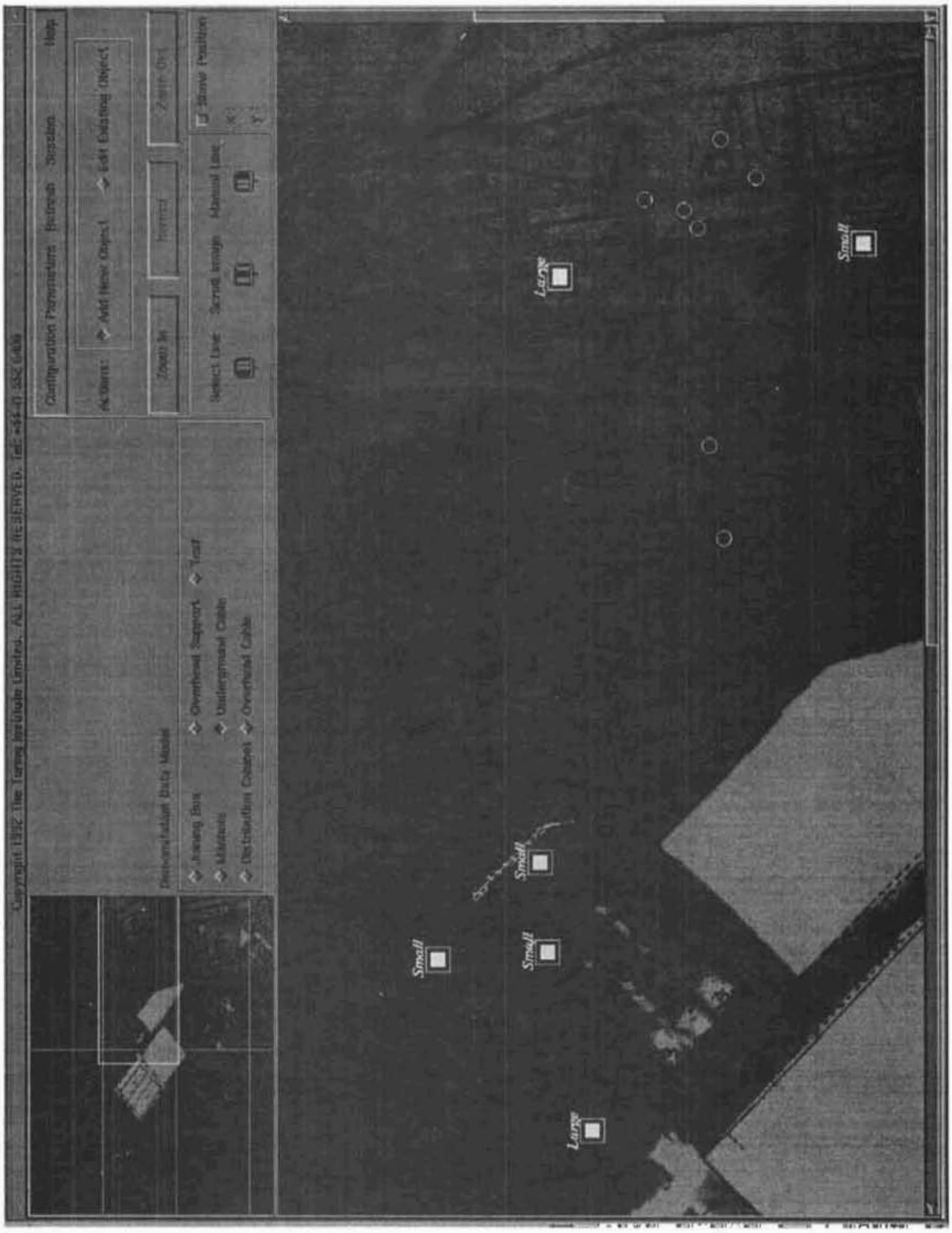

Figure 3: Screendump from DIGIST during operation. The converted lines, objects and conectivity have been overlaid on the original document..