Image to Haptic Data Conversion: A First Step to Improving Blind People's Accessibility to Printed Graphs

Wai Yu, Kenneth Guffie, Stephen Brewster
Department of Computing Science
University of Glasgow
rayu@dcs.gla.ac.uk
http://www.multivis.org

Abstract

This paper introduces a system which converts scanned line graphs into a data format which is interpretable by a haptic device. A virtual line graph can then be rendered and explored through touch by using the haptic device. This system provides an alternative method for blind or visually impaired people to access printed graphs. This method has a simpler production process than the conventional raised paper. Moreover, exploring graphs through a haptic device can provide assistance and guidance to less confident users. At the current stage, simple line graphs can be converted and rendered on two haptic devices: SensAble PHANToM and Logitech WingMan force feedback mouse. Evaluation of the system is being carried out and further improvements have been planned.

1. Introduction

Automatic conversion of printed information into electronic data formats has been studied for many years and as a result, scanners and Optical Character Recognition (OCR) software have been developed. Converting visual images into computer recognisable data provides people with the manipulation flexibility and the ability to preserve and reprint invaluable documents [1]. Computerising Braille is one of the examples to preserve aging Braille printout. It is a process to recognise Braille cells on an image captured by a camera. The electronic copy of the Braille document will be stored on a computer after processing. Although it is a good idea to preserve old Braille documents via optical media, it faces some technical difficulties, such as severely degraded paper quality, stains and marks left on the document and problems with double-sided Braille. All these make the recognition difficult and hard to achieve very accurate results [2].

Commercially available products have been developed to help blind people to access printed documents using scanners, OCR software and screen readers [3]. The scanned document is processed by the OCR software, and subsequently the device reads out the recognised text to blind people. This provides blind people with an easy access to printed documents without the need to convert them into Braille first. However, problems of recognising document layout and interpreting pictures and images cannot be resolved easily by OCR software. How many words are needed to describe a complex graph if a picture is worth a thousand words? In order to address this problem, we have been investigating the possibility of image to haptic data conversion so that graph features can be extracted and rendered on a haptic device.

Research work has been done on presenting graphical information to blind people using force feedback devices. Blind people will use these devices to feel the data representation through the sense of touch [4, 5 & 6]. Our previous work has shown that blind people are able to use a PHANToM to comprehend the contents of line graphs [7]. Therefore, it is desirable to develop a system which can interpret graphs and render them on a haptic device so that blind people can explore the data on the haptic representation. In this paper, we introduce our haptic line graph modelling methods and the attempt to make image to haptic data conversion possible.

2. System

The system consists of three main components: a flatbed scanner, an IBM compatible PC and a force feedback device which can either be a SensAble PHANToM or a Logitech WingMan force feedback mouse (Figure 1). The control flow of the system is illustrated on a schematic diagram (Figure 2). The scanner acts as a data input device through which printed graphs will be acquired and stored as digital images. Image processing techniques are then applied to extract useful features for the haptic rendering process. After the features have been extracted, the haptic rendering will take place and the user can then explore the haptic representation of the graph through the force feedback device.

The standard TWAIN interface is used to acquire the image of a printed graph from an optical scanner.

Considerations have been made to improve the accessibility of blind people. TWAIN will call up the user interface provided by the scanner manufacturer for setting some parameters of the scanner such as the scanning area, colour depth and degree of exposure. This will become a problem to blind people as it is impossible for them to know the interface arrangement and especially when different manufacturers provide different user interface for their scanners. Therefore, an alternative scanning control is provided. Blind people can use a short-cut key to scan a printed graph based on the default settings which would meet most needs of the application.

(a) (b)

Figure 1. (a) SensAble PHANToM, (b) WingMan force feedback mouse.

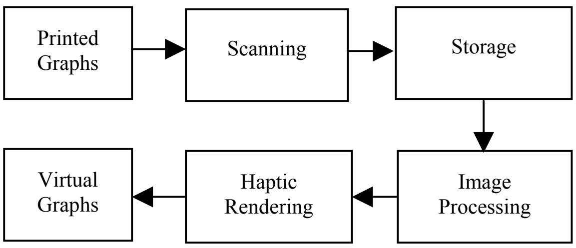

Figure 2. Visual to haptic data conversion process.

The image to haptic conversion process is mainly about transforming raster data to vector representations. The scanned image will be in the digital form consisting of pixel information. The features that need to be extracted from the image depend on the requirements of the haptic rendering process. Therefore, we need to know about the haptic modelling techniques that are used to create the haptic graphs.

2.1. Haptic Modelling

The haptic modelling of line graphs varies and depends on the haptic device being used due to the hardware limitations and software API support. In the PHANToM case, the haptic line graphs are constructed by using the GHOST SDK. Users feel the line graphs through the end-effector of the PHANToM. The lines are modelled as channels which have a V-shape cross-section designed to retain the PHANToM pointer effectively (Figure 3). The reason for constructing the line model as a concave object is due to the findings in our previous study [8]. We found that users have difficulties to keep the pointer on round objects securely. Therefore, polygons are used to construct the V-shaped channels and the inner surface is defined as touchable by the PHANToM so that the pointer can penetrate from the outside and become retained in the inside. By moving the pointer along the channels, users can trace the path of the lines.

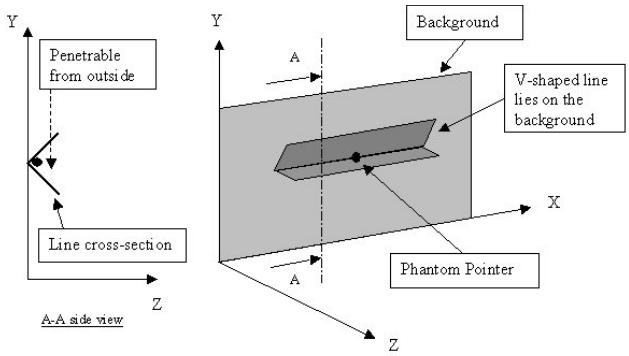

Figure 3. Haptic line graph modelling technique on the SensAble PHANToM.

In the WingMan force feedback mouse case, the Immersion TouchSense Developer Toolkit is used to create the force effect. Lines are modelled by using the spring effect and enhanced by a friction model. A constraint type of force feedback is produced by the combination of these two effects. In operation, when the mouse cursor gets close to the line, it will be snapped to the line like entering into a magnetic field (Figure 4). Strong force is applied to the direction which is normal to the gradient of the line so that the cursor is retained on the line and can only move easily along the path. Sharp corners are the source of problems in this modelling technique as the cursor can easily shoot off the line path if the user moves too fast. A remedy to this problem is now under investigation. A specific force feedback at corners is being developed so that the transition from one section of the line to another can be smoother.

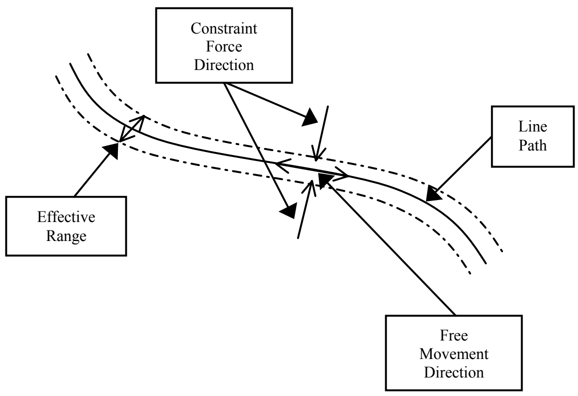

Figure 4. Haptic line graph modelling technique on the WingMan force feedback mouse.

Despite the different haptic modelling techniques, the data input required by both haptic devices is the same. The essential data required to represent a line includes the start, end and intermediate points which are the turning points on the line. In order to cope with multiple lines on one graph, a simple structure is designed to allocate the data. The information stored in this data structure is the number of lines, number of points on each line and the co-ordinates of each point. To link up the optical system to the haptic devices, image data need to be converted into the specified data format. In other words, pixels of lines have to be detected and extracted from the scanned image and then transformed into the data format required to generate the virtual graph.

2.2. Data Conversion

Data conversion relies on image processing as useful information has to be extracted and formatted for the use in the haptic rendering. This is not an easy process and could be complicated by several factors, such as the quality of the printed documents, the complexity of the graph content, and the type of graph being processed. In the present development, only simple line graphs are used for the purpose of the initial concept proving study. Further development can be made to extend the system capability to cope with more complex contents and wider range of graphs.

The printed graph is acquired from the scanner and stored as a bitmap file. The scanned image contains a large amount of information which is actually irrelevant to the haptic rendering process. As a result, it needs to be filtered out before the feature extraction taking place. The redundant information includes the colour on each pixel, noise on the graph, and text labels. The colour information and the noise can be reduced in the initial processing while the text labels will be ignored in the feature extraction in the later stage. Colour to greyscale conversion is used to reduce the amount of information and thresholding is used to further eliminate the unnecessary data.

At this point, the image is ready for the feature extraction process. A custom neighbourhood seeking technique is used to interrogate the interesting pixel points on the image in order to determine whether they are parts of a line or something else. It is based on convolution techniques and checks the surrounding eight pixels for possible neighbours. If the point is a part of a line then the algorithm will start tracing the line and recording feature points. The related pixels are then allocated together to indicate the start, end and intermediate points on the line. They are grouped together according to the line to which they belong and also to their position on the line. Therefore, they are in the same format as required by the haptic rendering process.

Complications occur when lines on the graph start intersecting which will confuse the algorithm as it is generally difficult to know whether the points belong to the original line or another one. Some assumptions are needed to deal with this kind of situation, i.e. assuming lines would not change direction at the intersection and continue on the same gradient. More investigations are required to explore different conditions and obtain satisfactory solutions.

3. Future Work

In the current development, the system only deals with simple line graphs however the concept of using image to haptic data conversion to provide access to printed graphs to blind people is demonstrated. It is possible to tackle more complex line graphs such as multiple intersecting lines and lines with different patterns. Moreover, converting other types of graphs, such as bar charts, pie charts and other types of data visualisation techniques, will be investigated and supported in the system. Besides expanding the capability of the system, an orientation adjustment method is under investigation so that the right orientation of the scanned graph can be automatically detected. This will improve blind people's accessibility in the system as it is difficult for them to tell the orientation of a printed document without any form of assistance. Furthermore, evaluation of the system is being carried out. The main investigations are focused on two different aspects: accessibility and usability of the system, and the effectiveness of the feature extraction techniques developed in the system.

4. Acknowledgments

This research work is part of the Multivis project which is funded by EPSRC Grant GR/M44866, ONCE (Spain) and Virtual Presence Ltd.

5. References

[1] G. Francois, Computerised Braille production: past, present, future. Computers for handicapped persons, 1989: pp. 52-56.

[2] Y. Oyama, T. Tajima & H. Koga Character recognition of mixed convex-concave Braille points and legibility of deteriorated Braille points. Systems and computers in Japan, Vol. 28, No. 2, 1997: pp. 44-53.

[3] Products for people with low vision, http://www.telesensory.com.

[4] C. Colwell, H. Petrie D Kornbrot A. Hardwick and S. Furner, Haptic virtual reality for blind computer users. In *ACM Conference on Assistive Technologies*. 1998. pp. 92-99.

[5] N. A. Grabowski and K. E. Barner, Data visualisation methods for the blind using force feedback and sonification. In *SPIE-Int. Soc. Opt. Eng. Proceedings of SPIE - the International Society for Optical Engineering*. 1998. pp. 131-139.

[6] F. Van Scoy, T. Kawai, M. Darrah and C. Rash, Haptic display of mathmatical functions for teaching mathematics to students with vision disabilities: design and proof of concept. In *First international workshop on haptic human-computer interaction*. 2000. pp. 78-81.

[7] W. Yu, R. Ramloll, S. Brewster & B. Riedel, Exploring computer-generated line graphs through virtual touch. To be presented at *ISSPA 2001 special session on Enhanced user interfaces for non-visual image display.*

[8] W. Yu, R. Ramloll, and S. A. Brewster, Haptic graphs for blind computer users. In *First international workshop on haptic human-computer interaction*. 2000. pp. 102-107.