# MultiVis: Improving Access to Visualisations for Visually Impaired People

**David K McGookin**
The MultiVis Project
G.I.S.T
Department of Computing Science
University of Glasgow
Glasgow
G12 8QQ
mcgookdk@dcs.gla.ac.uk
multivis.org

**Stephen A Brewster**
The MultiVis Project
G.I.S.T
Department of Computing Science
University of Glasgow
Glasgow
G12 8QQ
stephen@dcs.gla.ac.uk
multivis.org


*CHI 2006*, April 22 – 27, 2006, Montréal, Québec, Canada.
ACM 1-59593-298-4/06/0004.

## Abstract
This paper illustrates work undertaken on the MultiVis project to allow visually impaired users both to construct and browse mathematical graphs effectively. We start by discussing the need for such work, before discussing some of the problems of current technology. We then discuss Graph Builder, a novel tool to allow interactive graph construction, and Sound Bar which provides quick overview access to bar graphs.

## Keywords
Haptics, Visual Impairment, Visualisation.

## ACM Classification Keywords
H.5.2. Haptic I/O, Auditory (non-speech) feedback.

## Introduction
There are currently 11.4 million visually impaired people in the United States and 2 million in the United Kingdom (www.rnib.org). Many of these users interact with computer systems using screen reading software such as JAWS (www.freedomscientific.com). This technology, whilst allowing access to textual data is poor at providing access to graphical data, such as the graphs, charts and tables that sighted people read and communicate with in their everyday lives. Whilst paper based technologies are available they do not allow easy

access to computer based data, are inflexible and cannot be updated dynamically.

The MultiVis project is concerned with how to make such graphical visualisations accessible to visually impaired people. Primarily this is achieved through using technology such as SensAble technologies' (www.sensable.com) PHANTOM haptic device to create virtual haptic environments, and non-speech audio feedback. In this paper we will illustrate how virtual haptic technology can be leveraged to overcome two issues faced when visually impaired people try to interact with graphs: interactive graph construction and providing quick overviews of graph based data.

## Graph Construction

One educational task when learning about mathematics at school is graph understanding. This is primarily accomplished by getting students to carry out simple graph construction tasks. Conventionally, sighted students will use pencil and paper to complete the graph. This allows students to easily correct their mistakes (by rubbing out the line and redrawing it). Such easy manipulation is important since learning to construct graphs involves making mistakes, understanding those mistakes and interactively revising the graph accordingly [1]. This is a problem for visually impaired people as current technologies to create graphs are slow and cumbersome, failing to allow mistakes to be easily rectified and making the task of graph construction more frustrating than necessary. We have collected evidence for this view from group discussions at the Royal National College for the Blind (RNCB) Hereford and classroom observations at the Royal Blind School (RBS) Edinburgh. At the RNCB six participants aged 18-24 were asked to discuss questions relating to both their use and construction of graphs at school. At the RBS one-on-one teaching sessions with visually impaired pupils aged 16 on graph construction were observed. From participants' discussions the main way in which students interactively construct graphs is to use of a cork board covered with a raised paper set of gridlines. Here students use pins and rubber bands to create the features of the graph, such as lines, bars etc. This solution has the option of allowing the graph to be modified both during and after construction; however it is possible for the pins to become dislodged and fall out, or for the student to injure themselves by pushing the pin into their finger. When modifying the bars it is possible for the elastic bands to become detached and "fly off", which the student may or may not notice, leading to confusion. Additionally with this technique the graph must be dismantled after it has been constructed, since the materials must be reused. Participants in the group discussion found this was *"a bit disheartening"*.

## Graph Builder

In order to overcome these problems we developed Graph Builder; a novel graph drawing program that provides the ability to interactively create and manipulate graphs, as well as save and later recover them. Whilst other systems [2, 3] have discussed graph construction they do not allow the interactive manipulation of graphs that is required in the educational context described above. Graph Builder (see Figure 1) has been developed from existing work by Yu and Brewster [2] who developed an application using a SensAble PHANTOM haptic device which allowed users to interactively browse bar graphs. Their solution used "V" shaped grooves cut in to the background of the graph to represent bars (these being easier to follow than conventional raised lines).

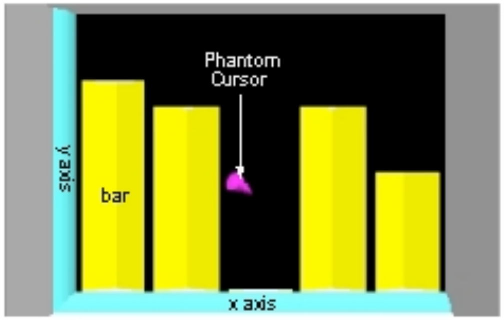


**figure 1**. Screenshot of the Graph Builder application.

The axes are presented as cylinders to differentiate them from the bars. We developed their approach and provided functionality to allow users to move the bars of the graph up and down. Users could manipulate the positions of the bars by holding down the "Ins" key on a standard numeric keypad. This changed the current mode from browsing to building. In building mode, when the user touched the top of a bar an audio "Clunk" sound was played and the user was locked onto the bar. By moving the PHANTOM cursor up or down the user changed the position of the bar, with a MIDI (Musical Instrument Digital Interface) note being played to signify this. Users could count the number of MIDI notes played to determine the current position of the bar. By releasing the "Ins" key the mode changed back to browsing and the value of the bar was set to the current position of the PHANTOM cursor. Several evaluations of Graph Builder using both blindfolded sighted and visually impaired users have shown that graphs can be built with a high degree of accuracy (participants averaging over 90% correctly constructed graphs). Due to the success of the bar graph version of Graph Builder we are extending the approach to other forms of graphs such as line graphs, as well as a collaborative version allowing both visually impaired and sighted students to work together to construct graphs (as might be required when a visually impaired student is taught out with a specialised blind school.

## Improved Graph Browsing

In undertaking the group discussion study at the RNCB Hereford we identified that many of the participants felt that graphs provided poor access to information. One went as far as to say, when asked about the sort of uses of graphs in her everyday life, *"I do avoid them as much as I can"*. This is surprising since for a sighted person a well designed graph is preferable to written text containing the same information [4].

Whilst previous work [2] shows that users can successfully extract information from graphs, it appears they do not perceive the same benefit in using graphs as would a sighted person. This may be due to the very "visual" way that graphs are constructed for a visually impaired person. The graphs used in this work, and other haptic graph browsing work, simply convert visual representations to haptic representations. Winberg and Bowers [5] identified in a collaborative task between visually impaired and sighted people that a shared representation is important. However, as indicated by work on visual graph perception by Lohse [4], different graph representations can have a large impact on the time and effort required to extract information, even when those representations contain the same information. Pinker [6] has identified that a "graph schema" existing in short term memory (which has both finite capacity and degrades over time) is used to hold information about the graph. Since the bandwidths of the auditory and haptic channels are much more limited than vision, we believe it is important that information is organised in an optimal way to be easily extracted from a graph presented in a different modality. Doing so should allow visually impaired people to gain a similar benefit from graphs as sighted users do.

In order to investigate this we have modified Graph Builder to incorporate a "sound bar" between the bars and the x axis. When the PHANTOM cursor touches the sound bar, a MIDI note is played, where the pitch is proportional to the height of the bar directly above the PHANTOM cursor. By moving the PHANTOM horizontally across the sound bar, a sequence of such notes is played providing a rapid overview of the general graph shape, allowing the user to quickly focus in on areas of interest. The sound bar therefore provides an alternate "view" onto the graph, presenting the information in a different but more optimised way for different tasks. If this technique proves to be successful other views may be identified and incorporated, allowing visually impaired people truly useful graph access.

## Conclusions

In this paper we have described two applications, informed from requirements capture with visually impaired people, of haptic technology to improve access to graphs: Graph Builder which allows users to interactively create simple graphs, which is important in the educational process and Sound Bar which allows users to gain a quick overview of a haptic graph. By providing applications such as these we can allow visually impaired users to better interact with graphs, be better informed about graphs and ultimately more inspired about mathematics in general.

## Acknowledgements

We would like to thank all at the RNCB and RBS. This work is supported by EPSRC grant GR/S86150/01.

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