

# Navigating maps with little or no sight: An audio-tactile approach

R. Dan Jacobson  
Department of Geography  
University of California  
Santa Barbara, CA 93106 USA  
[djacobson@geog.ucsb.edu](mailto:djacobson@geog.ucsb.edu)

## Abstract

This paper first presents a review of the options available for conveying maps and graphics to visually impaired and blind people. A novel audio-tactile methodology is described, and the results from its pilot study reported. Communication of spatial media, such as map, is problematic without sight. Tactile perception is serial rather than synoptic. By building a working model of the environment that uses both tactile and auditory feedback, a map is made far more accessible. Results from the pilot study demonstrated simplicity and enjoyment of use of this novel approach which integrates speech, verbal landmarks, earcons and recorded environmental sound to build a small spatial hypermedia system.

## Introduction

Whether blind, visually impaired, or sighted, our quality of life is greatly dependent on our ability to make informed spatial decisions. Space is fundamental to human existence and has great influence on human thinking. Access to representations of the geographic world (a map for example) are frequently denied a blind individual due to his or her lack of sight. For a long time tactile maps have sought to solve this problem. Tactile maps are static, cumbersome to create and have many associated cartographic problems. The fingertip's resolution is far less than the eye, it perceives serially – its “bandwidth” is very low compared to vision. The sighted cartographer is faced with the problems of simplification,

generalisation, classification and symbolisation to render a visual map tactile. A common problem with tactile maps is labelling. Braille labelling is inflexible and when enough labels are applied to facilitate suitable understanding the map often becomes cluttered and illegible (Tatham 1991). Using labels in a separate legend or key reduces the immediacy of the graphic and introduces interpretative problems as referencing is disrupted (Hinton 1993). Technologies are evolving to help address some of these problems. The aim of this research is to create a way of accessing map information that is easy to learn and use, and supports interaction that is natural, flexible and efficient. It is hoped that this will expand the availability of maps to a broader spectrum of the population.

## 1 Enhancements and alternatives to conventional tactile maps

Techniques for producing hardcopy tactile maps have improved (eg Andrews, 1988), however, the perceptual constraints remain the same - fingertip resolution and a “static” media. Moving from one map to an adjacent map is physically clumsy and awkward. There have been two major developments. Firstly, the use of computer technology for the generation of the art work that produces the tactile map. Secondly computer systems to assist the reading of the tactile map.

### 1.1 Automated tactile map creation

Geographic Information Systems (GIS – loosely defined as a spatial database) can be used as a way to store, manage and manipulate spatial information for the generation of tactile

maps. Coulson (1991) pioneered the use of a GIS, exploiting its cartographic functionality, for the production of tactile maps. A sighted operator would create a map, first plotted on paper then rendered tactile by microcapsule paper. The structure of data stored on a GIS and the ways in which this can be accessed are beneficial to this map manipulation and management.

### **1.2 Augmented tactile maps**

An alternative solution has been to develop audio-based systems that link sound with touch, enhancing the tactile map with the addition of audio. For example, when a raised area on a tactile map is touched a corresponding sound label is triggered. Two such systems include NOMAD (Parkes 1988) and 'talking tactile maps' (Blenkhorn and Evans 1994). Fanstone (1995) has exploited the GIS capabilities of NOMAD to build a hierarchical audio-tactile GIS of Nottingham University campus. Access within a map is very efficient users reporting enjoyment and ease of use (Jacobson, 1996). However, access from one map to the next remains problematic. For example to 'zoom in' or to move to an adjacent the user has to locate the speech label indicating that it is possible to zoom in. Then remove the tactile map, search for another tactile map, register this on the touchpad and then continue map exploration. This break in the continuum of map reading is disrupting and confusing.

### **1.3 Novel digital technologies**

One development that has great potential to solve this problem is hypermedia. Hypermedia which comprises of text, still imagery, sound recordings (even tactile and olfactory output) is a network of information 'linked electronically by multiple routes, chains, or trails in an open-ended, perceptually unfinished assemblage described best in terms of links, nodes, networks, webs and paths' (Landow 1992, p.3). A well known example of a hypermedia environment would be the World Wide Web. Within a hypermedia environment

a user can navigate between textual and cartographic information nodes in order to get a well documented, multi-faceted representation of space, from varied sources and differing viewpoints (Milleret-Raffort 1995). A hypermedia document (if structured correctly) should allow a seamless navigation through the document, passing through various media, following a line of thought or inquiry. Conventional hypermedia systems are designed for predominantly visual in nature. They can, however, also offer people with visual impairments a way of exploring the world (Jacobson and Kitchin, in press)

Non-visual hypermedia systems seek to provide sensory substitution with spoken audio information replacing textual and image based information. Such a system now exists for blind users on the World Wide Web (Webspeak 1995). Here, images are bypassed, textual information is converted to speech, and hypertext links are explained. There has been a long period of development of auditory alternatives to the visually dominant Graphical User Interface (GUI), for example, Soundtrack (Edwards, 1989); Karshmer and Oliver (1993); The Graphical User Interface for Blind People Project (GUIB- Savidis and Stephanidis, 1995); the Mercator Project (Mynatt, 1997). These developments are important as they allow a blind user to work in parallel with their sighted counterpart. However, the development of systems for accessing spatial information (map-like information, rather than pull-down menus and screen icons) has been lacking. There are few notable exceptions (see Kurze and Holmes, 1996; Kurze 1997). Maps are of crucial importance, as they have the ability to not only present information with an academic view of the world but have the potential to impact on the daily living problems facing blind people. As such they can lead to an improved quality of life through enhanced, orientation, mobility and independence.

## **2 Preliminary GIS and web studies**

Research undertaken at the Univeristy of Wales, Aberystwyth, UK between 1994 and 1996 explored the potential of GIS and

hypermedia for communicating spatial information to blind and visually impaired people.

A GIS front end, ArcView, was used to construct a spatial system for visually impaired people (legally blind, but with some residual vision). The GUI was stripped down and many unnecessary component buttons and menus removed. The final system worked in two modes, a low vision zoom and pan query mode which displayed a map of the campus. With a single mouse click users could zoom-in to the area selected. By re-clicking the mouse button the user continued zooming-in until the area in question filled the display. With a further click an audio file was played, 'speaking' the name of the building. Finally a large photograph of the building was displayed. In the second mode the user typed in the name or function of the building (for example 'Llandinam Building' or 'Earth Sciences') a map was then displayed of the campus and subsequent maps, each displayed after a mouse click zoomed the user in to the building requested (see Jacobson and Kitchin, in press.)

As such, ArcView was effectively reduced to a point-and-click hypermedia system. Users of the system expressed great interest and excitement asking 'can you do this for the town centre'; 'Now I can experience places I would never visit'. Due to the 'simplicity' of the final slimmed down version of ArcView and to allow optimum access and usability it was decided to continue with the project using the World Wide Web environment.

A series of hypermap World Wide Web pages were built allowing the user to navigate between low vision maps and spoken textual screens. The interface utilised large font hypertext mark-up language (HTML), and at the bottom right the screen magnifying software. Large scale abstracted and simplified maps were used to convey spatial information. An enhanced cursor is used to follow links, when a shape on the map is queried an audio file was displayed describing the building. This interface enabled users to

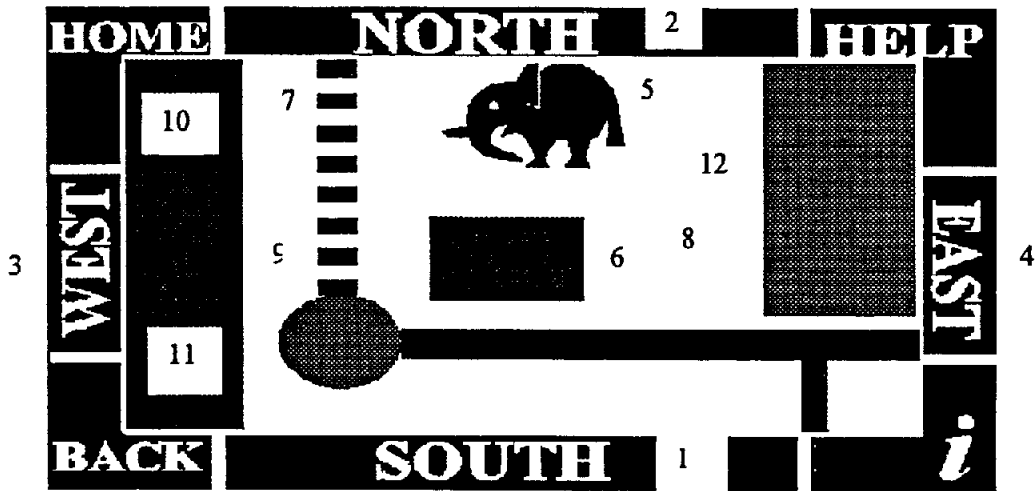
access the low vision and spoken maps remotely.

### 3. Prototype and pilot study of audio-tactile system

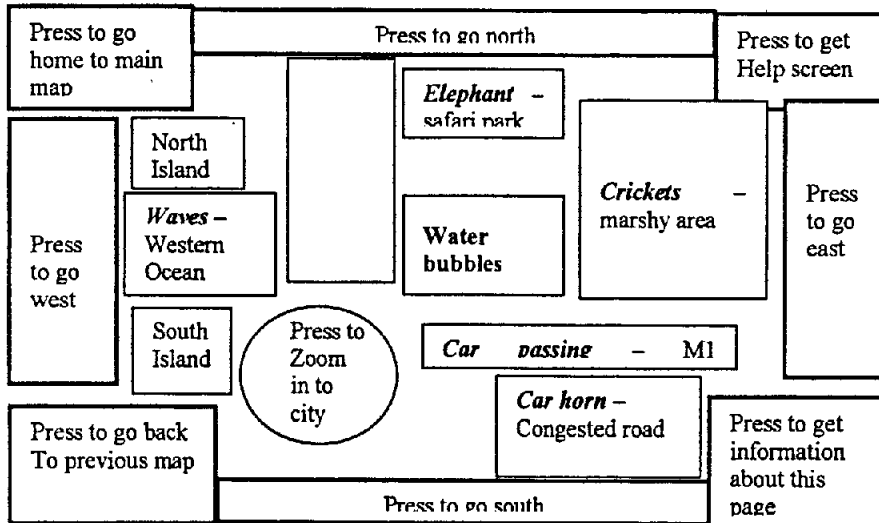
The prototype used a low specification PC (DX4-100 processor, 16 megabytes of ram, and a 16bit soundcard) The touch pad and associated software retail for around \$300 and will work with any windows based PC. The touch pad can be attached to a monitor so a user with limited vision is able to view the screen, or used at table-top level where a totally blind individual is able to scan the pad with their fingertips. Spatial information is presented as an auditory map. Areas of the touch pad are overlain with sound, when the map users finger enters the designated area the sound is played. By touching areas of the pad users were able to determine the size and shape of a map feature by the change in sound. A collection of sounds are used to represent map information usually conveyed by visual symbols (text, color, line style, shape etc.). An off-line World Wide Web site is being built which utilizes interlinking auditory maps that can be traversed solely by sound and touch. As the user's finger is dragged across the touch pad, the system 'talks', playing audio files which are triggered by the position of the user's finger. By the use of spoken audio, verbal landmarks, environmental audio (such as traffic noise for a road) and auditory icons (earcons - Blattner *et al.*,1989) to denote specific events like the edge of a map, a link to further maps, or for the user to press for more information, an audio-tactile hypermedia is constructed conveying cartographic information.

Rather than direct manipulation of a tactile surface, such as pressing on the tactile maps in NOMAD, this system uses a touch pad. Therefore the user has no direct cutaneous stimulus from tactile relief. The encoding from the audio-tactile stimulus meant that map

Figure 1: Overview of sample audio-tactile map information (main map in pilot study)



(a) Screen dump of main audio tactile map (numbers refer to 1(c)) 13



(b) Audio overlay on visual map (*dark text* – indicates the playing of an environmental sound)

- 1 To the south is a large conurbation: An area of many cities
- 2 To the north is an area of rolling farmland
- 3 To the west is a windy ocean
- 4 To the east is a hot dusty plain
- 5 The safari park has many animals from East Africa
- 6 The lake is a popular escape for the city people during the hot summer months
- 7 Trains travel from the city into the wine country
- 8 Open space and farmland around the city
- 9 Many boats trawl the sea for shoals of cod
- 10 North island is home to a large colony of seabirds
- 11 South island is used for missile testing
- 12 The marsh is an area once filled by the sea, now unsuitable for development
- 13 The main map shows a city and its surroundings. To the west is an ocean. In the south west is the city. To the north a train line, to the east a motorway and to the eastern fringes a marsh.

(c) Links to verbal information from the main scro-tactile map information (main map in pilot study)

information is built up from kinaesthetic sensing of movement across the pad, sensing of the distance traversed across the pad, proprioceptive sensing of the location of the fingers and location information obtained by referencing with the hands to the outside frame of the touch pad. Linking enables a blind user to traverse from one auditory map to another. As each map loads, a verbal overview describing the map is played. From all maps there is direct access to a help screen that explains the system and the modes of interaction.

Figure 1(a) displays the simple user interface for the auditory hypermap system. As the map-reader's finger moves across the touch pad and over the "SOUTH" bar the audio message "Press to go south" is played. Once this part of the touchpad is pressed the central area is filled with an auditory map to the south of the previous one. If no maps are available, this is verbally relayed to the user. North, west and east all work in a similar manner. Home returns the user to the main auditory map. The help button explains how to use the system. When exiting from help the user is returned to the correct map. The "i" button plays information about the map in view (e.g., 'this is the city area map. Downtown is in the north of the urban area, and the harbor to the west etc.'). The back and forward buttons allow the user to traverse through the 'history' of their links

### 3.1 Methodology

Evaluation of the system involved 5 visually impaired people and 5 blind people. The system was evaluated individually. Initial training took place for 15 minutes using the help screen of the model. Users were familiarised with the touchpad, were shown how to follow a link, obtain more verbal information, and to follow a link. The structure of the menu surrounding the map was explained (buttons north, south etc.) and the function of the buttons to go back and home shown. Questions were answered and people familiarised themselves with the system. There were given no information about the

content, structure or links between the maps. During the evaluation phase individuals had 15 minutes to navigate through and explore the maps. They were told that they were free to go where they wished and to return to places previously visited. At the end of this 15 minute period, the computer was turned off and the participant gave a verbal description of the maps and map-layout imaging they had to explain the maps to somebody over a telephone. The participant then graphically reconstructed the maps using a tactile drawing pad which enables a blind user to feel what they are drawing. The whole process was videotaped and a log made of peoples paths through the audio-tactile maps. Semi structured interviews were used to get impressions of the system, feedback on how it could be improved and for ideas of where it may be beneficial (such as in schools or at tourist sites).

### 3.2 Results

All users were able to successfully interact with the system. This included people who had never used a computer before. Interview responses suggest that the system aroused great interest and that map access was 'simple, satisfying and fun' (totally blind participant). Users were able to both graphically and verbally reconstruct the maps with varying degrees of accuracy. Further evaluation is planned to directly compare these results to tactile map access of the same scenes. Figure 2 shows a graphical reconstruction by a visually impaired map user, and figure 3 a graphical reconstruction by a totally blind participant

The audio-tactile hypermap system was designed as a prototype to explore the possibilities for conveying spatial information in this 'touch-audio' manner. Ultimately it is intended that such a system could act as a front end to a more fully functional GIS, enabling the selection and presentation of map like information to visually impaired people. For example, to construct a map of 'y' town showing roads, location of crossings and public conveniences, all at the request of the user.

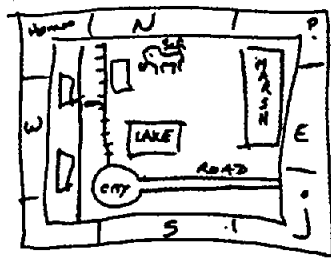


Figure 2 : Graphic reconstruction by visually impaired individual

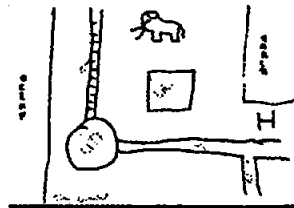


Figure 3 : Graphic reconstruction by a totally blind individual

#### 4 Future research

There is a need for future research to address the further development and use of new interface technologies such as voice recognition, touch screens and tactile displays. Probably the most pressing need is to improve the user interface, as this is the largest barrier to successful and meaningful interactions with representations of spatial information. There have been several novel and interesting approaches that require further investigation. A vibro-tactile mouse which registers the mouse's position over a desired spatial object on a map (Nissen 1997), tonal interfaces for computer interaction (Alty 1996), and 'The Voice' which can convert a two dimensional picture, map or representation into a 'tonal soundscape' (Meijers 1993, 1997). Much of GUI of this research could be directed at conveying representations of the real world (maps) to blind people in order to develop fully functional non-visual GIS systems. Further research is needed on the sonification of maps

and graphics. Krygier 1994 outlined auditory cartography and Blattner et al., 1994 have worked on the sonic enhancement of two dimensional graphic displays. Clearly there is the need for visually impaired people to be active participants in the research process and for the process to be user-led with frequent validation

#### Conclusion

This research is highly relevant and has implications beyond the blind community that it is targeted at. New internet developments offer great potential. The internet is widely used commonplace and rapidly expanding. The internet can potentially distribute information from anywhere to anywhere. The nature of the protocols such as VRML and HTML offer good approaches and techniques so a non-expert can build information is readily accessible to blind and visually impaired people. This novel audio-tactile approach offers, a dynamic, flexible, low cost media for the presentation of spatial information.

Because this audio-tactile mapping system resides within the protocols of the world wide web it means that the maps can be accessed audio-visually by sighted people using a conventional mouse. With the addition of the touch pad a partially or totally blind user is able to remotely access the content of the auditory maps from any computer with an internet connection. By adopting a 'design for all' approach the spectrum of people able to access map and graphic information is increased to include not only people with limited vision, but also potentially children, the elderly and people with learning disabilities.

Visually impaired people's need for spatial information is greater than their sighted counterparts as they are unable to (fully) perceive the environment through vision. This lack of visual perception severely limits independent travel. The computing community is in a unique position to address this need and improve the quality of life for people with visual impairments by increasing the capacity for independent travel and education through

obility and learning aids.

## acknowledgements

Our thanks go to all the participants in Belfast, Northern Ireland who offered their time to participate in the pilot study.

## References

- Andrews S. (1988) The use of capsule paper in producing tactile maps *Journal of visual impairment and blindness*, 79, 396-399.
- Battner M.M., Sumikawa D.A. and Greenberg, R.M. (1989) Earcons and Icons: Their structure and common design principles. *Human-Computer Interaction*, 4, 11-44.
- Battner M.M., Gilnert E.P. and Papp A.L. (1994) Sonic Enhancement of Two-Dimensional Graphic Displays. In *Auditory display: Sonification, Audification, and auditory interfaces* (Ed) G. Kramer, Addison-Wesley, Santa Fe Inst, Reading, MA pp 447-460
- Benkhorn P. and Evans D. G. (1994) A system for reading and producing talking tactile maps'. *Proceedings of the 9th International Conference on technology and persons with disabilities*, California State University, Northridge.
- Boulton M.R.C. (1991) Tactile-map output from geographical information systems: the challenge and its importance. *International Journal of Geographical Information Systems* (5) 3, 353-360.
- Burrows A.D.N. (1989) Soundtrack: An auditory interface for blind users. *Human-Computer Interaction*, 4, 45-66.
- Fanstone J 1995 Sound and touch: a campus GIS for the visually impaired. *GIS Europe*, April, 44-45.
- Fontana R.A.L (1993) Tactile and audio-tactile images as vehicles for learning. *Non-visual Human Computer Interaction*, 228, 169-179.
- Fontana R.D. (1996) Talking tactile maps and environmental audio beacons: An orientation and mobility development tool for visually impaired people. *Proceedings of maps and diagrams for blind and visually impaired people: Needs, solutions and developments*, October 21-25 1996, Ljubljana, Slovenia.
- Fontana R.D. and Kitchin R.M. (in press, due 1998) Geographic information systems and people with visual impairments or blindness: Exploring the potential for education, orientation and navigation. *Transactions in Geographical Information Systems*.
- Fontana R.D. and Oliver R.L. (1993) Special computer interfaces for the visually handicapped: A case study of the manufacturer. *Proceedings of the Third International Conference EWHCI'93*, Moscow, Russia, August 1993, 272-280.
- Krygiel J.B. (1994) Sound and geographic visualisation In A M MacEachren and D R Fraser Taylor (eds.) *Visualisation in modern cartography* Pergamon. 149-166.
- Kurze M. (1997) Rendering drawings for interactive haptic perception. *Proceedings of Computer-Human Interaction*, March 22-27, 1997, Atlanta, GA.
- Kurze M. and Holmes H. (1996) 3d concepts by the sighted, the blind, and from the computer. *Proceedings of the 5th international Conference on Computers Helping People with Special Needs*, July, 17-19, 1996, Linz, Austria.
- Landow G.P. (1992) *Hypertext: The convergence of contemporary critical theory and technology*. Baltimore: Johns Hopkins University Press.
- Hatfield, UK, February 1-2.
- Meijer P.B.L (1992) An experimental system for auditory image representation. *IEEE transactions on biomedical engineering*, 39(2), 112-121.
- Meijer P.B.L. (1997) Soundscapes from the voice - Introduction and overview Internet World Wide Web address [http://ourworld.compuserve.com/homepages/Peter\\_Meijer/voicover.htm](http://ourworld.compuserve.com/homepages/Peter_Meijer/voicover.htm)
- Milleret-Raffort F. (1995) Some cognitive and technical aspects of hypermaps In T. L. Nyerges *et al.*, (eds.) *Cognitive aspects of human-computer interaction for geographic information systems*, Kluwer academic publishers, Netherlands.
- Mynett E.D. (1997) Transforming graphical interfaces into auditory interfaces for blind users. *Human-Computer Interaction*, 12, 7-45.
- Nissen J 1997 (Pers. Comm.)
- Parkes D. (1988) NOMAD - An audio tactile tool for the acquisition, use and management of spatially distributed information by partially sighted and blind people. *Proceedings of the second international conference on maps and graphics for visually disabled people* Nottingham, UK: Nottingham University, 24-29.
- Savidis A. and Stephanidis C. (1995) Building non-visual interaction through the development of the rooms metaphor. Companion of the *CHI'95 Conference on human factors in computing systems*, Denver, Colorado, 7-11 May, 1995, 244-245.
- Tatham A.F. (1991) The design of tactile maps: Theoretical and practical considerations. *Proceedings of international cartographic association: Mapping the nations*. (Ed) K Rybczak and M Blakemore. London, ICA, 157-166.
- Webspeak (1995) *The pwWeb Speak Project*.

Internet World Wide Web address at  
<http://www.prodworks.com/pwwwebspeak.htm>