Navigation for the visually handicapped: Going beyond tactile cartography

R Dan Jacobson, Postgraduate researcher, Institute of Earth Studies, University of Wales, Aberystwyth.

Abstract

Wayfinding for the visually handicapped, is made more complex by the loss of their visual sense. In spite of this they can hold spatial concepts and are often competent navigators. Tactile maps, those sensed by touch, have been shown to improve their spatial awareness and mobility. It is however the development of a personal guidance system (PGS) relying on recently developed technologies that may herald a break through for navigation for the blind and visually impaired. It would enable the visually handicapped to move more freely and independently through their environment. It would provide on-line interactions with representations of their environment, in audio or tactile form, providing orientation, location and guidance information, enabling them to plan, monitor and execute navigation decisions.

Introduction

Navigation, the art of wayfinding, is an ability common to us all. It is mostly a subconscious, innate process but is also a learned bchaviour, one that we develop from early childhood. A process that we rely on countless times to function in the spatial world.

If 'wayfinding depends in essence upon a knowledge of the spatial relations between places' (Downs and Stea, 1977, p.59) then the visually impaired and the blind could be expected to be spatially handicapped. For without vision, the richest source of spatial and environmental information (Warren, 1978) they face many unique problems. The key environmental information needed to build the spatial relations between places has to be gained through senses other than vision. This creates a severely disadvantaged position, as information about their immediate environment, the next few steps, can only be explored by using a cane and other non visual cues. It may be the case though that in spite of the loss of one sense, the information they receive through their remaining senses provides enough information to form the basis for spatial cognition. Their cognitive mapping skills are flexible enough to adapt to this sensory loss. However the congenitally blind, those blind from birth, were at first thought to suffer from an absence of spatial cognition (Merry and Merry, 1933). It has since become apparent that they can deal with spatial concepts (Worchel 195 1; Fischer 1964; Kennedy 1983) and they are competent wayfinders (Leonard and Newman 1967), although their emphases are based upon different information.

The following two descriptions of a route illustrate this point. Firstly a congenitally blind person:

> After descending from the bus you have to walk straight ahead a little on Kalyayevskaya Street, with the houses being on the right; you have to be **on your** toes on the comer of Sadovaya and Kalyayevskaya streets; you have to cross Sadovaya Street first, and then Kalyayevskaya Street. Now I walk on the left side of the street; passing a house I come to a small square where I have to cross a streetcar line; there is no need to be in fear on this square as there are few automobiles here; near the next house there are always a good many people as this is a trolley bus stop; next there is a house with a projection; some distance from this house there is another house with a projection and a gate through which I must pass; the gate may be identified by the deep depression in the sidewalk; on the right side of the courtyard there is a house which must be bypassed; behind the house there is a vacant space; here you must walk along the fence for in rainy weather there are puddles; after a few steps to the right there are the steps which lead to my house.

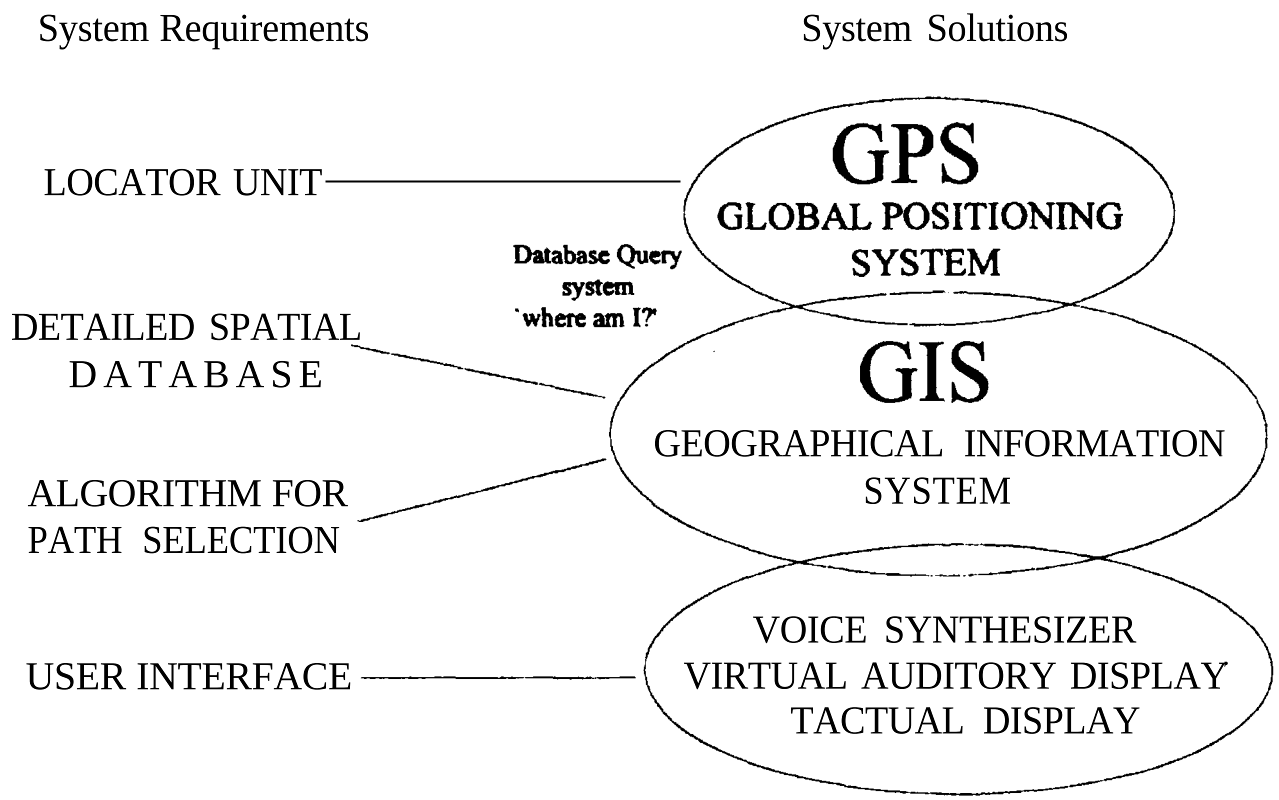
And this by a sighted person,

> Descending from the autobus, I cross Sadovaya circle, and walk on the left side of Kalyayevskaya Street. Passing the 13th division of the militia, I enter a courtyard, and there I see a small two-story house on the right side.
>
> (Khopreninova, 1956, quoted in Downs and Stea, 1977, p.69-70)

Personal Guidance System (PGS)

Because the visually handicapped experience little or no visual reference, they are far more reliant on their cognitive mapping abilities. Tactile maps may go some way to aiding navigation problems by improving the spatial knowledge base of the visually disabled. Research carried out at the University of Wales Swansea (Jacobson 1992) demonstrated that tactile maps could be used to improve general spatial cognition. Golledge (199 1) has also shown their worth as a navigational aid using portable strip maps. Other small scale, experimental locational and navigational aides have been developed. These primarily electronic systems are fragile, prone to malfunction and some require constant calibration. Systems like talking signs in Paris or Tokyo are triggered by infrared transmitters built into the signs. A hand held receiver produces a voice output matching the wording on the signs. Other systems use small scanning sonars, such as Sonic Guide (Spungin, 1985). However it is the potential benefits of a personal guidance system (PGS) which probably offers the best and most reliable solution (Golledge ***et al.,*** 1991). This is envisaged as a portable **computerised** tool with an audio and/or tactile interface to enable the visually handicapped to move more freely and independently through familiar and unexplored environments, and generally to aid navigation of the visually handicapped. Golledge's (199 1) system consists of four modules; a locator unit, a detailed spatial database, an algorithm for path selection and a user interface (see Figure 1).

Figure 1: Personal Guidance System



Module 1: The locator unit

As with all navigation this is a two fold problem, comprising of orientation - which way am I facing - and location - where am I within an environment. The location problem can be solved relatively simply using a real time, differential global positioning system (GPS) which gives an accuracy of 3 to 5 metres anywhere in the world 24 hours a day (dependent on a local base station). A portable hand held receiver receives signals from a minimum of 4 of 24 orbiting satellites and, in real time, by relating this position to that of a known base station or control, a position can be **computated**. However there are problems of losing satellite fixes in urban areas where buildings reduce the size of the available sky area. When this positional information is integrated with a large scale spatial database 'where am I' is found. In a PGS this interaction is between the first two modules, the locator unit and the spatial database, which would be based upon and use part of the **functionality** of a geographical. information system (GIS).

Such linking of GPS and GIS has been carried out successfully with extensive testing in different environments by Bossler *et al.*, (199 1). A further stage to help determine location and orientation is to have a database query system where the user interrogates the database. Here, in response to queries, the user would tell the system about environmental features they can perceive at their current location (such as sounds or smells, or the nature of the surfaces around them). When these two approaches are combined (GPS and database query) it would be a powerful tool for matching conditions to estimate current location and would offer far greater accuracy than the locating ability of the GPS used alone. Collins (1985) provides an example of using environmental data in an interactive context.

Module 2: **The detailed spatial database - geographical information system**
A detailed spatial database would form the core of the system containing information about locations and attributes of the environment within a well-defined navigational area such as a town or college campus. The database would help the visually disabled to determine accurately their current position anywhere within the environment, on or off their immediate route, and would act as a guide to movement. To achieve this the data captured has to be unambiguously related to the users' needs. The visually handicapped will use vastly different cues to the sighted. Consider the two route recollections sighted from Khopreninova (1956). The visually handicapped will commonly use such **information,as** head high projections, overhanging trees, cracks in surfaces, small changes in relief, or breaks in slope such as kerb lines. This entails large scale compilation for base map of the spatial database and requires unconventional methods for generalisation and simplification.

Golledge *et al.*, (1991) built such a database using ARC/INFO a geographical information system, representing environmental features as polygons with uniform surface characteristics. This polygonal form gives an indication of the fundamental spatial properties such as distance apart and nearest neighbour.

These are qualities which are almost impossible for the visually handicapped to access by any other means. Even experienced navigators have difficulty integrating route learned knowledge into a working whole of configurational knowledge. Using a GIS at the pre-navigation stages, when fitted with a suitable tactile interface, PGS users can begin by examining features in isolation and then build up more layers of data to patch together a more complete **knowledge of an unfamiliar environment.** A GIS with its inherent data structuring of spatial information (such as **layering)** and with procedures useful to the design of tactile maps (such as changes of scale and simplification), may prove to be a valuable educational tool (Coulson, 199 1).

Module 3: Choosing the route

Conventional algorithms for route selection must be modified for the blind traveller as safe wayfinding involves the ability to identify hazards and avoid obstacles. **Golledge's** (1991) proposed algorithm that would be used within the PGS to select a route would work on and from the GIS data, using appropriate criteria for the users, such as avoiding traffic. The algorithm would need to operate in street networks, within large, open buildings and across **open** barrier free spaces. It could work from a weighted topological network, building a **pattern of safe routes that avoid obstacles. A large scale is** crucial **and algorithm** would need the versatility to re-route user to avoid unexpected barriers.

Module 4: User interface

Given the particular problems of travelling with no or limited sight, the user interface in a PGS is of paramount importance. A conventional screen display would be impractical and it is essential that the interface works unambiguously and accurately.

During their pilot study, Golledge et ***al.,*** (199 **1)** considered three approaches. One was to use **a** voice synthesizer (Collins, **1985),** although the ambiguity of spatial language can bring problems of interpretation (where, for instance, are the limits of 'near' and **'far').** Recent research in spatial linguistics has highlighted the difficulties of using such natural language in the spatial domain (Mark and Frank, 1989). Despite these problems Golledge ***et al.,*** (1991) suggest that giving verbal directions would be preferable at this, the output stage of the system.

Another, more revolutionary approach uses a virtual auditory display in conjunction with speech synthesis. Landmark positions would be indicated by spoken labels appearing as virtual sounds (sounds that appear to originate **from** their true spatial location relative to the user's position) at their correct location within range of the user's hearing, by wearing a set of headphones developed by Loomis et *al.,* (1990). Attribute data beyond mere positional information can also be communicated to the traveller, such as the function of a nearby building. Travel can then be guided by series of auditory beacons, which the traveller can hear without environmental sounds. being blocked out.

A third approach is to use some kind of tactile display, such as a strip map with a raised outline.or on a vibrotactile array. Whilst this method has many benefits in that environmental and navigational information is presented in a spatial format that mirrors the real world, and these spatial inter-relationships can be recreated by the fingertips, at present output devices are clumsy. A large impractical volume of paper has to be carried to navigate a traveller from one side of town to the other. However such devices could be vitally important at the pre-processing and planning stage of the journey, where they serve as an educational tool rather than an en-route guide to navigation.

Conclusion - The way forward

Navigation with none or limited vision is never easy. Those who are visually handicapped, have to rely on their remaining senses to form the cognitive map knowledge that will guide them through their living environments. A portable personal guidance system (PGS), when fully operational would vastly 'alter the way in which the visually handicapped are able to manage their constructs of cognisable space. This system giving navigational updates, almost like a running commentary, has a vast potential for enhancing the mobility and independence of its users. The PGS is set to alter the way the blind navigate. The concept of a PGS is comparable to that of an automated vehicle guidance system (AVGS), blind pedestrians using a PGS - like drivers using an AVGS - would rely on the information in a comprehensive database to help select a path and to monitor their progress. Just as an automated vehicle guidance system may affect the way we drive, with digital road atlases, global positioning systems and automated vehicle tracking, the PGS will have the potential to alter the way the visually disabled navigate, Ideally a PGS would give users an accurate cognition of their position in a general environment, the bearing of their destination from that position and other spatially related information.

Research due to begin at University of Wales, Aberystwyth in October 1994, will focus on the further development of a PGS for the visually disabled. An audio-tactile interface 'NOMAD' is hoped to be acquired. NOMAD uses a touch sensitive pad wired to a personal computer and can then be programmed to 'speak' about the tactile map placed on the touch sensitive pad. In conjunction with NOMAD enhanced photographs for the partially sighted may be scanned and image processed to provide a 'multi-media' environment for the visually disabled to explore spatial and navigational concepts. Any further development is likely to limited mainly by financial constraints.

The ultimate aim is to spark a change in the mind of the user and to build their cognitive maps into a more complete whole enabling them to have a greater degree of independence and freedom of choice regarding navigation.

References

Bossler, J., Goad, C., Johnson, P., and Novak, K. (199 1) 'GPS and GIS: Map the nation's highways', *Geographic Information Systems,* March: 26-37.

Collins,C. (1985) 'On mobility aids for the blind' in Warren, D.H. & Strelow, E.R. (eds.,) *Spatial Sensing for the Blind,* Martinus Nijhoff Publishers, Dordrecht, pp. 35-61.

Coulson, M.R.C. (1991) 'Tactile-map output from geographical information systems: the challenge and its importance', *International Journal of Geographical information systems,* 5(3): 353-660.

Downs, R.M. & Stea, D. (1977) *Maps in Minds: Reflections on Cognitive Mapping,* Harper and Row, New York.

Fisher, G.M. (1964) 'Spatial localisation by the blind', *American Journal of Psychology, 77: 2-14.*

Golledge, R.G. (1991) 'Tactual strip maps a navigational aids', *Journal of Visual Impairment and Blindness,* Sept: 296-301.

Golledge, R.G., Loomis, J.M., Klatzky, R.L., Flury, A., and Yang, X.L. (1991) 'Designing a personal guidance system to aid navigation without sight: progress on the GIS component', *International Journal of Geographical Information Systems,* 5(4): *373-395.*

Jacobson, R.D. (1992) 'Spatial Cognition Through Tactile Mapping', *Swansea Geographer, 29: 79-88.*

Kennedy, J.M. (1983) 'Pictorial displays and the blind: elements, patterns and metaphors', in Weidel, J.W. (ed.) *Proceedings of the First International*

Symposium on Maps and Graphics for the Visually Handicapped Association of American Geographers, Washington D.C., pp. 75-86.

Khopreninova, N.G. (1956) 'Orientation of locality by sightless persons', *Uchenyye Zapiski Chkalovskogo Gos. Pedagogicheskikh In-ta (Chkalov* State Pedagogical Institute), #8.

Leonard, J.A. & Newman, R.C. (1967) 'Spatial Orientation in the Blind', *Nature, 215:* 1413-1414.

Loomis, J.M., Hebert, C., and Cicinelli, J.G., (1990) 'Active localisation of Virtual sounds', *The Journal of the Acoustical Society of America, 88:* 1757-*1764.*

Mark, D., and Frank, A., (1989) 'Concepts of space and spatial languages', in *Proceedings, Auto Carto 9.* 9th Annual Symposium of Computer-Assisted Cartography (Baltimore:ASPRS/ACSM), pp. 536-556.

Merry, R.V. and Merry, F.K. (1933) 'Tactual recognition of embossed pictures by blind children', *Journal of Applied Psychology, 17:* 148- *163.*

Spungin, S.J., (I 985) 'Corridors of insensitivity: technology and blind persons', *Journal of Visual Impairment and Blindness,* March: 113-1 16.

Warren, D.H., (1978) 'Perception by the Blind', in Carterett, E., and Friedmann, N., (eds.) *Handbook of Perception,* Vol. 10, Academic Press, New York, pp.65-86.

Worchel, P., (195 1) 'Space perception and orientation by the blind', *Psychological Monographs: General and Applied, 65: l-27.*