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A New Direction for Applied Geography

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A New Direction for Applied Geography

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The aim of this paper is to encourage those interested in applied geographical research to broaden their horizons to consider exciting new areas where geographical expertise has much to offer. A brief overview of dominant past trends is followed by a suggestion to apply geographical knowledge and research methods to benefit disabled populations. Several possible venues for making this commitment are explored, and some interesting and useful contributions are reviewed to show that geography has as much to offer as other disciplines in searching for solutions to the problems of the disabled. © 1997 John Wiley & Sons, Inc.

SOME REMARKS ON THE TRADITION OF APPLIED GEOGRAPHY

Although applied geography has been a widely practiced field for much of the century, it has become a recognized specialty group within several national geographic associations only during the last decade. But it has a substantial international following and a clearly defined path to the future.

In many ways, the development of applied geography was an inevitable consequence of general trends in the search for geographic knowledge. In a broad spectrum, we can regard geographic activities in the early and middle-parts of the century as pursuing a course that legitimized the discipline. Efforts were undertaken to provide a sound basis for using spatial data, and the process of understanding spatial interaction and spatial relations in both large- and small-scale environments was initiated. Once a good foundation had been laid, however, it was also inevitable that the search for academic legitimacy would require the discipline to develop a body of relevant theory. The theoretical revolution of the late 1950s and 1960s began this process. It was accompanied by the development of appropriate measurement tools and analytical devices. Just as inevitably, this need spawned the quantitative revolution that emphasized those mathematical, statistical, and logical inference processes as having specific geographic relevance. As what was regarded as a relevant theory expanded, there was sequential development of behav-

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ioral, political, economic, social–theoretic, postmodernist, and information–theoretic approaches used in researching geographic problems. These included survey and ethnographic research of the behavioral and humanist approaches, and the politicized ideological arguments of the social theorists. More recently this evolution of method and theory has turned to the digital domain of databases and computer-based processing models of the information and technological society in which we currently find ourselves.

A natural consequence of the two-decade exploration of relevant theory was the empirically based search for applications. This focused attention on the applied domain, which slowly extended its influence into the traditional academic areas of both physical and human geography, and encouraged the rapid development of new technologies designed to assist in the diffusion of such applications (Applebaum, 1954, 1959; White, 1945).

Much of the geography pursued throughout this century has in fact been applied. Perhaps this has been most obvious on the physical side, where geographers analyzed soils, erosion, vegetation, hydrology, weather, and climate, and applied their findings in diverse fields ranging from agriculture and hazard mitigation to predicting alpine snow melt runoff and the impact of settlement on endangered species. Simultaneously, human geographers developed land-use classification schemes for both rural and urban environments, explored different aspects of city planning, examined the geographical patterns of pricing and costs in transportation systems, and examined the movement of goods and people. They also explored local and national impacts as traditional transportation systems (such as coastal or inland shipping and the railroads) began to decline in importance as mechanisms for transferring commodities and people. (For an overview of the trends see Gaile and Willmott, 1989.)

But perhaps applied geography became most recognized in human geography, with its exploration into location theory, market area analysis, retailing, and consumer behavior. Marketing geography is generally recognized to have been a focus of the new applied geography (Applebaum, 1954; Epstein, 1967). Examination of the location of retailing firms and the spatial distribution of their customers, investigation of market-area boundaries, evaluation of both simple deterministic gravity models and probabilistic alternative ways to define market-area dominance, and examination of market penetration and locational choice provided an immediate and desirable tie to the business community (e.g., Huff, 1962, 1964; Huff & Black, 1997). The dramatic expansion of the power of location theory after the development of location models (e.g., Isard, 1954) not only firmed the tie with the private sector, but was greedily adopted by the services sector. Locating public services such as day-care centers and group homes for disabled populations and finding optimal locations for effective and efficient provisions of emergency services (e.g., police, fire, emergency medical and health services) expanded the domain of applied geography into areas other than the traditional marketing, land-use planning, and transportation sectors of the economy (Rushton, Goodchild, and Ostresh, 1973).

THE CHANGING FACE OF GEOGRAPHY GENERALLY

Since the 1970s, society has been moving into an age based on information and technology. Geographers have contributed to this evolution. In technology, their interest in remote sensing and image processing as a primary means for accessing detailed information about the general environment was the precursor and barometer of this change

As computer processing of large volumes of remotely sensed and otherwise collected data became possible (with the help of mainframe computers), geographers (particularly cartographers) were rapidly diverted from traditional paper-and-pencil production methods to computer-based digital analysis and representation of geographic patterns (Monmonier, 1977, 1982). Computer cartography and graphical presentation of material in both image and tabular form were as necessary to the governmental and business worlds as they were to the academic. And the inevitable combination of large and complex digitized spatial databases stored in computers, together with the analytical methods developed in the posttheoretical revolution era, and the increased personalization of computers as they progressed from mainframe to desktop to wearable versions (with approximately equal capacity), facilitated the most significant and powerful contribution of geography to the applied world—the geographic information system (GIS).

For the last 25 years, information has become the dominant medium of growth, change, and power. Although often belittled by derogatory remarks about excessive scientism and increasing technocracy, there is no doubt that the processing of information has been the most dominant evolutionary theme of the past quarter century. Individualized, interpersonal, and intergroup interaction, social and cultural development, and economic growth and change have all resulted from processes of telecommunication, computerization, and globalization of activity. In geography, these trends have had significant impact as a need arose to examine the deconstruction and reconstruction of social and economic systems within and among countries. A new age based on information services has meant changes in the structure and functioning of urban places, the focusing of international attention on new areas of the globe, the emergence of world cities and new bases of economic and political power, and a new social order with substantial demographic and social changes (e.g., the increasing infusion of women into the work force at all organizational levels) (Golledge and Stimson, 1997). Together, these forces have resulted in changing behaviors, changing interaction systems, changing distributional methods, and a changing face for geography.

Geography's earthbound existence, and its miniaturization of the events and patterns of the world into static, two-dimensional representations (i.e., maps), has necessarily changed. Viewing the earth from space has given the geographer better and more accurate access to many relatively unknown places and previously unobserved patterns and relations. Monitoring at a global level has clearly identified global problems such as deforestation, atmospheric pollution, acid rain devastation, and marine pollution. But mechanisms for looking at the human dimensions of existence at a global level have proven much more difficult to come by. However, a change in perspective has diffused across the many areas of the discipline as these external technological changes have provided (at the flip of a switch or the click of a mouse) the databases so laboriously compiled in the past by field observation. Geographical analysis and the representation of geographic phenomena in cross-sectional or dynamic form via computer representation is inevitably impacting the discipline. It is also changing the need for geography by society. As we globally recognize problems of resource depletion and environmental degradation, the need for geographers to take their expertise into areas of environmental protection and resource management has become more urgent. So applications of geographic knowledge and methods have spread markedly from serving the business community or governmental agencies in narrowly defined ways to investigating larger problems that deal with the well-being of humanity as a whole.

But this does not mean that this applied work has neglected the individual. Just the opposite is true. Although more attention is now focused on the problems of the global environment, so too has awareness grown of questions of equity and opportunity, questions of individual and social well-being, and questions of how best to use expertise to make better use of human resources and to improve quality of life. Thus far, much of geography continues to look at aggregated pictures; but some geographers are pursuing the task of taking what has been developed for larger-area operations and applying it at the individual level. It is this latter area on which the rest of this article is focused.

So what has geography gained from this evolving structure? What distinct contributions can geographers make to solving today's problems? In addition to the scale at which they often work, geographers have a unique mix of environmental and human understandings. Their focus on the essential spatial relations underlying human and physical behaviors (from the eroding and depositional actions of streams, to the patterns of intercity telephone calls and the spatial patterns embedded in the selection of marriage partners) provide a theoretical and empirical basis for examining human–environment relationships that differs from other disciplines. Although other disciplines often use spatial variables as part of a larger explanatory schema (e.g., as an independent variable in a multiple regression equation), geographers use spatial variables as the dependent variable (i.e., the variable to be explained). As part of this perspective on the world, geographers have focused on observable (or empirically recordable) events. This focus helped develop an emphasis on external representation of those events. As a result, data, analyses, and representations are essentially spatial, and configuration, layout, interaction, and pattern are the focus of attention. This emphasis has remarkable relevance for living in, coping with, and understanding the complex world in which we live. It has even more relevance when the human–environment interaction mode is constrained—as when disability places a filter between people and the world in which they live.

AN EXAMPLE OF A NEW DIRECTION IN APPLIED GEOGRAPHY: THE CASE OF HELPING DISABLED PEOPLE

Imagine trying to walk through an unsigned, unfamiliar, unmapped environment. How would you do it? For the blind or visually impaired traveler, it is unlikely that this activity could be undertaken in a successful and graceful way without help. How can applied geography help under these circumstances?

In 1990 the U.S. census of population indicated that there were approximately 52 million people in the United States who were classified as disabled. This was the first comprehensive attempt in the U.S. to examine disability at the national level. The census definition of *disability* was behavioral rather than physiological, and included those who qualified within any of the following criteria:

> Cannot walk three city blocks unassisted, cannot climb a flight of stairs; cannot lift and carry a weight of 10 pounds; cannot read ordinary newsprint even with the assistance of aids such as eyeglasses or contact lenses, cannot hear speech in a normal conversation; cannot make oneself understood in normal conversation.

These definitions are rather broad and can be loosely interpreted. However, they include a wide variety of people with disabilities, including those who have a physical functional limitation (e.g., loss of use of limbs, vision impairment or blindness, loss of hearing), those with learning disabilities or cognitive dysfunctions (e.g , mentally retarded, mentally ill, brain damaged), and those suffering from disabling diseases or bodily conditions (e.g., diabetes, heart disease, cancer, AIDS). Each disabled group relates to its environment in different ways and can be regarded as living in a separate reality (Golledge, 1991a, 1991b). This reality is conditioned by the perceptual sensing, filtering, and processing of information that members of each group are required to use. For example, approximately 1.1 million persons suffering from dysfunction of limbs interact with their environment by means of a wheelchair. Of the 1.1 million legally blind individuals and the 3–4 million who are severely vision impaired, approximately 100,000 use a long cane for guidance, about 10,000 use guide dogs, and about 10,000 use other miscellaneous technological means for obstacle avoidance and navigational assistance (Golledge, Costanzo, and Marston, 1995). In each of these cases, direct sensing of the environment has to be mediated through an assistive device. In the case of the wheelchair user, this may mean searching for routes that include curb cuts and ramps; for the blind or visually impaired person, it may involve searching for routes as free as possible from obstacles. In each case, these people can be seen as having to live within a transformed reality, a reality in which the efficiently defined paths, routes, and distances of the able-bodied world may have been significantly transformed before being used by those with disabilities. For example, a brief walk past a construction zone for an able person can turn to an obstructed nightmare for a person who must use a wheelchair, crutches, or a walker, or who is blind. In the balance of this article, the focus is on how applied geographers can help disabled groups to understand and use the different realities in which they must of necessity live and interact. Particular attention is paid to those who are blind or vision impaired.

APPLIED GEOGRAPHY AND THE VISUALLY IMPAIRED

The most fundamental needs of vision impaired or blind populations include access to information (particularly that usually presented in written format), access to the environment, and independence of movement. Accessibility is an important concept for all individuals, whether disabled or not (Talen, 1995). In particular, access to the built environment in which daily activities are conducted is essential. Access includes not only physical mobility, such as making a trip to a store by a selected transportation mode, but also being able to recognize and use key choice points or decision points in the environment (e.g., landmarks, streets, or neighborhood features). Accessibility therefore involves the ability to interpret, recognize, and understand the layout of features in the environment, as well as being able to travel in as obstacle-free a manner as possible.

Access to written information has been partially solved by the development of tactual languages such as Braille. More recently, electronic scanning and communication by speech synthesis has greatly increased access. However, only about 10% of today's blind or vision-impaired population in the United States can read Braille (Golledge et al., 1995; Stone, 1995), and although digitized and synthetic speech is developing rapidly, no data exist on how many people with vision impairment have adopted this new technology. There has, however, been a concerted effort by both public and private organizations to locate Braille symbols in buildings to identify different floor levels when using elevators, to identify features in public use areas (such as restaurants), to provide tactual menus in restaurants, and to make available Braille or auditory renderings of newspapers, magazines, and books. But blind people are still faced with a substantial print barrier. For those who read Braille, such signage and translations of written material are extremely valuable. Even more value would accrue if Braille signage was extended to the

TABLE 1 • Some Technical Devices to Aid Blind Mobility

Traditional Obstacle/Hazard Avoiders	*Recent Navigation Aids*
Long cane	Tactile maps
Mowat sensor	NOMAD
Sonic guide	Talking signs
Nottingham obstacle avoider	Verbal Landmarks
Laser cane	UCSB personal guidance system
Echo locators	Makino GPS—cell phone
Auditory traffic signals	Chico State Beacon System
	MoBIC
	Verbal messages: tapes of routes
	STRIDER
	Open university talking labels
	Fanmark locator system

world at large (e.g., Braille street signs or advertising signs in stores). By far and away, the greatest part of the blind or visually impaired population, however, gets no advantage from this type of assistance.

Approximately 1 million totally blind people in the U.S. are dependent on other humans for guidance, information processing, and environmental interpretation and use. Loss of independence is probably the most humbling of all the disadvantages associated with the loss of sight. A device that can reduce dependence in all manners of communication with the local environment would be of the utmost importance to increasing the quality of life for the blind or vision-impaired individual. A selection of such developments to date is provided in Table 1.

Navigation versus Obstacle Avoidance

Most attempts to produce technical devices to assist vision-impaired or blind individuals in their commerce with the everyday environment have focused on obstacle avoidance rather than assisting navigation. Many of the obstacle avoiders developed so far have a limited range (usually confined to the proximal area of the body), and vary from hand-held mechanical devices such as long canes to more complex laser-based or ultrasound devices such as the laser cane or the sonic guide (Kay, 1964a, 1964b; Brabyn and Brabyn, 1983). Obstacle avoiders help determine the physical location of barriers to free and safe movement and are used to find paths that circumvent such obstacles. However, they provide no information about the general location of individuals, their orientation or heading, or the configuration or layout of the features in the environment through which travel takes place.

Navigational aids focus more on route learning and often consist of little more than verbal reminders about the expected location of choice points or significant cues along paths that are frequently traveled (e.g., taped summaries of what might be expected to be encountered along a fixed route). A slightly more advanced navigational aid would provide additional information about distances between landmarks, segment lengths of paths, turning angles at choice points, and significant on-path and off-path features that are likely to be encountered. Such an aid is discussed later in this article

All of these features can be perceived by sighted travelers, whose cognitive maps therefore cover more geographic space than do those of blind people. Thus whereas blind people may have quite complex maps of a local area (with an emphasis on features not necessarily noticed by sighted people, such as surface textures and resonance of different materials), the sighted person usually has a greater number and variety of features represented in a cognitive map. When navigating in most complex environments, the sighted individual has access to a large amount of information not only from billboards, labels, and signs that can be visually scanned while traveling, but also from access to configurational information obtained by looking at base maps of the local area or simply by viewing it from a height. A complete navigational aid, giving access to information similar to that enjoyed by sighted people, would provide the equivalent of this mapped or viewed information. In other words, information should be available not only about the segments, turns, and interpoint distances and directions associated with a single path, but also about on-route and off-route landmarks on other paths that can help develop a geocentric frame of reference. Additional information also may allow the traveler to determine body orientation and course within that frame of reference, as well as helping to observe the locations of cues within the larger-scale environment relative to each other and that general frame of reference. As of this time there is no readily available device of this nature. The closest technology might be a portable (or possibly disposable) tactual map (Golledge, 1991a, 1991b).

Maps for the Blind

Geographers have at times used their expertise to help solve many movement problems. For example, in place of the mapless, unsigned environment, they, along with psychologists, engineers, mobility instructors, and other groups have developed tactual maps that could be used to assist the blind with navigation and general environmental understanding. Tactual maps were originally developed to allow a blind or visually impaired person to get some idea of large-scale spaces that were not easy to traverse or comprehend (e.g., to learn the location and shape of Africa: Sherman, 1963, 1965; Andrews, 1984). For example, a sighted person might live in Seattle, or Washington, DC, without ever traveling extensively in either city. An awareness of these places still could be developed by looking at pictures, images, or maps, and learning layouts from these representations. These options have not been open to blind people. Much of the geographic work with tactual maps has been inspired by the need for such information. Preparing a tactual map of Seattle or Washington, DC, for example, can allow the visually impaired or blind individual to explore via touch the arrangement and organization, location and layout, of city features (see Wiedel, 1983; Andrews, 1983, and Tatham & Dodds, 1988 for examples).

The design, production, and use of tactual maps has attracted researchers and developers from several disciplines. In particular, cartographers such as Sherman (1963, 1965), Wiedel and Groves (1970), and Andrews (1981) have focused on their design and production aspects. They (and many others) have constructed such maps by using raised inks, and by thermoforming, vacuum forming, etching, and accretion (e.g., relief models). But they have not been alone in these efforts. Psychologists such as Franks (1974, 1982; Franks and Baird, 1971; Franks and Huff, 1976; Berlá, 1972a, 1972b, 1973; Easton and Bentzen, 1980; Bentzen, 1980; Bentzen et al., 1981; Gill, 1973; Schiff and Foulke, 1982) also have pursued a variety of related problems including symbol design and interpretability, and other design features such as information density and legibility. The work in haptics by psychologists such as Lederman (1982) has extensively examined perception of texture by touch, and this area of psychology today has much to offer to the tactual mapping domain. However, only recently (since 1983), has there been a concerted interdisciplinary and international effort to advance the technology and use of tactual maps and graphics (Wiedel, 1983; Tatham and Dodds, 1988). At a series of international meetings, suggestions have been made for further work on selection of the most useful forms for presenting tactual maps and graphics, developing ways to teach tactual map interpretation and use, communicating the potential of tactual maps to users, and evaluating the effectiveness of tactual information. Geographers and cartographers, like members of other disciplines interested in spatial relations, have also become interested in cognitive maps (Kitchin, 1995), but the melding of this work in that attending to questions of what material to put on tactual maps is still in its infancy. With regard to other disciplines, researchers in design and architecture moved the tactual map indoors (Preiser and Brecht, 1981; Passini, 1980, 1984); Bentzen et al. (1981) took them underground; and Andrews (1984) used them to depict a university campus. Geographers have shown they can take them to all places and all scales, capturing the essence of environments with a potential not likely to be reached by any other group.

Tactual maps are developed on a different principle from the standard, three-dimensional relief maps usually developed by commercial map makers. Instead of just showing gradient or elevation, as is typically the case with the latter, a tactual map for a blind person may seek to elevate significant features such as surface road networks; arterial highways; significant transit stops, and areal land uses such as parks, recreation areas, or commercial districts. The tactual map will also delineate natural features such as rivers, lakes, cliffs, swamps, and other significant or dangerous features. The blind person learns the environment by exploring the tactual image with the fingertips or palm, creating a sensory impression that can be stored in long-term memory as part of an individual's internal representation of the world at large (or cognitive map; see Casey, 1978; Andrews, 1983). As mapmakers, geographers more than anybody else have the experience and expertise to decide what features are best displayed on such maps. Obviously, a significant amount of differentiation among map features is necessary for successful tactual exploration. But, there is a danger. A tactual map that is cluttered with information is very difficult to interpret. The dense representation of features makes it hard not only to distinguish things, but to remember their place, their location, the nearby features, and the layout of which they are a part.

Tactual maps usually have not been developed as local learning tools, but rather as educational devices. A sighted person may open an economic atlas of the United States and quickly gain some idea as to where different agricultural products are grown, where industry is located, what the dominant urban pattern consists of, where settlement is sparse, and other general human geographic information. Thematic tactual maps can provide similar information, (Andrews, 1981) but they may be difficult to interpret when many different features are overlain. Up to the present, however, few tactual atlases have been developed, because of the cost of preparing the individual maps. Thus, although geographers have the capability of producing maps in either very simple or very complex forms, and thus of representing selected or exotic multifeatured environments, their research has not yet led them to effective ways of cheaply producing and making available the type of mapped information so easily available to those with sight (but see Andrews, 1983; Golledge, 1991a, 1991b).

One recent and highly innovative attempt to solve the problem of map presentation of geographic data has been undertaken by geographer Don Parkes and his associates

(Parkes and Dear, 1990). They developed a product called NOMAD, which is an auditory-tactual information system. The purpose of the system is to allow the vision-impaired or blind person to explore the shape or layout of information via touch, and to reinforce touch with verbal description. This is done as follows.

Initially, Parkes imagined a talking map. To operationalize this, he took a standard diagram and laid it over a network of auditory disks so that when the map was touched and a disk was activated by pressure, it described what was at that spot. Parkes later chose as the basis for his system a touch-sensitive pad overlaid with a 1-cm electronic grid. Information at each geo-reference point could be accessed by the use of digitized or synthesized speech. Overlaid on the grid would be a tactual diagram. This could be a tactual map of an eyeball, a map of the world, or a set of shapes designed to teach simple geometric forms. The visually impaired person would, as he or she tactually explored the surface of the diagram, put pressure on the underlying touch-sensitive pad and activate geocoded synthetic voice messages that described what was currently being touched (e.g., "This is Australia." "This is England."). Geography thus entered the world of the blind. People who never before had access to the few tactual maps that may have been produced in an area now had the opportunity, now could explore the shapes of countries while getting some idea of the meaning of distance at an international and national scale. They could be exposed to the layout plan of the cities of New York, Chicago, San Francisco, Dallas and so on; they could trace a route or use guided instructions to connect origins and destinations, whether they be in a local area or on an international trip; they could sense the geographical patterns of agriculture, pasturalism, recreation, urban settlement, and so on while having what was touched be verbally described at the same time. Instead of having to define the geography of these features from fuzzy verbal descriptions alone, a combination of touch and speech provided a multimedia learning tool that significantly simplified the entire process. Applied geography thus provided a missing window to the world.

But people still needed assistance with their real-world, day-by-day knowledge acquisition, not just information about geographic patterns of production and consumption. Accessing the real world meant taking tactual maps into the field; it meant providing the equivalent of a street map used by a sighted pedestrian. Such tactual maps also could encourage preplanning and preprocessing of route information at home. One could lay out a potential route and learn it by rote by tracing the path, remembering its sequence of turn angles, learning the distances between such turning points, and learning a description of the area to be traversed, all before undertaking the journey (see Gärling and Golledge, 1989 for a discussion of travel plans). Often journeys are complex, involve many turns; often unexpected barriers such as construction work, crowds, and obstacles, are encountered. One way of solving this problem has been suggested by one author of this article (Golledge, 1991b). After experimenting with Parkes's NOMAD and realizing the value of producing tactual route maps on chemically treated capsule paper (which costs as little as $1 per sheet), Golledge suggested developing the pedestrian's equivalent of an American Automobile Association strip map. Thus, a route, once planned, could be broken into segments, each end anchored by a significant choice point. Strips representing each segment could be arranged in order. At the beginning of each strip would be an orienting arrow, and at the end of each strip, a turn arrow indicating the direction to be traveled over the next segment. On- and off-route landmarks or other significant information could be indicated along the strips either symbolically in raised tactual form or by Braille lettering. These strip maps could be disassembled and rearranged to represent different paths in the environment, and could even be considered disposable. In other words, because the cost of preparing a strip map was relatively small, used strips could simply be torn off a pad and thrown away; or they could be kept and traced in reverse direction upon the return trip. Recent research by Bell (1995) has provided evidence of the superiority of sets of segmented strip maps over a single continuous strip map of the same route, for wayfinding purposes. His findings revealed that segmented strip maps were equivalent to survey maps as route and layout learning tools.

ROUTE-FOLLOWING ACTIVITIES

In recent years, some experimentation has been undertaken on the idea of auditory maps. Initially, these were simple recorded descriptions of directions for following a path together with statements about what would be found along the way. For example, one would carry a cassette and play a tape which might give the following message:

> Walk north 100 yards and you will come to the corner of Chapala and Victoria Streets. As you travel along the sidewalk, traffic will be to your left and a bus stop for the local transit vehicles will be located 20 feet north on the right side of the Victoria Street corner; it is marked by a permanently located bench and a metal pole with a sign attached. For the first 50 yards, on your right you will pass by a parking lot. Thereafter, on your right, there will be a hardware store with one entrance located close to the Victoria Street intersection. In the distance on your right will be a local landmark, the Arlington Theater; on your left will be the Prudential Building.

These taped verbal descriptions were attempts to serialize information and give the blind traveler not only route guidance, but some general layout information about the larger environment.

Perhaps the earliest auditory maps were of the voiceover type (Thrower, 1961). But here vision was still required. Loomis (1985) first suggested a true auditory map that could be presented as a virtual acoustic display in which landscape features would identify themselves by synthesized speech which appeared to emanate from their actual physical location. Routes in auditory space would be traced out by virtual beacons located at virtual turn points representing the places where real changes in direction were required. Weber (1993) later suggested incorporating acoustics into computer cartography in a manner similar to the use of voice in animated cartoons. The contribution of sound in such contexts depends on whether it is used as a symbol or earcon, or as a metaphor that is monic in character (Gaver, 1986). So far, only the Loomis model actually represents auditory data in a maplike geocoded representation with distance and direction incorporated into the acoustic virtual display (Loomis, Hebert, and Cicinelli, 1989). This mode was selected as the user interface for a personal navigation system that is described later.

In addition to taped serializations of routes and synthesized sound in a virtual acoustic display, experimenters today are using infrared-based talking-sign technology and inductive-loop-based verbal landmark technology to provide auditory information for travelers (Loughborough, 1979; Bentzen and Mitchell, 1995). Optimal location patterns for auditory signage have still to be developed. Successful solution of this geographic location problem could help provide effective wayfinding information. With the talking-signs technology, small infrared transmitters are placed at specific locations within the environment, and their messages are broadcast over a 50–60-ft radius. A portable receiver with a 51° receiving arc picks up the sign and allows the individual to orient toward its origin. Once one has established the direction and label of the sign, it is possible to walk to it. This technology is available from Talking Signs® Inc., and can be used as supplementary wayfinding information within buildings or in crowded and complex settings such as transportation terminals (e.g., multilevel subway stations, or airports; Crandall, Bentzen, Myers, and Mitchell, 1995).

As opposed to this directionally guided infrared technology, Verbal Landmark technology provides the equivalent of a building directory list. Located at relevant spots within an environment, an inductive loop broadcasts a continuous message which is again picked up by a handheld portable receiver. There is no directional component, but one simply hears a listing of things that are available in the immediate vicinity and a description of where they are (e.g., a list of tenants of a building; a list of features in a bus terminal, etc.). Other innovative technologies include bar-code readers with auditory output. These rely on proximal reading of bar-code strips placed at different places in the environment. Finding such signs is not an easy task, and this technology has so far been little developed. However, Makino (unpublished) has developed a wheeled bar-code reader that could access floor-level bar codes to assist navigation.

All these technologies indicate that as we move further into the information-dominated world, sensors other than vision are being explored as aids to geographic understanding. Geographers know relatively little about things such as human ability to localize with the use of spatialized sound, or how, where, and when auditory information should occur in an environment. Until a better understanding of these fundamental issues is achieved, further exploration into building auditory maps or converting different environments into accessible auditory spaces will be limited.

However, there are some interesting experiments going on. For example, Makino (unpublished) has built a global positioning system (GPS) into a cellular phone. At any location within the cellular phone's range, a pressed button activates the GPS and sends the user's coordinates to a central base station where they are downloaded into a digital base map of the local area. A verbal message comes back to the user of the cellular phone indicating where he/she is in the environment. Obviously, an accurate locational device is needed, and a comprehensive and accurate database is similarly required for matching purposes. The latter is firmly in the domain of geographic information systems and spatial databases, both of which are the focus of a significant part of ongoing geographic research.

A GPS-based navigation device (Fruchterman, 1995) is currently near market stage. Called STRIDER, it uses GPS for locating the traveler in real time, and a set of commercially available city street maps (Atlas Speaks) that are used to define local position and articulate instructions for route following. Directions are given in global compass terms along with street names and distances (e.g., "face north, go 100 yards to corner of Venice Street and turn left"). Geographers such as Frank and Mark (1991) and Couclelis (1996) as well as linguists (Klein, 1983; Talmy, 1983), and psychologists (Taylor and Tversky, 1994; Landau and Jackendoff, 1993) have all expressed concern about the interpretability of spatial information presented as natural language. Nevertheless the auditory strip-map design of STRIDER appears to be both useful and acceptable and could profit by further cartographic exploration into spatial terms, including locational description, direction, and perspective viewing (a domain dominated by psychologists), and route description.

Another navigation aid is under development by a UK/Swedish/German consortium. Called MoBIC (Gill, 1996a, 1996b), this also uses GPS as a locating device, but whether it will use differential correction is uncertain. It is planned to be developed as a backpack, with probable reduction to waist-pack size (weighing 3–4 kg), or to be configured as a vest to be worn by the user. At this stage MoBIC is still in an early stage of development and appears to be at least a year or so away from production. It is worth noting that, although this and other devices being developed use GPS, and require accurate spatial databases, *none of the groups developing them has a geographer associated with the project!*

The UCSB Personal Guidance System (PGS)

Imagine a world without signs: no street signs, no address numbers, no advertising signs, no building directories, no transportation identifying numbers or vehicle destinations. Imagine taking a trip in such a world, or even an unfamiliar environment. Assume there is no map to refer to. How can your destination be found? With help from a passerby? Do you try to build a mental image while exploring? Do you use a specific search heuristic (e.g., center to perimeter)? Do you try to develop a travel plan from which you make decisions about turns, straightaways, and directions? This task would be simpler if the environment itself could offer information in a clear and unambiguous way. Filling it with talking signs and verbal landmarks may be one effective way of doing this. An alternative, offered by a multidisciplinary research group of psychologists and geographers at UCSB, offers a different alternative based on traditional spatial databases tied to an acoustic virtual display.

The purpose of developing a personal guidance system (PGS) is to allow vision impaired or blind users to travel without assistance over both familiar and unfamiliar territory. It should instill in such travelers feelings of independence and confidence. Technical details of the structure and operation of the system are given in Loomis and co-workers (1994, 1995). However, the basic components will be elaborated here.

The system can be represented as three modules (Loomis, et al., 1994).

Module 1: Determining Location and Orientation

A. GPS signals. Knowing one's location and orientation is the first and most fundamental step toward successful independent travel. This first module is designed to provide such information. The primary means of determining position is a global positioning system (GPS) receiver with differential correction (DGPS). Use of GPS for use as a navigation aid for the blind was first proposed by Collins (1985) and by Loomis (1985). The first published experiments using GPS for this purpose were undertaken by Brusnighan, Strauss, Floyd, and Wheeler (1989). Use of GPS as a primary means of determining position appears to be viable now, at least in certain open environments. The full complement of 21 GPS satellites and 30 backups that make up the U.S. NAVSTAR system are now in orbit. This system allows localization of a GPS receiver with almost uniform accuracy over much of the earth's surface. At this time commercially available hand-held GPS receivers provide a localization accuracy of about 100–200 m when selective availability [the deliberate perturbation of satellite signals by the U.S. Department of Defense (DOD)] is operating. Recent agreements by DOD indicate a decision has been made to remove the random error perturbation by the year 2000. Differential correction is a way of obtaining much higher accuracy than is available under selective availability (SA—the perturbed signal). In DGPS one uses a base receiver with known coordinates in addition to the roving receiver carried by the traveler. Errors in the signals arriving at the base station are computed for each satellite and then transmitted by radio link to the rover receiver. Within the environment near the base station local errors correlate almost perfectly with those at the base, so the base receiver errors can be used to correct the computed position of the rover being used by a traveler. With DGPS locational accuracies of 1 m or less are common. In the U.S., differential signals are now being freely broadcast by a network of Coast Guard stations whose service areas will eventually blanket all of the country.

Pedestrian use of GPS for locational purposes suffers from a number of shortcomings. First is the possible loss of satellite visibility when nearby buildings or dense foliage block a substantial part of the sky. Signal loss is most noticeable in the downtown areas of moderate to large cities, where a concentration of tall buildings at time occludes much of the sky from a street level perspective. For accurate positioning, any GPS system requires a constellation of at least four satellites and line-of-sight access to the transmitter of the differential correction. Either of these requirements may not be met when the system is very close to a tall building or under dense foliage.

Another problem involves multipath distortion resulting from reflections of the GPS signal from nearby structures. Because distance to a satellite is computed from the time delay of signal transmission and signal reception, positions derived from reflected signals are in error.

For travel within some urban environments, therefore, it seems that for GPS to be a useful device it will have to be supplemented by some other means of determining position. Alternatives include dead reckoning (based on measurement of traveler velocity), inertial navigation (based on measurement of traveler acceleration), or some form of local positioning system (LPS).

B. Orientation. The second part of this first module is the orientation device. It is essential for a traveler to know bearings to surrounding landmarks so that a correct course can be maintained. In our PGS, head facing direction is indicated by a flux-gate magnetometer. Knowing the orientation of the traveler's head is important for communicating information about the location and direction of local or distant features. However, if path following, rather than environmental learning, is the prime goal, then a single compass mounted on the torso will do (see the MoBIC version of a pedestrian guidance system, Gill, 1996b). In the PGS case, however, orientation is much more critical because our user interface has been developed to provide a stream of locational and bearing information about the actual location of landmarks or other features in the environment being traversed. Knowledge of head orientation is required for the virtual display to ensure that no matter in which direction the head is facing, the verbal landmarks will call out from virtual representations of their stable locations in the objective environment.

Module 2: Geographic Information System

The second module consists of a spatial database of the relevant environment which is embedded within a set of analytical and display procedures normally called a geographic information system (GIS). The software for this system provides for the computation of optimal routes of travel and for accessing information within the database as desired by the traveler. The GIS links the spatial data about objects (such as their shapes and locations) to known spatial attributes (such as the object's functional category or its properties, such as surface trafficability). The GIS provides spatial layout information to a user but can be further developed to provide information about the number of objects of a given type within a given region (e.g., the number of restaurants of a given type within a specific radius of the current location). Data can be retrieved from the GIS by spatial or semantic cues relative to the traveler's current position and orientation (Golledge, Klatzky, Loomis, Speigle & Tietz, unpublished).

The database is configured as a number of layers, each layer corresponding to entities such as walkways, buildings, large permanent obstacles, bicycle paths, roads, and so on. At this time the software accepts other spatial databases created by any CAD program provided that they are in drawing exchange file (DXF) format. Usually CAD maps alone do not contain sufficient information at the scale necessary for walking without vision. Also, most CAD maps do not allow attribute tables or analytical data to be directly linked to geocoded data (Cowen, 1988). Our GIS module is, however, intended to provide functions that are different from those in many existing GISs, and to do so in support of navigation. Conventional functionalities included in the GIS are buffering, overlay, corridoring, and entity attribute linkages.

The contents of the spatial database are recorded as points, lines, circles, and polyline entities. These are separated into layers based on a preset classification scheme. AutoCAD's DXF format was used for disk storage of the base map. The loaded format closely resembles the DXF format in that entity lists are maintained separately for each layer. Attribute information is contained in separate text files, which are computer scanned when a map is loaded.

In real time it is possible to assign an attribute to an entity. Each entity is assigned a unique identifier referred to as its handle. To assign an attribute, an entity is selected, its handle is acquired, and a named attribute is given a value. This is a relational model, and a set of attributes are stored as a table with one column being the handle of the associated entity. All relevant information discovered by database manipulations is transferred to the traveler via the third module—the user interface.

Module 3: The User Interface

The user interface provides for two-way communication between the GIS and the user. User control of the computer is currently accomplished with a keypad, but speech control is probably a more effective method. In the PGS, information is conveyed via a text-to-speech synthesizer (RC Systems No. 8600). The synthesized text is simulated to come from a virtual source located at some external point. Exact descriptions of how the virtual auditory sources are placed can be found in Loomis et al. (1990). At this time there are two different modes a user can activate—the path mode and the layout mode.

The input component of the user interface will allow the traveler to select a destination, add landmarks to the database (i.e., personalize it for their own local area), change the display mode (as from auditory beacons to spoken landmark names), and change display parameters such as map scale. Because the interface is still in the development phase, we have yet to decide whether a small keypad or voice input in conjunction with limited-domain speech recognition will be the most useful and acceptable mode.

SPECULATING ABOUT THE FUTURE

Imagine you are on your first trip to an unfamiliar destination in a country whose language is unknown to you. Signs and signals become irrelevant because they are expressed in an unknown language—which is conceptually equivalent to not being seen. However, in the future, the traveler could carry a personal guidance system and, at the destination airport, could buy a data disk and GIS, which could be available in a selection of languages. By activating a locator as one begins traveling, the location and tracking facets of the system begin their work. Landmarks from the larger environment and contained in the database begin to identify themselves and local or proximal environmental cues call out their names as they are activated by falling within a travel buffer surrounding the traveler's location (as pinpointed in the database). The problems of navigation, location, and orientation, will all disappear. One might be confident that one could never become lost again.

This article has been somewhat speculative and somewhat superficial. But all the things referenced and discussed in the article exist at least in prototype stage. Geographers have contributed to few of these devices. As the discipline continues to evolve its information processing and analysis capabilities, it must keep pace with the rapidly changing world, and be on target to assist with that change and to mitigate the negative effects of such changes on at risk populations, such as those who are disabled.

So, the appeal in this article is for applied geographers to go beyond their traditional and well-established areas and to use their expertise in the emerging informational and technological world. It is obvious, even from this narrowly defined article, that conventional geographic principles and techniques can be used in practical and imaginative ways to influence the understanding of environmental growth and change as well as improve the quality of life for needy populations. I hope that those reading this message will take it to heart and begin to explore worlds and realities other than the traditional large-scale, physical, objective worlds that have dominated geographic thought and activity for so much of its history.

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