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To: S. Doherty, R. Golledge, R. Klatzky, J. Pellegrino, W. Tobler

From: J. Loomis

Re: Digital Map and Navigation System for the Visually Impaired

A realistic short-term goal of the project is to develop a digital map system for the visually impaired that would display map information stereophonically through earphones. This would permit the user to familiarize himself/herself with some local area and to plan a route for going from A to B, all while sitting in a chair. A much more ambitious and long-term goal would be to use this digital map system as part of a larger navigation system that would keep track of the user's position, indicate to the user the position of nearby landmarks and things of interest or potential hazard, and when requested provide the user with the most efficient route to some specified target location.

I. Digital map system

The major components of a digital map system for the blind involve (A) representation of a geographical region by computer (digital map) and (B) display of portions of this digital map to the user under user control.

A. Digital map. As I see it, there are two quite different issues in the design of a digital map. First, one needs to decide what information must be incorporated into the map to permit area familiarization, route planning, and navigation by a visually impaired person. This is one aspect of the computer/user interface problem (the other being involved in the display of map information). Determining what is important to the blind user would seem to require a combination of interview and experimentation (using a prototype device). Ideally, this applied research would be guided by knowledge about how the blind represent geographical space. Since little is yet known about this, basic research on this question needs to be done, but I do not believe this research project should attempt to do this, for there are just too many applied questions that need to be dealt with if the project is to succeed. Rather, it would be more reasonable to write a separate proposal for basic research to be funded concurrently.

The second major issue in designing a digital map involves determining the appropriate software implementation. What type of data structures will be most useful in representing the geographical data so that it can be accessed efficiently by the display and route-planning routines? One possible representation would be two parallel two-dimensional arrays where the two dimensions of each array represent the quantized geographical coordinates of the mapped region. One array would give the altitude for each quantized pair of coordinates. This information would never be displayed to the user, but would be essential in keeping track of the "eyepoint's" location during real or imagined locomotion. The second parallel array would be used to represent all of the important environmental features in the map (streets, street intersections, prominent buildings, rivers, bicycle paths, etc.). Wherever there were some important feature, the array variable for that coordinate pair would give an address pointer to an atom file that would specify the string identifier (e.g., street or building name), a string specifying the type of landmark (e.g., river, bicycle path), map scale priority value, and links to neighboring features; the array variable for all coordinates for which there were no important surface feature would equal zero.

In my view, an essential feature of the digital map and its display would be the capacity for changing scale. For example, the user could first get the "big picture" by selecting the largest map scale and then begin exploring at smaller and smaller scales. Naturally, the smaller the scale, the more detail would be displayed (this would be done using the map scale priority value; only those with the highest priority values would be displayed at the largest scale). This feature would give the digital map a seemingly big advantage over existing tactile maps.

B. <u>Display of map information</u> At any given moment, the user wants to display only a small fraction of the map information. The user would control display in a number of ways. First, the user would select the display scale. Scale selection could be done using manual adjustment, with touch or synthesized speech providing information about the control setting. Second, the user could "move around the region" by controlling the "eyepoint" location much as is done in computer simulation of various vehicles. During real navigation, of course, the "eyepoint" location would be that of the user as determined by the navigation subsystem. The "eyepoint" could be controlled by thumbwheel cursor controls with "eyepoint coordinates" provided by speech synthesizer. Alternatively, as Bobby has suggested, the observer could institute "automatic locomotion" along allowable paths (streets, walkways) at selected velocities. My suggestion for displaying map information is to give the blind person an "auditory perspective" of the surrounding environment not unlike what would be experienced in the actual traverse of the surroundings. This contrasts with the traditional "bird's eye" view of an orthographically projected map (e.g., street map or tactile map of a city). I believe that this perspective view would facilitate interpretation of the map, but it is possible that overhead viewing of an orthographic map (or its tactual counterpart) is in fact optimal.

How would this auditory perspective be achieved? What I have in mind is that all map features (streets, street intersections, important buildings, bicycle paths, rivers, etc.) at a given scale within a given scale-dependent radius of the "eyepoint" and within, say, a 60 degree sector centered about the user's straight-ahead direction (re the head) would be displayed stereophonically to the user in a serial fashion. If the feature were to be displayed, the string identifier would be sent to a speech synthesizer. On the output side of the synthesizer, the speech signals would be conditioned by special-purpose stereophonic display hardware. This hardware would control the binaural intensity and interaural time delays to simulate a sound coming from a given azimuth relative to the straight-ahead position of the head. A fluxgate compass (magnetometer) or optical gyro would be used to sense head orientation. The stereophonic cues would be a function of head position to simulate a sound source whose position was fixed with respect to the user's body. Direction of the head would determine which sector of surrounding space would be sampled, but the apparent azimuth of the environmental landmarks within that sector would not change as the head turns.

The programming work for the digital map and display system is formidable and would require at least one full-time software engineer with considerable skill.

II. Navigation system

The digital map system would take at least three years to develop. If successful in the first three years, we could apply for an additional three years of funding to further develop the digital map software as well as to develop a position sensing or position keeping device. (Alternatively, someone else could develop the navigation hardware in parallel with us during the first three years). The navigation device would simply provide the "eyepoint" coordinates to the digital map system. There are three methods of sensing or keeping track of user location during locomotion: (1) using external navigation signals (Loran C, GPS Navstar, etc.), (2) dead-reckoning/inertial navigation, and (3) a combination of the two. Position sensing using external signals would be the easiest in locales where they are available and accurate, for it would be independent of the mode of locomotion and errors would not accumulate. At present, high-resolution position sensing is not yet available to civilians, and the present systems do not work well in urban environments. The second method (position keeping by dead-reckoning/inertial navigation) will work in all environments but errors accumulate and the system has to be corrected either manually (by inputting current position) or by map correlation (a technique that assumes the user to be moving along constrained paths in the environment.) For a pedestrian, special hardware must be developed to perform the dead-reckoning, and this same hardware would not work if the user were traveling in a vehicle. Solution to the position sensing problem requires our enlisting an expert in mechanical/electrical engineering.

This second stage of the project would also be used to develop software for optimal route-planning and to optimize the laborious work of entering the desired map information into the computer.