Integration of Voice-Operated Route Planning and Route Guidance into a Portable Navigation and Object Recognition System for the Blind and Visually Impaired

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Abstract
A voice control program was integrated into our portable navigation and object recognition system for the blind and visually impaired. So far, a keyboard or touch screen was required to control this system. Trials at pilot locations have shown that there are many situations where the use of hands and fingers is inconvenient or sometimes impossible. To expand usability voice-operated selection of destinations and voice commands for enhanced navigation support were added.

1. INTRODUCTION

Various products exist to provide navigational help for the blind in specific locations. Most common, perhaps, are Braille markers on doors, elevators and bank machines. Less common are tactile environmental maps at building or park entrances. Although helpful, such aids cannot announce their presence, and blind navigators must depend upon others to direct them to the Braille information. More technical devices provide auditory cues, such as announcing building floors or traffic light changes, but these are unavailable in many areas.

To support more independent ambulation by blind people, complex indoor location and navigation systems have been developed. Most require installation of a special infrastructure, such as optical beacons or Radio Frequency Identification (RFID) tags. The impressive accuracy achieved by some of these systems is offset by several disadvantages. Installation is time-consuming and costly. Beacons can be occluded by environmental changes, like door position, and signals impeded by weather conditions, like temperature and humidity. Outdoor navigation systems based on the Global Positioning System (GPS) have proven similarly unsatisfactory. Maps used in such systems are made for car navigation, resulting in low accuracy and low resolution. Further, as with most indoor applications, signals can be blocked or unavailable.

Our basic navigation support for the blind and visually impaired relies on the step-recognition method of the TANIA system (Tactile Acoustical Navigation and Information Assistant). TANIA utilises a movement and GPS sensor, tablet computer, and enhanced mapping to provide precise navigation of up to one-step accuracy (Hub et al. 2007). It allows virtual explorations by tapping on the touch screen with a tactile overlay, and real exploration by walking normally. Among the information that can be provided by the TANIA system outdoors are current location, street name and section, navigation advice, detailed route descriptions, and so on. Indoors, information such as floor and room numbers can be transmitted to the user. In both cases, any desired text information can be added to map elements. Its operation is relatively simple, even for sensory handicapped children with limited vocabulary and for elderly people with no computer experience. Previously-installed infrastructure is not required, which expands environmental access for blind users to any area where adequate digital mapping has been done (Hub 2008).

The extended version of our system provides interactive object recognition based on 3D environmental models. It consists of a bicycle helmet with an integrated stereo camera and a movement sensor. By comparing sensor and camera information with 3D environment models using a connected portable computer, objects in viewing direction are recognized and named, and the presence of other people detected and announced. Additionally, distances and special features like object colour can be provided to the visually impaired user. Different languages are available, allowing users to learn or practice basic vocabulary in foreign languages. All this information can be transmitted to the user acoustically or via a small connected Braille display.

2. RELATED WORK

There are many orientation, navigation and obstacle avoidance systems available, based on various technologies. Because they have been described already in previous work (Hub, Hartter & Ertl 2006) only those most similar to ours will be discussed.

Indoor or underground navigation systems are based on pre-installed infrastructure, consisting of optical beacons (Maganti, Sawa & Yanashima 2001), RFID tags (Naviwalk) or electronic transmitters (Bowen 2006), typically installed in the corners of rooms. Such systems are workable only within environments where this special infrastructure is available and functioning. While these systems can be precise to within millimeters, changes to the environment require expensive and time-consuming infrastructure changes. If, for example, dividing walls are moved or temporary changes made, as during exhibitions or construction, then extensive re-measurements would be necessary. In contrast the TANIA system is fluid, allowing the user to alter the map or portions thereof to reflect alterations in the environment. Changes can be generated by public institutions, by friends or relatives of blind people, or by blind users adept at system operation.

The global positioning system (GPS) offers sensory handicapped people the possibility of independent navigation in outdoor environments. Several products for the blind are under development or already on the market (Gomez 2007) (Hang 2006) (May 2007). There are also systems which combine GPS technology and indoor systems, e.g. (Ran 2004). However, serious restrictions exist with all currently-available products. Most cannot incorporate new global navigation data in an inexpensive and simple manner. TANIA, on the other hand, can be enhanced by a GPS sensor, which facilitates system initialization when necessary. Available GPS navigation systems only allow the linkage of text or speech information in locations where GPS signals are present. More importantly, they do not incorporate precise location data obtained from the most immediate source of feedback about the current environment: the blind, visually impaired or deafblind user. Information provided by the user can be used to pinpoint exact location, and readjust or correct the map as necessary. Other systems fail to provide for user-generated location and map corrections necessitated by GPS inaccuracies and insufficient map resolutions.

3. VOICE-OPERATED NAVIGATION FOR THE BLIND

Basic Technical Setup

The TANIA system consists of a lightweight (~500 g), portable tablet PC suspended from a strap worn around the neck. An inertial sensor (MTx, by Xsens) is fixed at the center of the strap and connected by cable to the tablet PC (figure 1). Once the user’s initial position is entered, e.g. the name of the booth or exhibitor in an exhibition hall, the user’s current position is determined by the inertial sensor, which consists of a 3D compass, a 3D gyroscope, and a 3D acceleration sensor. Related positional data, such as room or booth numbers, or distance covered along a specific route, can be presented acoustically and visually on the touch screen of the tablet PC.

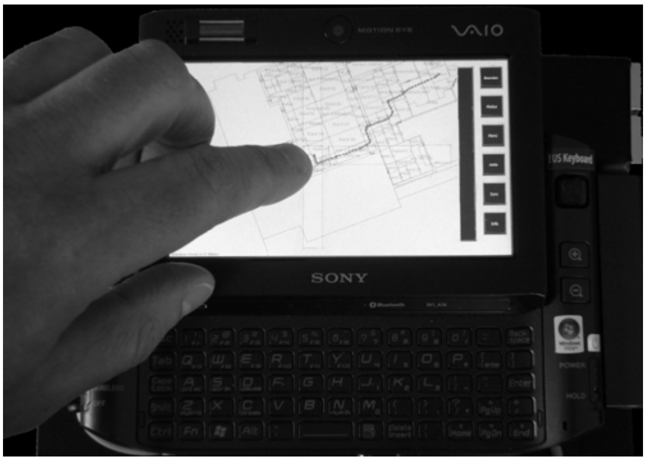

Figure 1: Prototype of the TANIA system. By tapping on the touch screen information about the location and current environment can be received. Map operations such as scrolling and zooming can be done with a joystick and a cursor. Several soft keys and hardware keys control the system. The keyboard can be used to insert augmented text information about the current location and to search for objects and information.

Additionally, TANIA can be connected and adapted to commercially available portable Braille displays. Given software specifications, connection can be made to standard computer ports or interfaces, like USB or Bluetooth (Hub, Diepstraten & Ertl 2005a). This not only allows deafblind people to use the assistant system, but facilitates its use in situations when acoustical output must be avoided or cannot be heard.

Real and Virtual Explorations of Environment

Tracking support is based on a step recognition method originally developed by Kourogi and Kurata (Kourogi & Kurata 2003). We adapted their algorithm to our inertial sensor, and, in deference to feedback from users and signal characteristic analyses, mounted it behind the neck on the tablet PC strap. Accuracy of one step can be achieved when walking in areas without interfering electromagnetic fields. By synchronizing map information with collision and corner detection methodology, accuracy is maintained at reasonable levels even in the presence of interference, or for long walks in large buildings.

Moving one’s finger on the map presented on the touch screen provides a spatial impression of the current environment, or of any other area where adequate digital mapping has been done. Stored text information can be accessed via tactile-acoustical switches or by tapping on the map, allowing the user to address navigational tasks and virtually explore alternative routes. The touch screen includes four tactile orientation strips, providing perceivable orientation cues for forward, backward, left and right movement. In the tracking mode the user’s position is automatically centred in the middle of the touch screen, where the strips intersect. By tapping in this spot the user can receive information about his or her current position.

Software and hardware keys support basic map functions, like selecting different maps, zooming, and scrolling. More advanced options give current directional orientation, measure the distance and orientation to selected destinations, and synchronize to the next architectural object. An information key provides an overview of current system status.

Obtaining and Formatting of Maps and 3D Environment Models

One of the simplest but most time-consuming challenges of this project was obtaining rough maps of pilot environments, since it was not always possible to make exact measurements on site. Available maps were usually not digitalized. Therefore we had to scan the hardcopies and redraw the maps, using a drawing or modeling program (Map 3D and 3D Studio Max, by Autodesk), frequently used by architects. The same programs were used to name map regions and objects. For 3D versions, we converted the maps to the OSG format (OpenSceneGraph) and for the 2D versions to the eXtensible Markup Language format (XML).

Detailed 3D environmental models in the OSG format were already available (figure 2), and could be easily augmented with additional information areas (Hub, Diepstraten & Ertl 2005b) by tapping on a corresponding software switch. Textual information, descriptions and/or safety warnings could be entered via keyboard. Subsequent changes can be accomplished very easily in this format by adding or editing the structure elements (“nodes”) of the scene graph. When the changes are complete, the updated map can be saved by the user.

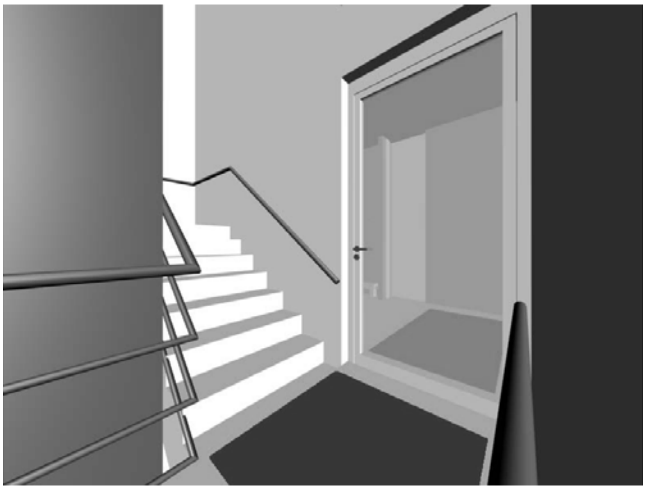

Figure 2: Virtual information areas (rectangles on the floor) can be inserted into 3D models or 2D maps in such places as hallway intersections or at stairways. Augmented information can be linked to these areas, via keyboard, by map makers or blind users.

Given time and cost constraints some environments had to be modeled in 2D. For these maps the so called XML format was used. This format makes it easy to augment the map with information like tables. Therefore, we have configured our special XML map format (Augmented World Modeling Language) in such a manner that it is compatible with the OSG format. This will support use of 3D models when available.

Integration of Voice-Operated Route Planning and Route Guidance

A voice control program was integrated into our portable navigation and object recognition system. So far, a keyboard or touch screen was required to control this system as described above. To expand usability voice-operated commands for enhanced navigation support were added.

Figure 3: The navigation system and object recognition system is based on detailed 3D environment models. The complete system can be controlled via voice using a headset.

The new voice-operated support via headset (figure 3) includes the selection of destinations by numbers or by spelling. Short voice commands can be used to control the complete system. Acoustical navigation advices can be provided periodically, automatically near the next waypoint, or if desired. Indoors and outdoors the next waypoint along the planned route can be announced two times, first in front of the waypoint and when the waypoint has been reached. Additionally, clear, concise and appropriate orientation advices are provided.

4. RESULTS

During the usability tests with voice control it turned out that misunderstandings can appear caused by ambient noise or by unclear articulation. The hands-free operation of the system is more convenient than the control via keyboard but in some cases more time-consuming. This depends on the number of offered options, e.g. the number of possible destinations. Blind users report that the use of voice control technology represents an additional step toward increasing independent orientation and mobility.

In general, it turned out that assistant systems based on augmented environment models offer blind people increased navigational independence and facilitate equal access and social interaction.

5. FUTURE WORK

Technical and Political Challenges

The TANIA system and its extended version represent one attempt to develop a technological solution to the independent mobility problems faced daily by visually impaired individuals. In order to achieve significant functional improvement in accessibility for these people, several technical developments must be realized, and several political challenges overcome.

Firstly, funding for devices such as TANIA must be provided by government agencies or social services organizations. This would necessitate improved public awareness of handicapping conditions, and a sincere commitment to the right of accessibility for all citizens.

In order to use such devices, all public buildings should be equipped with WiFi access points. Maps of streets and models of buildings should be provided and updated by public institutions or governments. 3D models of the interior environments of public buildings should be available, as well, allowing blind people with navigation devices to download the latest information via WiFi access points. Businesses and shops should map their interiors as well, providing this information over the world wide web. This idea is no more farfetched than was the idea, years ago, that every household should have a telephone, and more recently, that computers should be in every home and business. At present, information about direct and real distances to a target destination is available, but mobility maps of greater resolution, with detail necessary to adequate route planning (showing sidewalks and walls, e.g.) must be created. Again, this takes awareness and commitment to the issues involved in accessibility.

Laws passed recently in many countries mandate equal accessibility to public buildings and transportation systems for all citizens. While necessary adaptations have been made to accommodate people in wheelchairs – ramps, renovated toilet stalls, wider doorways, e.g. – barriers for blind and visually – impaired citizens remain. Braille descriptions on products, rooms or elevators, talking traffic lights, and tactile maps are not as prevalent. Further, this group remains unable to plan walking routes, or independently explore new environments. Barriers due to funding issues can be minimized with an accelerated campaign of public awareness, including the passage of laws which mandate accessibility.

Towards an International Navigation Network for the Blind

Formats have to be optimized, converters have to be implemented or adapted. Maps and environment models have to be ready to download and brought up to date including the latest changes. Mapping in private houses could be done by anyone who is able to. Often maps of the architects can be found somewhere. And the format of the maps have do be so, that at least the advanced blind user could do changes. But there is no doubt that for a worldwide navigation system a network of servers has to be present that brings together all the map information. The project will need the help of sponsors to cover the most important parts that are relevant for blind people in the world. To bring together all groups a non-profit organization was founded (BNI 2008) that will coordinate the project and hopefully enable that these systems will be available for people in the developing countries, too.

6. DISCUSSION

Trials with our system thus far demonstrate that this system offers some significant advantages over comparable systems. First, basic functions can be learned in five to twenty minutes, even for people with limited computer experience. Second, changes in the environment can be easily included by loading new maps or changing details on existing maps. This can be done by institutions, the blind user, or others familiar with the system. Third, when walking parameters are set correctly, system accuracy is more precise than that of GPS systems. If location errors occur, they can be easily corrected by the user. Fourth, the system functions when GPS signals are too weak or not available.

Additionally, the system offers users privacy. The only way for others to locate the hardware address of the user is to determine where new maps have been downloaded from public access points. This feature allows users more freedom than they enjoy with some other systems, which allow tracking of user. Further, if the user’s name is not saved on the system, then no personal information can be provided to third parties.

Perhaps the most important advantage is that it can potentially be used everywhere where adequate mapping has been done. And, because system encompasses a complete computer with a large hard drive and multiple interfaces, information can be accessed by the user as it is needed, from the world wide web. The system provides its users with potential unlimited independent mobility, and can help to reduce the isolation of those who lack willing sighted assistants.

7. CONCLUSION

Assistant systems for the blind based on detailed and augmented maps or 3D models offer blind people more navigational independence and facilitate their equal access and to social interaction. With coordinated effort from many interested groups, a worldwide navigation and information system can be realized. Trials at pilot locations have shown that users can be trained within a minimal time period, and with reasonable expenditure of financial resources.

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