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Precise Indoor and Outdoor Navigation for the Blind and Visually Impaired Using Augmented Maps and the TANIA System

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Abstract. The use of a small, portable Tactile Acoustical Navigation and Information Assistant (TANIA) by ambulatory blind people in complex environments is presented. TANIA utilizes an inertial sensor, tablet computer, and enhanced mapping to provide precise navigation of up to one-step accuracy. Its operation is relatively simple, even for elderly people with no computer experience. Previously-installed beacon or tag infrastructure is not required, which expands environmental access for blind users to any area where adequate digital mapping has been done. Current development in pilot locations is described, including examples of how maps are augmented with specific, location-based information. Such data can be presented to the user acoustically or in Braille. Given the ever-increasing availability of global positioning and information services, systems such as TANIA suggest the potential for independent and precise worldwide navigation by blind people.

Keywords: Assistive Devices, Deaf-Blindness, Navigation & Orientation Technology, Orientation & Mobility, Wayfinding

1. Introduction

There are many orientation, navigation and obstacle avoidance systems available, based on various technologies. Because they have been described already in previous work (Hub, 2006), only those most similar to our TANIA system (Tactile Acoustical Navigation and Information Assistant) will be discussed (Figure 1).

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

Indoor or underground navigation systems are based on pre-installed infrastructure, consisting of optical beacons (Magatani, 2001), RFID tags (Naviwalk, 2008), WiFi acces points (Bowen, 2006), or other transmitters typically installed in the corners of rooms. Such systems are workable only in environments where this special infrastructure is available and functioning. While these systems can be precise to within millimeters,

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changes to the environment require expensive and time-consuming infrastructure changes. If, for example, dividing walls are moved or temporary changes made for exhibitions or construction, extensive re-measurements become 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.

Several products based upon GPS signals are on the market (Trekker, 2008; Sendero, 2008). There are also systems which combine GPS technology and indoor systems e.g., the Drishti system (Ran, 2004). However, most cannot incorporate new global navigation data in an inexpensive and simple manner, and text or speech information can be received only in locations where GPS signals are present. More importantly, these systems 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. This shortcoming is significant because GPS or differential GPS signals can be weak or inaccurate and map resolutions insufficient for precise navigation. Information provided by the user can be used to pinpoint exact location, and readjust or correct the map as necessary.

2. Methods

The TANIA system consists of a lightweight portable computer suspended in front of the user, with a GPS sensor and small movement sensor (MTx, by Xsens) mounted on the neck strap (Figure 2).

Fig. 2: Usability tests indoors and outdoors show that the TANIA system can enhance mobility in known and unknown environments significantly and thus help to avoid social isolation. The combination of its step-based tracking method and GPS signals allows for precise navigation wherever detailed mapping has been done.

Using these sensors the pedestrian's velocity can be estimated, steps counted, direction determined, and path tracked. Initial position is determined using GPS signals or entered by the user if GPS signals are weak or absent. As the user moves, current position is determined based on inertial measurements and optionally synchronized with map and/or GPS information. A map is presented on the computer's touch screen, and by tapping it, the user's current position, whether indoors or outdoors, can be accessed. Accuracy is achieved from detailed map data, including guiding grids for open squares or large rooms, and shape-adapted segments for irregular streets or floors (Hub, 2008).

Related positional data, such as house or room numbers, or distance covered along a specific route, can be presented acoustically and visually on the touch screen of the tablet PC. 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. 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.

The TANIA system allows virtual explorations by tapping on the touch screen, and real exploration by walking normally. 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 the points of compass. In the tracking mode the user's position is automatically centered 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. In addition, TANIA can be used as a communication device by deafblind people and anyone able to type on its conventional keyboard (Hub, 2007).

During the California State University Northridge Technology & Persons with Disabilities Conference in Los Angeles, the National Convention of the National Federation of the Blind in Atlanta, and the SightCity exhibition in Frankfurt, Germany, usability tests with blind subjects were conducted indoors and outdoors. These tests were extended to large environments in several German cities. Augmented information was linked to appropriate map locations e.g., information about products and exhibitors at booths or schedules at bus stops and train stations.

Guiding Grids for Worldwide Precise Navigation Support

A conventional GPS guiding system typically provides the user with street name, the current GPS coordinates, and occasionally with house numbers. Some systems incorporate points of interest into the map, linking user-made text or speech information. While quite helpful, these points are time-consuming to install and edit, and unavailable until set up by the user or others.

In contrast, TANIA's guiding grids produce a route description like this: "Walk along Main Street from segment A1 to A10, turn right and cross the intersection using segments A10, B10, C10, then turn left at C10." The name of new navigational segments or street sections can be announced automatically while walking across segment borders. To accommodate curves that might be missed when walking along the curb with the cane, grid segment sizes and names can be varied. These accommodated grids allow safe navigation of multilane intersections with or without traffic islands, roundabouts, and crooked crosswalks. Information can be added to the street names, such as whether and on which side/s of the street sidewalks exist, the direction of traffic in multilane streets, the presence of beeping traffic lights, and the location of Braille markers on architectural objects. In addition to the new grid information, compass headings and distance information remain accessible to the user. The number of steps can be counted and saved or reloaded when paths are completed.

Another advantage of guiding grids over conventional street maps is their usefulness in extreme weather conditions. If sidewalks are covered by snow or dirt from roadwork, and the boundary between street and sidewalk occluded, it is difficult to stay on a sidewalk using only GPS signals. With guiding grids the user is always aware of his or her position relative to map segments, even when physical features of the pathway may have changed since map construction. Further, detours around obstacles pose no problem for the user, who can use adjacent grids to return to the desired path.

The drawing of useful grids can be accomplished by anyone who is familiar with drawing programs and experienced in the area of blind navigation. Automatic drawing or simple cut and paste strategies are adequate for streets laid out in regular patterns, and for rows of similar buildings. Grids can be easily integrated into city maps often available in digitized form from local governments and other public institutions. When accessibility laws are extended to include existing maps and related information, as has been accomplished in several countries already, mapping is even easier.

The addition of guiding grids makes the TANIA system useful even in developing countries or regions where there are no streets at all. It is much easier to draw virtual paths on a map than it is to construct real pathways, whether paved or unpaved.

3. Results

Usability tests with blind and deafblind subjects have shown that the TANIA system can be learned easily, even by elderly people. Blind users reported that TANIA significantly enhanced their navigation abilities. Users can orientate themselves and navigate in known and unknown environments with an accuracy of about one large step.

4. Conclusion

The TANIA system significantly increases orientation and mobility for the blind, deafblind, and visually impaired, especially in unknown environments. Its augmented maps provide access to location-based information presented acoustically or in Braille. Additionally, since the TANIA system does not require alteration of the environment, it can be used everywhere in the world where adequate mapping has been done.

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