Cellphone Accessible Information via Bluetooth Beaconing for the Visually Impaired

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Abstract. We describe a complete hardware/software system, dubbed Universal Real-Time Navigational Assistance (URNA), which enables communication of relevant location-aware information to a blind person carrying a Bluetooth-enabled cell phone. Although URNA can be used for a number of different applications (e.g., an information kiosk at a shopping mall or public transit information at a bus stop), we concentrate on the challenging case of an urban intersection. Information provided to the user as he or she approaches the intersection includes a description of the intersection topology and real-time notification of the state of the traffic lights.

1. Introduction

Persons who are blind cannot rely on the techniques sighted people use for safe ambulation. Although short-range mobility can be effectively managed by means of the long cane or a guide dog, wayfinding remains a serious problem for a blind person moving in an unfamiliar environment. A blind person cannot, for example, read which lines serve a certain bus stop, or even read the number of an approaching bus. He or she cannot access information from a kiosk in a shopping mall. Likewise, a blind person cannot make use of street signals or regular traffic lights when crossing an intersection.

This paper describes a complete hardware/ software system meant to enable a blind person access to location-aware information via a Bluetooth-enabled cell phone. This work was born out of the observation that cell phones have become a commodity of widespread adoption, and that most current models are Bluetooth-enabled. The fact that there is no stigma attached to using a cell phone (as opposed to other specialized equipment) bodes well for its widespread adoption as an assistive technology device by the visually impaired community [6].

The use of Bluetooth for data beaconing has been proposed in different contexts (see e.g. [2,5,1]). Due to its limited range, Bluetooth is an ideal solution for location-aware information broadcasting. For example, a Bluetooth transmitter located at a bus stop could transmit the schedule of the lines serving that stop to bystanders. Several transmitters embedded in the traffic light pedheads of an urban intersection could broadcast a static description of the location (e.g., the names of the streets in the intersection, whether the traffic is one-way or two-way, whether there is an island in the middle, etc.), as well as real-time information about the traffic light status at each crosswalk. This information can be very useful for a blind person negotiating the crossing of the intersection, notoriously a difficult and dangerous undertaking [2].

Our system, dubbed Universal Real-Time Navigational Assistance (URNA), addresses exactly this last application. We have built an FPGA-based prototype controller, that interfaces with an actual traffic controller and with a number of Bluetooth modules. Static and real-time information transmitted via Bluetooth is then presented to the user on his/her cell phone via a suitable interface using Text-To-Speech (TTS). Our prototype has been tested successfully by blind subjects on a mock-up intersection that makes use of real traffic and pedestrian lights.

2. Previous Work

Several wayfinding strategies for blind individuals traveling in an urban environment have been proposed [2]. For example, a GPS, combined with a geographic information system (GIS), can provide helpful for wayfinding. However, the accuracy and reliability of GPS is not always acceptable in environments with tall buildings obscuring one or more satellites. Also, GPS only provide static location-based information, and not real-time information such as the status of a traffic light.

Accessible Pedestrian Signals (APS) are simple devices that have been deployed widely to assist blind and low vision individuals at intersections. These systems are connected to pedestrian traffic lights and provide alternative information using acoustic and possibly tactile interface. However, experimental tests have shown that the acoustic signals in typical APS are often confusing [7]. In addition, acoustic APS contribute to noise pollution and are not always acceptable.

The Talking Signs system [4] uses an infrared (IR) beacon that can be placed near a pedestrian traffic light. A speech message is transmitted by modulation of the IR light, and decoded by a hand-held receiver carried by the user. Unlike our proposed system, Talking Signs requires one to purchase and use a dedicated device. This results in an economic burden, the inconvenience of carrying yet one more gadget, and the stigma associated with the use of a "special" device.

3. System: Overview

In order to develop a realistic prototype, we created a mock intersection utilizing an actual traffic controller and traffic lights. A brief description of the system is provided here; for more details, the user is referred to [3]. We used an Econolite ASC/3 controller, which supports the NTCIP 9001 set of protocols for traffic equipment interoperability. At the heart of our system is the Navigation Controller (NavCon), an FPGA-based board that interfaces with the traffic controller (via Ethernet) and with a number of Bluetooth modules. Whereas NavCon is located in close proximity with the traffic controller, the Bluetooth modules are located at the different pedheads in the intersection (see Fig. 1). NavCon communicates with the Bluetooth modules via RS-422, a serial protocol using differential signaling. Connection cables can be extended to the pedhead modules making use of existing conduits. The Bluetooth modules communicate with the cell phone of a user entering the radio range. We developed a software module (Pedestrian Navigator or PedNav), which is a J2ME application written for mobile devices supporting the Connected Limited Device Configuration (CLDC) 1.0 specification and higher. The application runs on the Mobile Information Device Profile (MIDP) version 2.0 and later, which includes all smartphones on the market today and most conventional mobile phones as well. The role of PedNav is to accept incoming connections from nearby NavCon beacons, authenticate them, and relay useful information to the user. PedNav uses specific Java APIs defined by Java Specification Requests (JSR) to use certain hardware-level functionality. To access the Bluetooth hardware from Java, we use JSR-82 (which needs to be supported by the phone's Java Virtual Machine (JVM)).

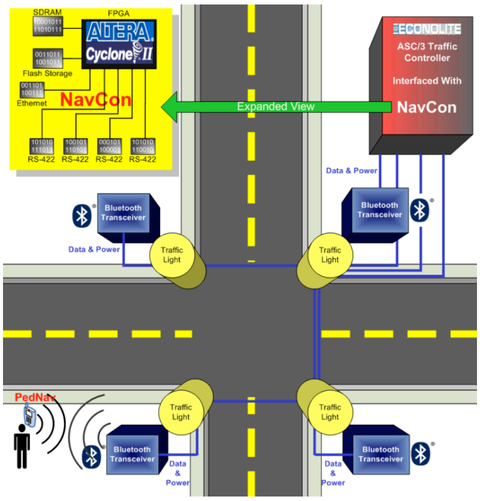

Fig. 1. The layout of the URNA architecture in a traffic intersection.

4. System: User Interface

Information is presented to the user's cell phone via TTS (text to speech). We used the TTS produced by Loquendo for Symbian phones. Note that it is expected that good quality TTS will be a built-in feature in mainstream cell phones in the future.

When a cell phone is detected in the area and an obligatory authentication phase is completed, the phone plays a short beeping tone at short intervals. At this point the user can either ignore the beep, or acknowledge it by pressing a button. Once a button has been pressed, a general announcement is spoken, for example:

"This is the intersection of Mission Street and Bay Street. Press LEFT for Mission Street, or press RIGHT for Bay Street."

After the user has pressed either button, real-time traffic updates are sent, which may look like the following:

"Mission Street is now safe to cross."

"5... 4... 3... 2... The light is turning red."

"Red... Red... Red..."

At this point, the user may go back to the previous announcement to choose another crosswalk, or to go back into the Alert menu. From the Alert menu, the user can always temporarily disable Bluetooth beacon reception if they do not wish to be disturbed.

5. Experiments

For our experiments we created a mock-up traffic intersection within the courtyard of the E2 building at the University of California, Santa Cruz (see Fig. 2). Two real traffic lights, including pedestrian lights, were connected to the traffic controller, which also connected through the NavCon system to one Bluetooth transmitter. The power of the transmitter was set so as to enable communication to a cell phone within a 20 meter range. Two demo days were organized in the June of 2007. The system was tested by several users, including two blind persons, one person with low vision, and one Orientation & Mobility instructor. The system worked as expected and comments from testers were generally very positive and encouraging.

Fig. 2. Experiments with our instrumented mock-up traffic intersection.

Discussion with the testers also outlined a number of issues for future improvement, including:

Multiple beacons for location-aware information. The current system relies on the user to select the street in the intersection he or she is interested in. Information about the traffic light state for that particular street is then relied to the user, regardless of the crossing direction. However, it is often the case that the traffic light state for the same street is different depending on which side of the intersection the user is at. In order to automatically recognize the location of the user within the intersection, it may be possible to use several Bluetooth beacons, possibly with oriented antennas, with only one beacon reaching a particular location within the intersection.

Multilingual support. Due to diverse population in most urban environment, it is important that the system allows the user to select a particular language.

Better user interface. The current system relies on a menu-based interface, with the user switching between different levels of the menu using the cell phone keyboard. However, many phones have keyboards that are not easily accessible without sight. A voice-activated system would be desirable in such case. It should be noted, however, that the level of background noise at traffic intersection may make this option impractical.

Extension to different urban scenarios. Besides traffic intersections, this system could be used in a number of other situations. For example, a Bluetooth beacon placed on a bus would allow a blind passenger waiting at a bus stop to figure out the bus number as the bus is approaching.

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