S-K Smartphone Based Virtual Audible Signage

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Abstract

People with visual disabilities are at a clear disadvantage for using printed labels, signs, and other visual cues to aid independent travel. Remote Audible Infrared Signage (RIAS) has been shown to be effective in providing valuable orientation information for blind travelers; however limited RIAS transmitter and receiver deployment impact its availability. The Smith-Kettlewell Virtual Audible Signage (VAS) project uses ubiquitous smartphone technology to simulate the proven RIAS interface by using an iPhone as a receiver for virtual transmitters that mark signs and landmarks in the real-world environment. The virtual signs are recorded in an online database, and location and orientation sensors on the phone allow it to be used as a haptic pointing device that simulates the RIAS user experience. This paper describes an experiment to evaluate pointing accuracy of the VAS prototype, as well as the assessment of an audible warning signal presented when confidence in the orientation information was low. The system showed consistent performance with minimal impact of the presence of the warning on increased pointing error.

Keywords

Accessible signage, blind wayfinding, iPhone, GPS

Introduction

A world without access to printed signs often leaves people with vision loss lacking the necessary information to successfully navigate the physical environment. Identifying street corners, public buildings, transit stations and open spaces, like parks, is a challenging task without the information embedded in signs that are often taken for granted as a means for environmental access. The Smith-Kettlewell Virtual Audible Signage (VAS) project builds on proven benefits of Remote Infrared Audible Signage (RIAS) to augment the availability of accessible signage without the need to install transmitters or distribute receivers. The VAS prototype uses ubiquitous smartphone technology to provide a RIAS-like audible signage system by using the smartphone's built-in Global Positioning System (GPS) and orientation sensors. Similar to RIAS, VAS uses a gestural interface to locate audible signs with the smartphone as the receiver. The audible signs are records in an online database and are subsequently available via an iPhone app to provide virtual talking signs to visually impaired pedestrians as they engage in way-finding.

Background

RIAS, an infrared, wireless communication and orientation system was developed as a reliable and successful accessible signage system in indoor and outdoor environments (Crandall et al). Research demonstrates that RIAS significantly improves the ability of blind people to find very specific locations, such as entrances to buildings or rooms in indoor environments (Brabyn and Brabyn). Auditory signage reduces barriers to efficient transit use (Marston and Church) and dramatically improves performance for a variety of tasks including finding bus stops, boarding correct buses, and finding entrances and exits in public transportation terminals (Golledge and

Marston). RIAS also reduces the stress and anxiety associated with navigation and public transportation use (Golledge and Marston; Golledge, Marston, and Costanzo). A strong benefit of RIAS is the spatial/directional precision with which locations can be identified (Marston). However, the RIAS system requires hardware transmitters installed in the physical environment and dedicated hand-held receivers to decode the infrared information.

Virtual Audible Signage (VAS) is an additional approach to traditional RIAS that combines ubiquitous mobile phone technology with a cloud-based database. Since VAS uses smartphone technology and location based services (LBS) it lacks the spatial accuracy of RIAS. However, there are many research efforts that have confirmed the feasibility of using GPS to locate blind travelers in a variety of environments (Giudice and Legge). Perhaps most notable for the current project is the haptic pointer interface (HPI) project. HPI successfully demonstrated that the combination of GPS, a computer driven geodatabase, and an electronic compass attached to the end of a receiver can localize locations in outdoor environments (Loomis, Golledge, and Klatzky). Therefore, we hypothesize that a tool like VAS may prove useful for providing signage to large outdoor undefined geographic features such as parks, monuments, college campuses and much more.

Tool Development

The VAS prototype has been developed for Apple’s iOS platform (i.e., iPhone, iPod Touch, and iPad devices), and has been evaluated on the iPhone 4S model. The VAS prototype utilizes a combination of the iPhone’s built-in sensors to evaluate location and orientation of the device including global positioning system (GPS) to estimate location (as well as location error), magnetometer (i.e., compass) to periodically calibrate direction, and MEMS gyroscopes to detect rapid changes in orientation. Using these sensors, the VAS prototype can calculate where the iPhone is, as well as what direction it is pointing. Combining this information with an online database of virtual sign locations and associated audio messages, VAS allows the iPhone to play specific audio information when the device is pointed in the appropriate direction. In addition, the familiar RIAS characteristic of a clear signal when the receiver is pointed directly at the source, with increasing static as the receiver points away from the transmitter, has also been simulated for the virtual audible signs.

GPS location estimates always have some error associated with them. The error can vary depending on local geography, as well as the quality of the GPS receiver and antenna being used (Gustafsson and Gunnarsson). The iPhone GPS provides an estimate of this spatial error, allowing VAS to know both its location, and the spatial uncertainty. This is essential because the larger the spatial error, the less certainty the system has regarding the direction of nearby virtual audible signs. The system will therefore associate a confidence factor with each virtual audible sign in the environment. Distant signs are assigned a higher confidence factor, and closer signs will have confidence values that are more dependent on the estimated GPS error. Low GPS uncertainty will lead to increased confidence for nearby signs.

The built-in compass of the iPhone is not well suited to estimating quick changes in direction. Its values are averaged over a relatively large time interval, and it is often subject to local magnetic interference. However, the built-in gyro of the iPhone 4S model is extremely responsive and has minimal sources of interference. In order to allow users to quickly point the iPhone-based VAS prototype in different directions and receive real-time feedback, the software uses a combination of compass- and gyro-based information. When the iPhone is relatively stable with minimal magnetic interference, the gyro-based orientation is calibrated to that direction. The gyros can then measure orientation offsets from that calibrated direction. The system periodically recalibrates in order to counteract drift in the gyros.

Each virtual sign record in the database includes:

- Location--latitude and longitude of the virtual audible sign.
- Audio message--the message that the sign repeats, such as “Main entrance to Student Union.”
- Orientation--the direction in which the virtual audible sign is “facing.”
- Transmission angle--if the angle is narrow, you need to be directly in front of the sign and pointing straight at it to hear it. Wider angles allow the sign to be heard from locations further to the side.
- Range--How close the user needs to be to the virtual sign in order to hear it. Virtual audible signs with larger range values can be heard from further away.

Although this project offers many rich areas of investigation, this paper focuses on two major problems:

1. The development of a confidence factor for virtual audible signs based on estimated GPS error;
2. A user interface that can provide feedback on the sign’s location and content, as well as an estimate of location confidence.

Experimental Methods

A pilot field experiment was conducted to test the development of the confidence factor and the user interface of the VAS prototype. The experiment consisted of a blind participant who tested the VAS prototype and a sighted researcher to record pointing accuracy information.

Three locations (or virtual signs) were programmed as experimental points: a bus stop, a playground, and a bench all located in or near Alta Plaza Park in San Francisco, California.

A compass was attached to the end of an iPhone 4S, and base compass readings were taken of each of the three experimental locations relative to the location of the stationary blind participant. The blind participant then pointed the iPhone in the direction of each of the three experimental virtual signs using the gestural interface and auditory message as feedback. A sighted researcher recorded the compass heading after the blind participant indicated they were pointing at the virtual sign. This process was repeated 8 times for each experimental virtual sign, taking one reading from each virtual sign in turn until 8 readings were taken for each target.

The confidence factor for each virtual sign was calculated by taking the distance to the virtual sign divided by the estimated error. If the confidence factor was less than 3, there is a feedback sound or an uncertainty alert when the blind participant pointed at the virtual sign.

Results

The results (table 1) show the compass reading for each 8 of the trials and includes the true compass heading reading for each experimental virtual sign, mean, standard deviation and error estimates. Error was calculated by dividing the standard deviation by the square root of n-1.

Table 1 Compass Reading Results

Virtual Sign	True	T1	T2	T3	T4	T5	T6	T7	T8	Mean	SD	Error
bus stop	260	260	258	248	254	260	260	256	256	256.5	4.10	1.45
play ground	182	164	172	176	168	164	170	168	166	168.5	4.10	1.45
bench	116	108	118	102	112	112	116	114	114	112	5.01	1.77

The table displays the compass reads for the virtual sign for eight experimental trials. The cell "True" indicates the true compass reading of the virtual sign relative to the location of the participant.

Discussion

This experiment was intended to evaluate the effectiveness of the device and the methods used, rather than a behavioral study. Therefore, the use of a single subject is not only reasonable, but preferable, as it reduces pointing error resulting from individual differences. The number of readings for each location (n=8 for each virtual sign) is not sufficiently large to draw statistical inferences about the performance of the system. However, some broad conclusions are implied. Pointing error does not appear to be much larger for virtual signs in the near field than for those at greater distances. Similarly, pointing error is reasonably small, even for those signs that consistently included the uncertainty alert. This implies that the selection of a critical value of confidence factor equals 3 is either too large to be useful, or the uncertainty is not significantly contributing to errors in pointing.

VAS simulates the analog, directional, audio/haptic interface of RIAS. This provides the ability to clearly identify the direction of a source by maximizing signal-to-noise of the audible sign (i.e., finding the orientation where the sign's signal is clearest). However, the sensors used in VAS (i.e., GPS, compass, and gyroscope) introduce some level of inherent uncertainty in the direction of the virtual sign. When sensor error is low, the system can have a high level of confidence that it is presenting accurate orientation information. However, when sensor error is high, the user should be alerted to the fact that confidence for the orientation information is low. This prototype system implements a simple interface that pulses a brief burst of noise in with the sign's message once per second only when the confidence factor does not exceed a specified threshold. This interface allows the user to continue listening to the audio information from the virtual sign, but also communicates that its orientation information is not to be relied upon.

It is important to note that total sensor error as used in the calculation of the uncertainty factor can be introduced through GPS error, compass error, and Gyroscope drift. Only GPS error is accounted for in the current prototype VAS system. Future iterations of the system should enable more reliable calculation of the confidence factor by including error components introduced by the compass and gyroscope as well.

Impacts and Conclusions

VAS has the potential to greatly enhance the circumstances in which accessible signage can be provided. Although RIAS is a mature technology, it remains challenging to install the necessary transmitter infrastructure in many outdoor settings such as parks, college campuses, bus shelters, etc. VAS offers the potential for the proven benefits of RIAS to be extended to these contexts with no infrastructure required. The use of the iPhone as our prototype platform demonstrates the potential of users to take advantage of an existing hardware platform with rapid adoption among blind and visually impaired users, as well as many other demographics. This means that no extra receiver hardware needs to be purchased or distributed to users.

The prototype VAS system continues a tradition of research and development investigating location-based wayfinding technologies for blind travelers. While the VAS project requires additional research to improve confidence factor readings, the gestural interface has proven to be effective for a smartphone-based talking sign system. Continued developments will include extending the prototype to other smartphone platforms such as Android.

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