What You Said about Where You Shook Your Head; A Hands-free Implementation of a Location-based Notification System

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Abstract
The MIT Smart Helmet is an ongoing project at the MIT Media Lab that incorporates context-aware technology into a bicycle helmet for the purpose of enhancing rider safety. The following paper is an evaluation of a proposed feature being considered for integration: a location-based notification system that can be operated without the use of the hands.

Keywords
Context-aware technology, hands-free, wearable-computing, notifications

ACM Classification Keywords
H.5.2 [User Interfaces]: Evaluation/methodology

Introduction
In 2001, the MIT Media Lab began the "Smart Helmet" project in an effort to enhance the safety of bicycle riders by incorporating context-aware technology into a helmet that will assist the rider. The on-board electronics that have been incorporated include a Bluetooth microphone, accelerometer, siren, speakers, Light Emitting Diodes (LED's), and a microcontroller. The LED lights on the left and right sides of the back of

the helmet act as turn signals, flashing on and off when the rider tilts his or her head as detected by the accelerometer. If the rider needs to gain the attention of a vehicle, he or she can yell into the microphone which, detected by the microcontroller, will then turn on the siren. The microphone and speakers also allow the rider to communicate via cell phone. Even though these features may seem to complicate the already complex task of driving, this is mitigated through their design by providing control through caricatures that simulate what a rider might do to affect such an action without the helmet, and by providing this control without requiring the use of the rider's hands.

figure 1. The MIT Media Lab Smart Helmet as worn by Professor Ted Selker [1].

Hands-free controls are particularly applicable during the operation of bicycles because the way in which they are ridden relies on the use of both hands. Providing the rider technology that requires the use of one (or both) hands is dangerous. Stability and control can be severely degraded, especially since a rider's posture often rests much of his or her upper body weight on the handlebars. The Smart Helmet also does not incorporate any displays or controls to which the rider must attend visually. This allows the rider to maintain eye contact with the road.

A proposed addition to the Smart Helmet is an application that, when activated, records the rider's voice and the location at which the recording began. Then when the rider approaches that location at a later time, the previously recorded message is played back to the rider. A prototype program had been written for a Global Positioning System (GPS)-enabled cell phone, but the rider must still tell the program when to begin and end a new recording. This report explores the practicality of this feature, and the feasibility of designing an effective hands-free implementation.

Related Work

Location-based notification systems have been researched for several years now, including projects such as Place-Its, Forget-me-not, Cybreminder, Stick-E notes, ActiveCampus, Memoclip, and ComMotion. All involve a form of technology with which the user will "leave" personal or shared verbal notifications at specific locations. These notes are then played back to the user, or to other users at those particular locations at a later time. Some applications focus on delivering these notifications at relevant times, while others deliver them when the user is in proximity to the original location at which they were recorded. There is also an argument for using cell phones as a platform for these technologies because of their ubiquity [2-3].

Other projects have focused on enhancing location-awareness through wearable computing [4-5]. These were not developed around location-based notifications, but rather visual aids to navigation. There has also been work done with wearable audio messaging that delivers timely information while minimizing interruptions [6].

The aforementioned proposed feature of the Smart Helmet is an extension of this related work, uniting wearable computing with the location-based notification system. Although past projects were limited by inaccuracy and lack of portability, there are several key suggestions to consider for the Smart Helmet project: the ubiquity of cell phones and their supporting networks should be leveraged, and the benefits of location dependent information delivered in real-time can extend to all vehicles on the road.

Implementation

The location-based notification system has a main program that runs on the Java Midlet platform on a Nextel i870 GPS-enabled cell phone (see fig. 2). The program polls the phone's serial port every second, waiting for the command to begin recording a new data point. When the command is received, the current GPS coordinates are stored to a database, and the phone's voice recording function is turned on. When the program is commanded to stop recording, the audio file is stored to a database and associated with the GPS coordinate at which the recording began. When the rider comes within proximity of a stored GPS coordinate, the voice recording associated with that location is played back to the rider.

Head movements are measured with a 2 axis accelerometer in which the x-axis is vertical, while the y-axis is horizontal from the left shoulder to right.The current implementation does not include the Smart Helmet itself in order to maintain simplicity during this evaluation. In place of the helmet, an interface board was developed to provide the user a hands-free means to turn the program on and off (see fig. 3). For the initial evaluation, the microcontroller has a simple algorithm that commands the program to begin a new data point when the rider has "nodded twice within 5 seconds" (i.e., the x-axis of the accelerometer has departed from near-vertical and returned twice within 5 seconds). This action complements the natural nodding motion one would experience when hitting a pothole or bump, while allowing the rider's eyes to remain focused on the road. The algorithm sends the signal to stop recording after 10 seconds have passed.

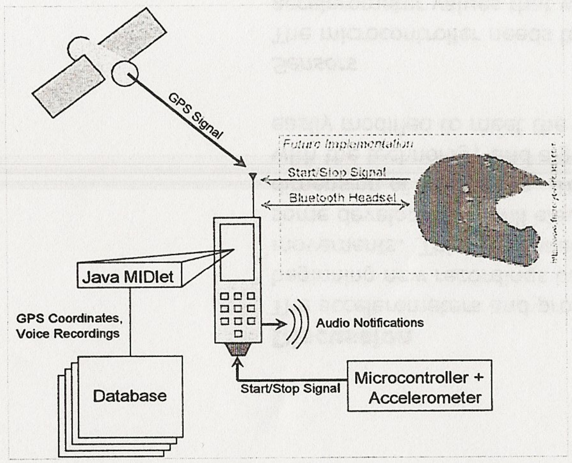

figure 2. System diagram for both the current and future implementation of the location-based notification system.

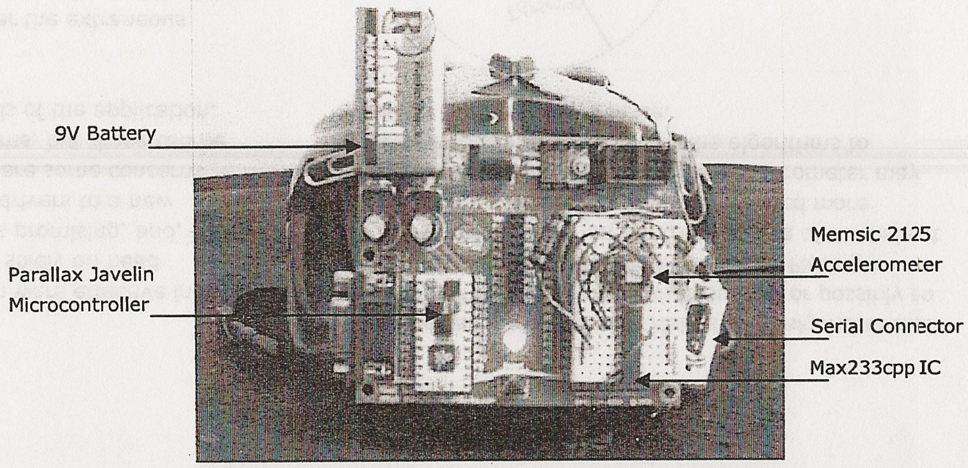

figure 3. The interface board as installed on the back of a bicycle helmet.

Discussion

The accelerometers and program were effective in beginning new recordings based solely on head movements. This functionality is promising, and, with some development, will elevate drivers to a new dimension of awareness. There are some concerns with the technology and algorithms, but these can be easily modified to meet the needs of the application.

Sensors

The microcontroller needs to filter the extraneous accelerometer values that will be prevalent while riding. The current algorithm looks for changes on the x-axis to determine if the head has departed from vertical, but the accelerometer is capable of measuring static, as well as inertial acceleration. In a perfectly controlled, non-moving environment, tilting the head forward will show a decrease in g-force; but in an operational, moving environment, the same decrease can be achieved by downwards movement. In fact, the thresholds were initially set such that walking with the helmet in hand was enough to begin a new recording.

With some modification, hands-free activation is possible within the operational environment. The accelerometer does not necessarily need more resolution, but the on-off threshold needs to be set in a range that does not trigger the program falsely, and does not require awkward and extreme head movements to achieve. The program could look for head motion on the y-axis, which may be less noisy while riding, but this is not advised. The eyes can remain focused on the road while nodding the head up and down much more easily than when tilting the head from side-to-side. Side-to-side movements are also reserved for activating the turn signals that are already incorporated into the Smart Helmet. An algorithm that effectively filters the noise would suffice, or possibly an alternative accelerometer configuration. Placing a second accelerometer on the front or side of the helmet could allow head position to be determined more accurately. Upgrading to a 3-axis accelerometer may provide enough information for the algorithms to manage the extraneous noise.

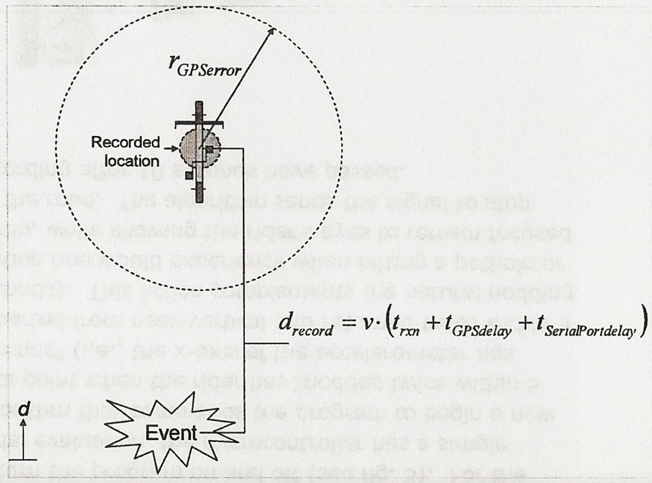

figure 4. Decomposition of the distance at which data is recorded, with respect to an event or location of interest.

System

The purpose of the proposed feature is to leave information at specific locations, but defining these locations accurately may not be possible with the current system configuration. Figure 4 assumes that the rider begins recording after passing an "event," designated here as a location of interest. There is an absolute error in the GPS coordinates that can be as large as 100 ft (30 m) or more—the circle defines a set of equally probable locations at which the system believes the rider could exist. Furthermore, the distance the rider travels away from the event before recording is dependent upon the rider's total reaction time, the delay in receiving the GPS signal, and the delay in reading the start-command on the serial port, all multiplied by the rider's speed. Keep in mind that a bicycle traveling 25 mph (40 kph) will be 37 feet (11 m) farther from the event with every passing second. Furthermore, there may be times riders choose to record after they have passed the location, such as hitting a pothole, but there may be instances in which the rider has enough *a priori* information to begin recording before, such as approaching a confusing intersection. With limited accuracy and no additional indication from the rider, the system cannot assume that a recording begins before or after the event without risking erroneous compensations.

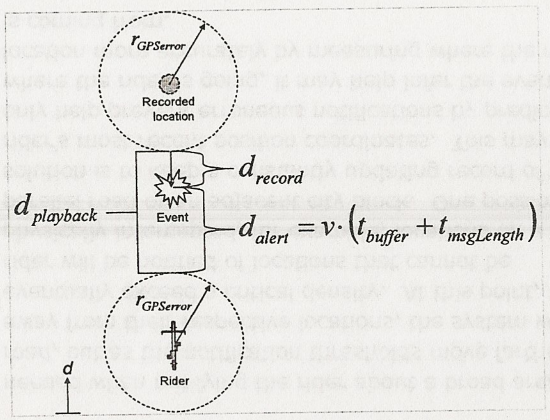

Figure 5. Decomposition of the distance at which a recorded notification should be played back to the rider, with respect to the location at which the recording began.

Figure 5 assumes that the rider is approaching a previously encountered event while traveling in a linear fashion, as if on a road. All distances are assumed to be as close as possible, such that there will always be enough time to deliver a successful notification regardless of location errors. For example, the proposed feature has no benefit if the rider is alerted after hitting the pothole, or if he or she is alerted so late that the hazard cannot be avoided. Missed detections could severely degrade the rider's trust in the system, and therefore these notification distance thresholds should be set conservatively.

The distance at which the rider should be alerted is defined by the time required to hear and interpret the message, plus a preset window of time in which to respond to the notification, all multiplied by current speed. The system does not know the exact location of the rider, which is assumed to be as close to the event location as probable. The system also does not know the exact location of the event, but rather the coordinates at which the recording began in response to it. However, the coordinates contain error as well, and therefore the recorded location is assumed to have occurred as close to the event location as probable. To guarantee effectiveness, the distance at which the recording should be played back to the driver must account for the alerting distance, the recording distance, and the worst-case errors in location.

The worst-case assumptions also apply to the delays in the system. When the rider nods to begin recording, it may take as long as 1 second for the program to recognize this command. Similarly, when recording begins, the program may wait as long as 1 second for the GPS signal to update. High accuracy may not be needed when notifying the rider about a broad area of road, but as the notification thresholds move farther away from their respective locations, the system will eventually exceed a critical density. At this point, the rider will be notified of locations that cannot be physically intercepted, for example, locations on a parallel road or an adjacent city block. One possible solution is to keep a constantly updating record of the rider's most recent position coordinates. This may not only help prevent erroneous notifications by predicting where the rider is going, it may help infer the event location more accurately by measuring where the rider is coming from.

Conclusion

Although there are several issues that require further development, this does not detract from the project's overall goal. The system's crucial contribution is that it assists riders in creating a virtual map of events and places that require attention. Imagine people creating their virtual maps; a bicyclist would be able to avoid the danger of an intersection with no signage, roundabouts will be navigated with ease, and riders will be notified of possible danger depending on varying traffic patterns throughout the day. This system is an advance over the process of alerting a municipality that an intersection is dangerous, and then having them wait until someone is hurt. The proposed system provides a means of ubiquitous, proactive safety for all who use it.

Further development may extend into external software applications that provide a visual interface for managing database information. Not only would this allow the rider to add, delete, and modify notifications as necessary, such a program could open the possibility of creating a online collaborative forum through which riders can share their information.

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