Orientation-based Interaction for Mobile Devices

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ABSTRACT
Our team has been exploring the possibilities of orientation-based sensors on mobile devices. We constructed a prototype system for delivering 3D acceleration and magnetic compass data to a Pocket PC and developed trial applications. One class of applications relied on the tilt sensors to provide a gesture interface to an application. A second class of applications used the magnetic sensors to create a style of portable augmented reality interaction called "Searchlight". Through our user studies, we learned that orientation-based user interfaces are fun and have the potential to improve the usability of mobile devices, but require a high degree of personalization.

Author Keywords
Tilt sensor, digital compass, augmented reality, gesture-based interface, mobile device.

ACM Classification Keywords
H.5.2.c Design for wearability, H.5.2.g Haptic I/O, H.5.m Miscellaneous.

MOTIVATION AND RELATED WORK
Because the position and orientation of a mobile device by definition changes over time, it is natural to try to exploit this variability as a method of input. There are a few broad classes of applications that one can envision with this capability.

One class of applications is the gesture-based control interface which has been explored by many. [1] explored tilt-based interfaces on portable devices in a menu and scrollable-map application. Later, [2] demonstrated a device that incorporated touch, proximity and tilt sensors for gesture-based control of a device. [3] present a similar system using gestures tied to areas of the body to trigger events.

A second class of applications is handheld augmented reality. We believe that handheld augmented reality is more socially acceptable than forms that rely on head-mounted displays [4]. The best early demonstration of handheld augmented reality is probably [5]. This visionary system was not mobile because of the rendering hardware and the position tracking system had a working area of a few cubic meters. More recent demonstrations like Peephole [6] share this limitation and are not truly mobile.

For coarse-grained position sensing (10m), GPS is frequently available outdoors, techniques such as Placelab [7] can bring GPS-like accuracy if there is sufficient coverage of GSM or 802.11 access points. As time passes, it is possible that the "position" part of the AR problem will be more and more tractable, so we will not address this problem at all for this project.

Magnetic fields have been used for centuries for navigation, and in contrast to the previously mentioned approaches for establishing orientation, a digital compass requires no infrastructure. Although the magnetic field is somewhat unreliable, like GPS, it requires no additional infrastructure. One of the main aims of this project is see how useful the magnetic field is for augmented reality and to see whether magnetic disturbances can be tolerated. Although gyroscopes and other techniques can be used to compensate for these problems [8], in this paper we will focus on building a simple, cheap interface.

INFRASTRUCTURE
Our orientation system uses two components - a 3D compass and a 3D acceleration sensor. A microcontroller samples the analog sensors and sends data to a host workstation over a serial port. Due to differences between PDAs, we use a workstation to sample the serial port data and send it over an 802.11 wireless link to a pocket PC running our application software. This also allowed us to develop applications using the Windows Mobile emulator on the workstation. The sensor package is physically attached to the back of the pocket PC so that both move together. The tether between the sensor pack and the laptop does limit the mobility of the configuration, so we are beginning to work on a direct connection.

Our 3-axis accelerometer is implemented with two Analog Devices ADXL202E, each about $10 in small volumes. The sensors are sampled at about 20Hz and the sensor data is somewhat jittery. Some applications need to provide an additional software low-pass filter on the raw sensor data to reduce this jitter. Additionally, these sensors require a one-time calibration.

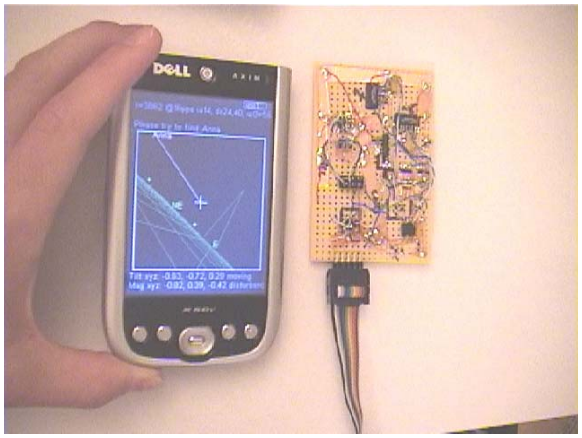

Figure 1: Our prototype sensor package shown next to a Dell Axim x50v running the Searchlight application.

The magnetic orientation sensing uses a 3-axis magnetometer. Each axis of the local magnetic field is sensed with a Honeywell HMC1001 sensor., currently, $20 each. We noticed late in the project that the PDAs were the source of very substantial magnetic fields (in one case on the order of 1.0 gauss). This can be addressed via calibration, but in a real application care would need to be taken in sensor placement.

GESTURE BASED INTERFACES

We explored three gesture-based interfaces to verify the controllability and effectiveness of the interaction.

1. Tilt-Based Scrolling

The simplest application that we developed was a test-bed for tilt-to-scroll interfaces. This interface has been suggested before in [2], [9], and [10]; we used it largely as a test of our hardware and software platforms, but our unique contribution was subjective research on the "fun factor."

In this application, the user is presented with a map of Florence, Italy. As the device is tilted, the map scrolls proportionally to its angle from level (steeper tilt translates to faster scrolling). The technical issues of large map storage and scrolling on a resource-limited device are outside of the scope of this paper; for testing, they were sidestepped by using a relatively small map.

Based on the first phase of user testing (see below), we added two additional features to the system—a configurable "dead zone" in the center of the system, which required a certain tilt threshold to initiate scrolling; and a clutch, requiring a button to be pushed and held for tilt-based scrolling to kick in.

User Testing

We tested our tiltable map on seven users (six male and one female), and each user was given four variations of the application: manual scrolling using the four-way keypad, unmodified tilt scrolling, tilt scrolling with a dead zone, and clutched tilt scrolling. After a simple explanation of the project, users were asked to use each mode of scrolling to find various places, and to find routes from point to point. After the test, users were asked which method they preferred, and for subjective feedback on each.

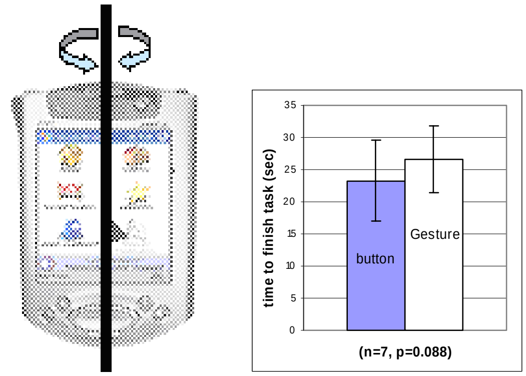

Figure 2: (a) gesture to swap gesture and (b) time

Of the seven users, four preferred manual scrolling, while three preferred clutched scrolling. Those that preferred manual scrolling cited the tilt system being too hard to control, not accurate enough, and hard to view while they were scrolling as reasons. The universal reason for preferring the tilt-based scrolling, however, was "it's more fun." This reaction led us to some interesting conclusions—based on our limited sample, adoption of tilt-based scrolling in classic "serious" examples (mapping, spreadsheets, documents) is unlikely to take off anytime soon, but tilt-based gaming consoles would be an interesting area for future exploration.

2. Application Swapper

This application allows users to swap applications on a mobile device. This corresponds to the ALT-TAB function on Microsoft Windows. Considering that most mobile devices have limited display size, which leads to displaying only one application window at a time, application swapping may happen more often on mobile devices than PCs with larger display.

The current method of changing applications requires using a menu, which means a minimum of three clicks, or having a separate task bar which takes up limited screen space. Moreover, all methods use the stylus, which might require extra time.

We used the gesture metaphor of flipping a book to change the windows. In most books users need to lift the right part of the page to turn to the next page. Users lift the left side of the page to go to the previous page. We used this metaphor to swap applications. Figure 2(a) illustrates the gesture. We can easily imagine this metaphor being used to flip/scroll pages on eBooks.

User Testing

Initial user testing was conducted with 7 users (3 female, 4 male). The users were given a task where they needed to look at a window with selected checkboxes and select the

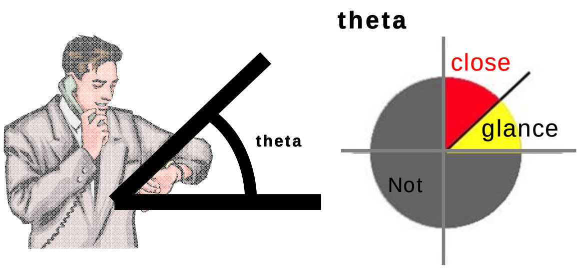

Figure 3: Semantic zoom states.

corresponding checkboxes in another window. Users were asked to do the same task once using previous/next buttons and another time using gestures to swap between the windows. The users were given time to practice both of the sequences before the actual measurements and the sequence of the experiments were alternated to counterbalance the learning effect.

Figure 2(b) shows the result of the user study. The average time needed to accomplish the task is comparable (button: 23.2sec, gesture: 26.6sec) for the two cases. Considering that this was the first exposure of gesture interaction for the subjects, gesture-based interfaces seem to be efficient. This gesture-based interaction method seems more promising in tasks where the user does not need to use the stylus.

3. Semantic zoom wrist watch

This is a prototype for a wrist watch application which detects the posture of the user to predict the user's intention. There are three predicted states of the wrist watch—Not Looking, Glancing, and Close. When the user is not looking (the display is not facing the user), the watch display will be turned off to save power. When the user is glancing, the display is close to flat, and the watch just displays the time. The third case is when the display has a very big angle facing the user (Close); here, the screen displays detailed information about the user's schedule in smaller font. The font can be smaller since the display is presumably closer to the user's eyes. Figure 3 illustrates the three different cases.

The initial user study on 7 subjects (3 female, 4 male) shows that the concept this prototype was very easy to learn. Many of the subjects said that it was easy since they already have tendency to bring things close to see more detailed information.

One objective of this user testing was to find out the right threshold for the three cases. The observations on how the users use their normal wristwatch show that the size and the weight of the watch have a huge effect on the angle the users bring up their watch, which should be taken into account in the next prototype.

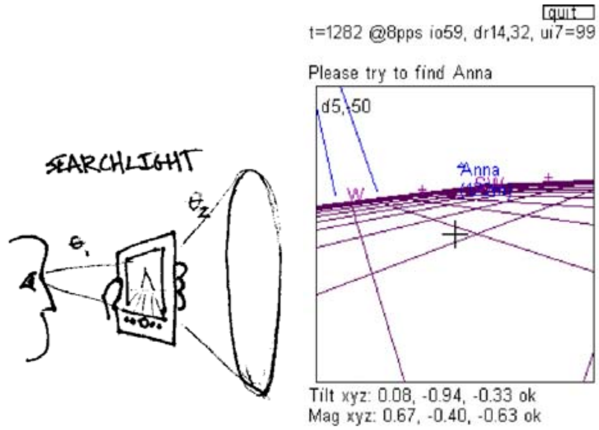

Figure 4: Searchlight is a concept for augmented reality.

SEARCHLIGHT – USING HANDHELD ORIENTATION FOR CHEAP AUGMENTED REALITY

Another application we tried was handheld augmented reality. The concept of augmented reality is that the handheld's display provides a moveable window into a virtual world which is somehow correlated with the real world. Unlike other approaches like Peephole and the "Boom Chameleon" [11] which provide high precision interaction with objects that are "nearby" in virtual space, the Searchlight methaphor tries to provide the best augmented reality possible without a special infrastructure for sensing orientation.

Demo "Friend Finder" Application

The interface design for the Searchlight test application is based on the "friend finder" feature multiplayer online role-playing games. A fictional central server maintains a list of (in this case fictional) friends or points of interest with their locations. Positions could be estimated by Placelab or GPS in real life, but were randomly generated for this test. A friend finder is a good application for this type of position sensing because friends that are close do not need to be found.

In our test application, the user holds the device up and a view of a virtual world is displayed. (See Figure 4). Users are asked to find the icon representing a target friend, move it into the crosshairs and press a button. After this task is complete a new friend is presented. We measured the time needed to locate each target and interviewed the subjects about their experiences. Trials were videotaped for later review.

Pilot Study

Two rounds of preliminary testing were done prior to real data collection. Three users were recruited and asked to complete the friend finder task for a set of 20 friends under three conditions:

(1) a training run with maximum screen size (240x320), (2) a timed run with maximum screen size, and (3) a timed run

with a cellphone-sized screen (144x192). All trials used a viewing angle of 90 degrees.

The time required to complete the training run was between 191-250 seconds, while the repeated run required only 146-190 seconds. As expected, some learning occurred which improved the task efficiency.

When the screen size was reduced, the task times varied from 131-150 seconds. This improvement shows that the Searchlight concept is viable for very small screens.

There was even some evidence that it was easier to pick the targets with the smaller display. Because the picking area is measured in pixels, and each pixel with a small display subtends a larger angle, the picking angle with the small screen is larger. The testers may also have been aided by the fact that the apparent jitter of the display in terms of pixels was lower.

The effort of raising the arms to bring the display to eye level was not natural to several people and they complained about having to look up. Since users will most often want to look out towards the horizon, we should re-map the orientation so that this can be done from a comfortable position.

Users complained about jitter and lag in the interface which caused them to sometimes overshoot. Current frame rates of 10fps probably need to be improved to at least 20fps.

CONCLUSIONS AND FUTURE WORK

We built a framework to gather orientation data for mobile devices, and a number of applications to use this data. Through development and user studies, we found that orientation-based user interfaces are fun to use and have the potential to increase handheld usability, but require significant personalization.

All around, we would like to revise the prototypes according to initial feedback—specifically, we want to eliminate the tether and make the prototype truly portable. With the revised prototype, we would like to conduct further user studies with a larger population.

For the gesture applications, we would like to explore the use of gestures in games, as well development of new applications mapping real-world metaphors to gesture-based mobile interfaces.

For the Searchlight application we would like to solve the ergonomic problems with the interface, and integrate the orientation data with position information from Placelab. Once this is done, a number of real applications can be developed.

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