Wearable GIS for Homeland Security Applications: Accomplishments, Prospects and Research Issues

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ABSTRACT
Under the NSF-funded Digital Government Initiative Project Battuta (http://dg.statlab.iastate.edu/dg/) valuable experience has been gained about the design, construction and use of a wearable system that combines basic GIS functionality and augmented reality display to assist human navigation. A UCSB wearable system has been designed and built, and a prototype user interface for the system (GEORGE) coded and implemented in Java. In this presentation, the accomplishments and findings from Battuta will be summarized, and used to provide an informed view of the possible capabilities of future systems. To get to this future, key research obstacles must first be overcome, and some of these are cataloged and assessed. Central among them are basic human cognitive responses to navigation assistance, human-computer interface concerns, problems of cognitive overload and stress, and distraction problems similar to those for cellular telephones. While it remains to be proven that wearable computing, using today's technology, is superior to other types of navigational assistance, this will clearly not remain the case for very long. Probably the dominant theme in the near future will be the migration to a standard wearable platform based on commercial off-the-shelf technology melded with custom software for visualization.

1.MOTIVATION

Project Battuta is a joint Digital Government Initiative project being conducted by Iowa State University and the University of California, Santa Barbara, funded by the National Science Foundation, with matching support from other U.S. Federal and private sources. The project has been working on integrating heterogeneous geo-spatial information resources using flexible architectures for adaptive data collection in mobile environments. Software and systems architectures have been developed for several configurations of high-mobility computing devices, including palm tops and touch panel displays. The UCSB component of the work has focused on wearable computing. The Battuta projects users are intended to be census enumerators for the 2010 Census and participants in the Department of Agriculture's National Resource Inventory. Nevertheless, the system's purpose is navigation and data collection in outdoor environments. We see a multitude of Homeland Security applications.

2. HARDWARE

The first generation UCSB wearable computer uses the CharmIT kit, at first based on the PC-104 standard but now based on more advanced CharmIT technology and the regular PC computing standard, running at 800MHz. Input and output devices were added to the core system. For text input, we have used a small keyboard strapped to the left forearm, and a mouse worn like a ring on one finger of the left hand, moved with the thumb and by squeezing the hand. The primary output device is a MicroOptical SV-3 display, a color monocular (320x240) clip-on display that magnifies the image displayed over a range of resolutions. The eyepiece of the clip-on display is suspended from a clear support and provides minimum occlusion by allowing a vision around all four sides of the virtual image. Field tests have shown that the clip-on monocular display is preferred, largely because it is far more flexible in use. We hope to move to a binocular stereo system for better augmented vision capability. The Battuta system uses two rechargeable lithium ion cam-corder batteries along with smaller batteries embedded in devices, and a primary hard drive contained in the same case as the CPU. The GPS unit is a Garmin 12 channel receiver mounted on the left shoulder with Velcro. A flux-gate compass with three-dimensional amplified sensing capability, and measures the users view roll, pitch and yaw continuously. The system components are wired together through pockets and pouches via USB connectors, and contained in a simple vest or a bag. A new addition is a forward-looking video camera, focussed on the user's hands. We are using this to create a gesture interface, which could replace all other human input elements of the user interface.

3. SOFTWARE

The user interface is driven by three kinds of real-time signals: a stream of location coordinates from a real-time GPS receiver chip, roll, pitch and yaw inputs from the digital compass, and a data stream from the gesture interface. These signals partially take the place of keyboard and mouse events. The Battuta system software was developed using Swing and Java Advanced Imaging (JAI) components of the Sun Java 2 development platform. This allowed the support of image processing, gave a rich set of GUI widget components, and provides platform independence for the wearable and other mobile systems. Swing is a Sun Java component set for the creation of graphical user interfaces with a cross-platform look and feel. Swing was also found suitable as an API set for some of the non-conventional GUI elements required for the wearable computer because of its enhanced support for more flexible graphic widgets such as irregular buttons. JAI is an important component for image processing. We found JAI to be cross-platform, device independent, highly interoperable, extensible and powerful enough to meet the requirements of image processing, including encoding and decoding different image formats, input and output, geometric transformations, rendering, color processing, image display and analysis. Coding the GUI required several hundred work hours and even more for debugging and testing. For different applications, and to facilitate usability studies, the system is designed to have alternative visualizations for the image and map data, and to allow the user a large range of choice. There are different factors that control how the geographic data are visualized upon the interface, which falls into two categories: dynamic signals, and user-controlled degrees of freedom. These include zoom, orientation, base map, perspective, egocentric vs. world view, and interaction modes. We have found that map text labeling is especially important, because the text must stay well placed and legible while other map features are moving or rotated, a fact complicated by the aligned menus.

4.THE GUI PROTOTYPE

The user interface design, together with the placement of component devices on the body and their broader potential impact on society, are regarded as three major issues that will determine the future of wearable computing. There has been limited research on interface design for different applications nor is there a user interface specifically designed for the alternative interaction modes used on wearable computers for a geographically oriented system. A wearable GIS system requires the management of multi-source and multi-scale geographic data and their display to the user. In this GUI dynamic visualization and multi-modal interaction are indispensable. If the GUI is too complex, the system will not be used at all. If is is not well-designed, the system will not be used effectively, or indeed be any better than current solutions. If the GUI is effective, it will allow the user full control over the multiple modes of input that the system supports. We have developed a user interface in which the use of pointing devices has been minimized so that the user interface can be controlled with keyboard toggles and alternative selection mechanisms. The view is elliptical, centered in the monocular display, with the peripheral elements reserved for menu choices, in a shallow menu system. Sound has been explored and rejected as an alternative input and control mechanism.

5. CHALLENGES, GENERAL AND SPECIFIC

The original SRI study on wearable computing in 1966 by D. Englebart called for "a new and systematic approach to improving the intellectual effectiveness of the individual human being." Thus augmented intelligence has first been implemented as augmented vision. Only recently has the integration of knowledge elements in real time become possible. Prior work by others has suggested the following design criteria for wearable computers. They should be highly intuitive to the first time user, the interface interaction should be an immersive, fully dimensional experience, the user should feel a sense of presence in the augmented environment, they should be fun, aesthetic and engaging, and should be adaptive to the users identity and experience. Hardware criteria include that the machine should be mobile and wearable, should register and overlay 3D geospatial data with real world views, should include spatialized audio, do rapid positional updates, include user-centric context such as roll pitch and yaw, should store and use a track history, share information through wireless connectivity, be low in cost and be small and lightweight. Today's prototypes only begin to approach this functionality. Thad Starner has laid out the challenges to wearable computing. Starner's ideal system is: persistent (provides constant access to information services); mobile and physically unobtrusive, senses and models its users context; adapts interaction modalities based on context; and augments/mediates interactions with the user's environment. Starner sees the principal challenges as both software and hardware. For the former, there are no studies yet of how to make design trade-offs in wearables, nor is there any appropriate user interface. Difficult hardware problems are power use and consumption, and heat dissipation. To these,we add the problem of human interaction with inadequate systems, especially that of preventing interaction overload, defined as: situations where the information presented to the individual exceeds his or her cognitive capacity. To be of value, these “shut down” situations should be understood and avoided.

6.OPPORTUNITIES

We see short term options for research that include the following elements:

- Porting current software to the emerging COTS systems, such as the Xybernaut Poma
- Integrating gesture into the user interfaces
- Adding sketch capability, perhaps integrated with gestures
- Use of the system for multiple tasks, e.g. Navigation and data entry
- Integrating multimodality into the user interface to study redundant back-up and human preference
- Better integration of WAN into the wireless capabilities