Challenges in Building a Whole Earth 3D Information Space

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Abstract

Mobile and wearable computers will increasingly be able to deliver interactive 3D graphical environments. In the near future, 3D terrain visualizations will be an important class of applications for users of mobile and wearable computers. These visualizations can be used to present additional information about a user's surrounding environment and thus enhance the user's environmental awareness and understanding. Such visualization will be useful in problem domains that require geospatial knowledge and coordination of tasks over large geographic areas. Recent advances in mobile computing hardware, sensing, and networking make such visualization applications feasible. However, a number of areas require further research. In this paper, seven key challenges to designing and building such systems are discussed. This paper seeks to increase interest in such applications, create a dialog centered on those key issues, and engage researchers from the virtual reality field and other communities.

1 Introduction

Humans live in dynamic and often chaotic environments. We use written directions, signs, addresses, and maps to understand and navigate these environments. However, even with these aids, there is much information that is unknown or out of sight. We may not know that a co-worker is three blocks away, eating lunch. We may not know the direction to the nearest transit station, and if we do find the station, we do not easily find or understand the bus schedule. Mobile and wearable computers provide a unique opportunity to assist people in understanding the surrounding environment.

I believe that it is appropriate and helpful to present this information in a dynamic 3D visualization. This visualization would provide a scalable framework of 3D terrain, 3D buildings, satellite phototextures, and road maps. Such visualizations have many advantages since they provide an accurate and easily recognizable model of the environment. Other information would be overlaid on this framework: destinations, routes, locations of friends and co-workers, weather and traffic conditions, etc. A number of tools would allow manipulation of this geospatial data, such as the ability to add annotations or to define notification regions, so that the user is informed when people move, conditions change, or other important events occur. The Situational Visualization project [17] at Georgia Tech is an exploration of technologies and techniques to support these applications. A scenario discussing the potential use of these applications is related below.

> *Sophie walks out of the airport, following signs to the rail station. Her handheld computer connects to a wireless network, finds the transit system server, and displays the arrival time and current position of the next few incoming trains. Judging by the distance to the rail station, she will miss the next train, so she relaxes and slows down her walking pace.*
>
> *Ethan's wearable computer chimes softly. He has set a notification region covering the airport to let him know of Sophie's arrival. As he sits in his hotel room, he brings up a 3D map of the city on the eyeglass display of his wearable computer. He brings up Sophie's location and confirms that she is still quite some distance from the coffee shop. However, he calls up the weather and notices that a line of thunderstorms will arrive in 15 minutes. He decides to leave for the coffee shop now, to avoid being caught in the rain. He walks to the coffee shop, using the 3D city map to find a route, avoiding hills and heavily trafficked streets.*

Such visualizations are also useful in tasks requiring coordination over a large area, such as military, law enforcement, fire fighting, or search and rescue. For example, wearable computer equipped soldiers from the Land Warrior project [19] gained a reputation for never getting lost. They could maintain an awareness of their location and surroundings with a GPS unit and very simple map software. More sophisticated maps could support more sophisticated activities. Fire captains could remain aware of the state and location of their firefighting crews. As search and rescue teams move, ground already covered could be automatically marked.

2 Technology Advances

The world has seen an explosive growth in information due to advances in storage technologies and sensor systems. This has led to a growing cloud of geospatial information that virtually envelops the Earth. This *Infosphere* contains any data that can be assigned a physical location near the Earth's surface, including terrain elevation data, satellite imagery, weather, and even traffic information. A variety of other information also has a geospatial character. For example, the TIGER/Line database can be used to map addresses to

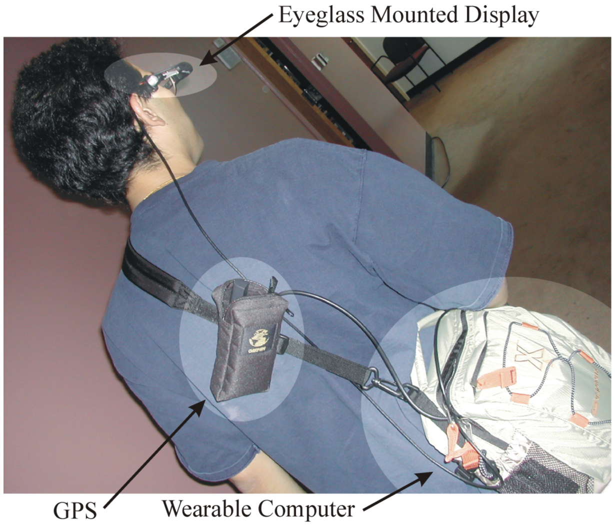

Figure 1: GPS and Wearable Computer

latitude and longitude, turning a phonebook into a form of geospatial data [3]. A growing variety of satellite and terrestrial sensor systems also feed this Infosphere. Future sensor systems could include human wearable sensors, or small, autonomous sensor motes, such as Smart Dust, that could be scattered throughout the environment and left to self-organize into communication networks [13].

Mobile and wearable computing can provide an interface into the Infosphere, changing and enhancing our perception of the environment. A number of key technologies have sufficiently matured to make this vision plausible. The laptop computing market sparked the development of low power processors, higher battery capacity, and portable hard disk storage. A growing interest in 3D gaming is driving mobile and low power 3D graphics. Wireless networking is becoming pervasive with WiFi LAN's and cellular data services like DoCoMo i-Mode in Japan and GPRS, the General Packet Radio Service, in US and European 3G cellular networks. Tracking technologies have also received some new boosts with the shutdown of Selective Availability, which had been used to limit GPS accuracy [5]. Many cellular phone systems can now determine the location of cell phones. While originally done to aid emergency response, cellular carriers now plan to offer other location based services.

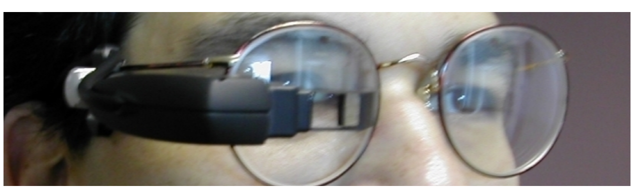

Figure 2: Wearable Eyeglass Mounted Display

3 Challenges

I have identified seven key challenges that should be addressed in order to create this vision of mobile and wearable interaction with the Infosphere. By enumerating these challenges, I wish to focus more discussion on these challenges and engage other researchers in developing mobile and wearable visualization.

1. Tracking
2. Content Creation and Management
3. Scalable Data Organization for Rendering and Access
4. Scalable Server Infrastructure
5. Collaboration
6. Interaction
7. Evaluation

3.1 Tracking

One approach to delivering information about the world is augmented reality, which displays virtual imagery overlaid on physical objects. However, this requires extremely accurate tracking. Combinations of vision-based tracking and sensor fusion techniques may be promising [26]. However, for some applications, highly accurate tracking may not be necessary. For an overhead map view, displayed on a handheld or eyeglass mounted display (Figure 2), the current accuracy of GPS tracking along with simple magnetic or inertial orientation sensors is sufficient. I have also found that providing a detailed terrain phototexture allows the user to compare their surroundings with their displayed position and easily make position corrections [17]. Another open problem is the lack of an integrated approach combining indoor and outdoor tracking. Since different tracking systems are currently used indoors and outdoors, there is no common location description that spans both environments.

3.2 Content Creation and Management

There are a number of research issues in creating and managing content for a 3D geospatial information space. File formats have long been an issue in modeling, virtual reality, and 3D web content. Similar issues will exist in a 3D geospatial information space. A variety of file formats are used to represent terrain, buildings, and other 3D objects. Furthermore, these formats may need modifications to provide variable levels of detail, an important issue for supporting a variety of devices that have different rendering capabilities.

Some work has explored surveying techniques for creating 3D models of buildings and indoor environments using wearable computers [21, 1]. Other work has pursued feature extraction and building model construction from aerial photography using automatic [7] and semiautomatic [25, 24] methods. Elevation data captured by laser, or LIDAR, Light Detection and Ranging, is another information source for building extraction [11]. However, capturing, processing, updating, and archiving such data will present tremendous challenges.

3.3 Scalable Data Organization for Rendering and Access

Most augmented reality and wearable mapping applications are prototypes with limited data sets and limited scalability. They provide environments with a small oasis of rich information and interaction around a particular locale, surrounded by a dataless desert. It is useful to examine visualization systems such as VGIS [8, 9, 10] that can provide a planetary data structure for geospatial information. Such visualizations provide a rich and accurate planetary terrain model, augmented with 3D buildings, locations of users,

Figure 3: A view of Atlanta from an airplane.

Figure 4: A view of Atlanta in the VGIS terrain visualization.

weather, and other information (Figure 4). Real-time navigation of these large databases is achieved through data preprocessing, out of core techniques, and level of detail management. Such techniques are even more important with the comparatively limited memory space and CPU power of mobile platforms.

3.4 Scalable Server Infrastructure

Users will need to access information about particular geographic regions. Since these regions are typically small and localized, it is possible to create a scalable infrastructure where servers and data are distributed geographically. This differs from geographically oriented web-like servers, like WorldBoard [23], which provide a index from location to data, i.e. they map location to particular pages on a single web server. Such data lookup systems do not facilitate division of data between multiple, geographically distributed servers. Also, network traffic will have little geographic localization.

A suggested approach is to provide a geographic server lookup system rather than a geographic data lookup system. There are three parts to this system: users, location servers, and data servers. The

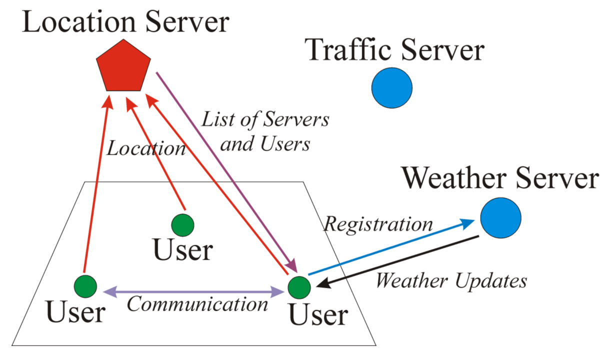

Figure 5: Server Infrastructure

users access information about particular geographic regions. The location servers provide an server address lookup service for geographic regions. The data servers provide specialized information such as weather, traffic, public transit schedules, or building information.

Users first register their position information with a nearby location server. Users will always be referred to the closest location server, which ensures that each location server only keeps track of users in a particular area. Users also send a radius, describing an area for which they want information. The location server will return the IP addresses and positions of other users in that area and IP addresses for data servers with information for that area.

A user may initiate communication with any of the nearby users. They might also register their area of interest with one or more of the information servers. While a user is registered with an information server and continues to give occasional position updates, the information server will provide data updates. Furthermore, if the user moves out of the region for which the current information server has data, the user could be referred to another information server.

3.5 Collaboration

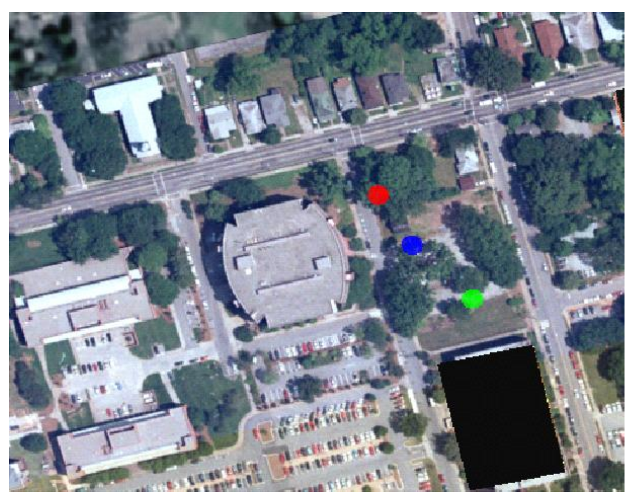

Figure 6: User locations displayed in VGIS.

A related issue is supporting collaboration between users. A variety of interface affordances will be necessary for initiating communication, identifying nearby individuals, and finding individuals who are important, but may not be nearby. If teams of collaborators are formed, it should be easy to see the status of these individuals, identify where they are in relation to the user, send messages and information, and possibly navigate to a rendezvous. Multiple display techniques will be necessary. For example, while users may find it useful to see a geographic representation of potential nearby collaborators (Figure 6), creation of communication channels should not involve chasing a moving user with a mouse.

3.6 Interaction

Figure 7: A multimodal speech and gesture interface

There has been a great deal of research in interaction techniques for small, handheld displays. Some notable examples include multimodal pen and speech interfaces [6, 4, 20] and tiltable displays [22, 2, 12]. However, there are still issues left to investigate. Tiltable display techniques have not been used in extended graphical environments that occupy several orders of magnitude. Furthermore, interaction techniques for eyeglass mounted displays (Figure 2) have not been fully explored. We have been investigating 3D interaction techniques that are appropriate for use with these displays, including analyses of multimodal speech and gesture interfaces [15, 16], and isometric joystick interfaces [14].

Further work needs to be done to develop interfaces that are appropriate for new tasks that mobile 3D visualization provides. For example, applications such as surveying and navigation require "spatial correspondence" affordances, to aid the user in creating alignment or correspondence between a virtual representation and features in the physical world.

3.7 Evaluation

As mobile and wearable visualization applications are developed, evaluation criteria and evaluation techniques will be required. The Situational Visualization project has been focusing on cognitive load and spatial cognition since these directly pertain to 3D terrain visualization applications. Continued exploration of other issues such as fatigue, input and display device placement, and distraction is also necessary.

I have conducted studies in controlled laboratory conditions to see if various interaction techniques and devices have an effect on cognitive load. I also plan to expand this work with studies of long term and expert use. This creates special challenges since these applications will be continuously available to the user, they are used in very naturalistic settings. Developing the means to capture and analyze usage in these complex, natural settings is an important issue [18].

4 Conclusion

An increasing amount of environmental information is being captured, created, and stored. Mobile and wearable computers provide an opportunity to access that geospatial information and enhance a user's experience as they travel through the environment. However, further work is necessary in several key areas to realize this vision.

The virtual environments research community has several strengths that could be useful in addressing these areas. A great deal of VR research has addressed tracking, modeling, network infrastructure, rendering, and interaction. It is my hope that the VR community, along with other research communities, will collaborate and participate in the development of mobile and wearable visualization.

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