Wearable Computing

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What Wearable Augmented Reality Can Do for You

Bruce H. Thomas and Christian Sandor

Imagine you're in a shopping mall trying to meet up with friends. Your sunglasses turn clear and paint virtual arrows on the ground, indicating the direction to walk. As a second example, a fireman has to enter a hospital filled with smoke. His mask displays an outline of the walls and doors, guiding him through the building and showing virtual beacons of patients' locations. Such scenarios will be possible in the near future with wearable computers supporting augmented reality (AR).

This article explores wearable AR concepts, presents applications, and peeks into the near future of its possibilities.

WHAT IS IT?

AR is the ability to superimpose virtual, registered information over a user's view of the real world.[1] Wearable AR[2,3] employs a head-mounted display (HMD), a wearable computer, and a set of sensors to determine the position and orientation of the user's head. As users move their heads, the HMD updates their virtual world view accordingly.

The basic AR process is this:

1. Build a virtual world whose coordinate system is identical with the physical world's (typically using the Universal Transverse Mercator coordinate system, a grid-based method of specifying locations on the Earth's surface).
2. Determine the position and orientation of the user's head.
3. Place the virtual graphics' camera in that position and orientation.
4. Render an image of the physical world on the user's HMD.
5. Render the graphical overlay over the physical-world image.

The most compelling argument for wearable augmented reality is its walk-up and ready-to-use aspect.

Figure 1a depicts an example of a user's view through an HMD. The physical world is the building in the background, and a virtual road, trees, and objects are overlaid onto the user's view. This particular AR scene lets the user view the landscape outside their building in the form of a road and a set of trees. The view of trees changes when the user, who is wearing our Tinmith AR system (see Figure 1b and www.tinmith.net), walks to a new vantage point. Obviously the building stays in the same location; because the road and trees are registered to the physical world, they're also stationary.

Tinmith is based on a modified Toshiba Tecra M5 with a Linux-base Pentium-M 2.0-GHz, 2-Gbyte RAM, Nvidia GeForce 6600 graphics chipset, 802.11 wireless networking, and Bluetooth. The computer is mounted on the back of the belt and has battery power for two to three hours. Headphones are fixed inside the helmet for sound. A GPS antenna (for positioning) and an InterSense InertiaCube3 inertial sensor (for orientation) are mounted on the helmet. The GPS receiver can track the position of the user's head outdoors with a better than 50-cm accuracy. Tinmith has a 640 × 480 pixel, 30-frames-per-second Point Gray Firefly firewire video camera attached to the HMD, which provides visual information about the physical world. The video from the camera is combined with the virtual world through the computing system's graphics card in what's known as "video see-through" AR.

BENEFITS

Having your computing system in a wearable form factor enables hands-free viewing of in situ information that is location based and registered to physical objects. Basic AR provides information about the physical world, and wearable AR lets users view that information in an outdoor setting. For example, a classic use is to visualize a proposed architectural structure, either

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in the context of an existing structure or a location's physical features. The ability to walk in and around the virtual structure lets users experience its size, shape, and feel in first-person perspective and fosters a more emotional engagement with the process.

Another benefit is that users can receive information while performing other simple tasks. For example, using an HMD would let users simultaneously walk and receive simple instructions, assuming that such multitasking was safe. Image processing would be required to understand the background to determine regions that would be best to present the information in terms of color, texture, size, and position on the screen.

Also, a wearable AR system can give users navigation guidance to a particular location in real time. The system can paint virtual arrows on the ground to indicate which way to walk, how far away the destination is, and distances between intermediate waypoints. Because users might not wish to walk while only looking at the ground, the system can also give users audio cues. It can also provide additional information describing any requirements such as locks, doors, or material to be brought to the location.

Wearable AR systems can also use *cueing*—that is, using highlighting and animation to indicate the exact location of an item to be manipulated. For example, the system might say, "Please pick up the indicated box or game piece."

Finally, these systems can give users other virtual information in the form of digital images, 2D diagrams, or 3D graphical objects if that information can help them in their current task. The users should also be able to rotate and scale this information to provide views from various perspectives.

The most compelling argument for wearable AR is its walk-up and ready-to-use aspect: the user receives the information just by looking at the desired artifact.

APPLICATIONS

Researchers have investigated a wide range of applications—medical, military, security, entertainment, navigation, shopping, maintenance, and more—for wearable AR.

This technology also has a place in shopping malls. A range of possibilities are available, such as providing product information, highlighting shopping lists, and answering users' questions about the price of items, as well as finding a destination. Although these seem trivial, a wearable AR system that's lightweight in form, use, and fashion would allow simple but required information to be available in a convenient form. Bluetooth earpieces are becoming more common, so why not sensible wearable displays?

Entertainment is a good candidate for early adoption of wearable AR, as long as the key issues of safety and appropriate playing spaces are resolved. The advent of more physically active games such as the Wii have shown that users want more out of games than just sitting on the sofa. Wearable AR lets users explore new worlds and interact with virtual creatures on a new scale. Although first-person shooter games such as ARQuake[4] and SkyInvaders (see Figure 2) have been the predominant game genre, other genres such as fantasy adventures, puzzles, and real-time strategy games are all good candidates for wearable AR. These types of games let users incorporate the existing physical infrastructure of the world around them. For instance, users operating a wearable AR system in London might try to solve the same or similar crimes as Sherlock Holmes did.

Manufacturing requires far more flexibility today than in the past. For example, auto manufacturers now offer more models with greater levels of customization. Because of the number of possible combinations, each assembly line worker must follow an ever-increasing number of unique operations for individual automobiles. Wearable AR can also be applied to

Figure 1. An example of wearable augmented reality: (a) a user's view through a head-mounted display and (b) a back and front view of our Tinmith system. Using the Tinmith system allows for full 3D rendering of computer-generated content. (photos courtesy of the Wearable Computer Lab, University of South Australia)

WEARABLE COMPUTING

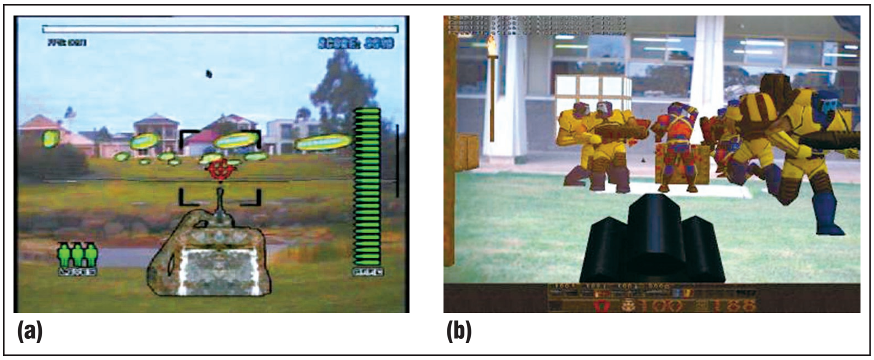

Figure 2. Wearable augmented reality for entertainment. First-person shooter games such as (a) ARQuake and (b) SkyInvaders are a predominant genre in wearable AR gaming systems to date. (photos courtesy of the Wearable Computer Lab, University of South Australia)

help improve industrial order-picking processes.[5] Figure 3a shows a worker equipped with an HMD who must retrieve a given part from a storage area. For obvious reasons, having the correct part retrieved in a timely fashion would improve the efficiency and effectiveness of the overall manufacturing process. In Figure 3b, a virtual outline highlights the box that contains the part she has to pick next.

Wearable AR would be of great help to the medical profession.[6] Doctors, nurses, and emergency medical technicians all have tasks that require high levels of mobility, real-time data monitoring, and physical examinations of patients. New wearable ultrasound devices would enable medical staff to look inside a patient's body (see Figure 3c) in a fully mobile fashion. A hands-free method of visualizing the information makes this form factor ideal for the medical profession.

Another example is depicted in Figures 3d through 3f: helping users navigate their environment by providing virtual "x-ray vision" (the ability to see through layers of objects). In this prototype, running on our Tinmith platform, we overlaid an image-based reconstruction of a remote scene (Figure 3d) on a user's view of the environment (Figure 3e) to provide x-ray vision capabilities (Figure 3f). This will let the user view the scene on the other side of the wall. To provide correct depth cues, we highlighted the edges of foreground objects.

Figure 3. Examples of wearable augmented reality, including (a, b) industrial order fulfillment (photos courtesy of Bjoern Schwerdtfeger); (c) medical uses (photo courtesy of Nassir Navab); and (d-f) x-ray vision for navigation. These figures highlight the breadth and depth of information that can be presented with wearable AR technology.

The current state of the art for wearable AR is custom solutions for industry, military, and entertainment applications. Today's off-the-shelf solutions use ultramobile PCs, but these lack the processing and graphics capabilities of high-end 3D wearable AR systems. A number of companies focus on wrist-mounted computers and displays such as the Zypad. These are suitable for commercial applications such as inventory management or delivery services, but the processing, display, and graphics capabilities aren't ready for wearable AR. The first stepping-stone to wearable AR will be handheld AR: the ubiquitous nature of mobile phones, with their current video and processing capabilities, makes them a good platform for early adoption of simple applications. Although these handheld AR systems won't be able to support the kinds of applications described in this article, simple navigation, entertainment, and information presentation applications will soon be available. It's the hands-free nature of wearable computing that will enable applications in domains such as medicine and the military.

The processing and graphics capabilities of our Tinmith system will be available in these form factors in the near to medium future. In conjunction with WiMax networking, wearable AR will be feasible in a socially acceptable form factor. The major current limitation is an appropriate HMD technology; improvements in size, weight, functionality, and style are required to make this technology fully usable. Today's massive HMDs are aesthetically unappealing and uncomfortable, and one of their major functional limitations is a limited field of view. Several promising technologies, such as laser retinal displays, are on the horizon to address this issue.

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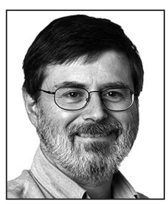

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