# Universal Design: Lessons for Wearable Computing

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When we as developers and designers create a system that requires user interaction—whether it is computer software, a kitchen appliance, or a door knob—we often fall victim to a common mistake: we use ourselves as the model for our system's potential users. Even developing for an "average user" is a pitfall that results in numerous users whose needs are overlooked. The average user might account for the largest spike under a bell curve, but nonaverage users account for a much larger percentage of the general population. Additionally, the number of people possessing all of the average attributes being considered in a design is very small. So, the designers' goal should be to broaden the section of the bell curve that their system targets. This concept is called *universal design*, and it's especially important in wearable computing because using a system while mobile and while in different environments can have a major effect on its usability.

## SIMILARITIES IN MOBILITY AND DISABILITY

Universal design attempts to create products that are as usable as possible by as many people as possible, regardless of age, ability, or situation.[1] Not only are such designs more accessible to people with disabilities, they are also more usable and functional for all users. For example, a system designed for a blind user shares similar attributes with a system designed for a user who is driving a car and cannot look at a screen. A system designed for a deaf user will also be useful to a person using the system in a noisy restaurant. Similarly, a wearable computer user attempting to control a graphical user interface while walking has much in common with an older user with low vision and low dexterity. Special concerns about user limitations exist for wearable devices that will be used in environments that the designer might not anticipate.

## UNIVERSAL DESIGN INSPIRES INNOVATION

The practice of universal design has resulted in many products originally intended for the disabled population that benefit everyone—closed captioning, books on tape, and even the telephone, for example. Conversely, sometimes a product's designers don't anticipate the large market their device will have among the disabled community. The RIM Blackberry, a wireless handheld that can send and receive email and text messages, has become hugely popular in the deaf community because it lets people who might not be able to speak on a cell phone have mobile communication access. In many senses, some of the first wearables were designed for communities with special needs. For example, in 1968 Hubert Upton describes a display in a pair of eyeglasses to aid in lipreading,[2] and in 1977 C.C. Collins describes a tactile system for assisting the blind in finding their way.[3] The "Universal Remote Console Design" and "Mobile One-Way Sign Language Translator" sidebars describe current efforts in creating enabling technology.

## WEARABLES AS UNIVERSAL TRANSLATORS

Although universal design generally tries to accommodate as many different users as possible, making devices that all people can access at all times isn't always possible. Imagine a hypothetical ATM that all users can access regardless of ability. The result would be an unusable device with a cacophony of sounds, graphics, and I/O ranging from eye-tracking to haptics. Another approach, which is particularly interesting to the wearables community, is to have users bring their own tailored interfaces to each public system. This concept is often known as an *alternate user interface* and could take the form of a cell phone, PDA, or wearable computer that lets the user have personalized input, control, and display mechanisms while maintaining an awareness of his or her preferences and characteristics.

A key requirement for realizing these alternative interfaces is a standard protocol that lets the user's control device and the public system communicate. Currently, the International Committee for Information Technology Standards (the V2 committee) is charged with developing a national standard for an Alternative Interface Access Protocol (see www.v2access.org). The AIAP's goal is to complement and build on industry activity in home net-

## WEARABLE COMPUTING

### UNIVERSAL REMOTE CONSOLE DESIGN

Gregg Vanderheiden, director of the Trace Research Institute (www.tracecenter.org) at the University of Wisconsin has advocated universal access to information systems since the early 1990s.[1] When the late Ron Mace, founder and program director for the Center for Universal Design at North Carolina State University, defined universal design in 1991 as "an approach to creating environments and products that are usable by all people to the greatest extent possible,"[2] he had architectural building design in mind. When Vanderheiden joined a national team Mace headed in 1995 to define universal design principles, he already recognized the importance of applying those principles to designing information appliances. Universal design principles were thus conceptualized as fully relevant to designing mass-marketed consumer appliances:

> "*A good universal design is a commercially practical, mass-market design that is usable by and attractive to the maximum possible number and diversity of users—given the best of today's collective knowledge, technologies and materials.*"[3]

Vanderheiden also understood that it was unreasonable to require manufacturers of consumer products—from thermostats to microwave ovens—to design interfaces into each of their products and models that could meet the diverse needs of people with disabilities. Instead, he realized it was more practical to devise a universal remote console that could provide easy access to a wide range of products. Clearly, it was more economical to design one specialized interface that each user could customize to meet his or her needs than to build such an interface into every appliance the person might need or encounter. Of course, to realize this goal, a universal remote communications protocol had to be established. This is now called the V2 standard, and it was designed from the beginning using universal design criteria.

Once V2 is fully established and implemented in consumer products and appliances, universal remote consoles will let most disabled people easily access consumer appliances that would otherwise be inaccessible. So, this one remote control device would let people with disabilities buy and use almost any mass-produced appliance at a mass consumer price, instead of paying two to five times more for specially adapted appliances. Further, if this remote console is small enough to carry in a pocket or purse, it could enable access to information kiosks, Internet kiosks, ATMs, transit system fare machines, and more.

Initially, a Trace research team envisioned a device about the size of a deck of cards but soon realized that constructing a console this size would be difficult. After creating an initial prototype that was somewhat larger, they began focusing more on adapting existing hardware to this purpose. Candidate hardware included palm-top computers, wearable computers, PDAs, and even cell phones. The challenge was to adapt and program this hardware to best meet universal design criteria so that simple and intuitive input and output could occur across multiple disabled populations, and users could adjust the device to best suit their individual abilities. To date, this includes output "displays" that employ large print and enlarged graphic presentation, and speech output. This system has been implemented in an iPAQ Pocket PC. Input controls are still a concern, however, because a person with vision loss cannot effectively use a touch screen, and the navigation buttons on an iPAQ might be difficult for some to use.

Trace Center engineers have more recently developed a prototype remote console voting tablet that better addresses some of these input issues. However, work must still be done in this area. In terms of wearable computers, a research team at the Atlanta Veteran's Administration Rehab Research and Development Center is currently using universal design criteria to develop a wearable computer with both voice and keypad input capability, and speech and tactile output.

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working, wireless networking, and metadata registries for discovery and interoperation of devices. Obviously, implementing this standard will benefit not only persons with disabilities but all users.

#### THE SEVEN PRINCIPLES OF UNIVERSAL DESIGN

The Seven Principles of Universal Design are guidelines developed at the Center for universal design at North Carolina State University in collaboration with a consortium of universal design researchers and practitioners from across the US.[1] These principles can help guide a design process, ensuring not only that the resulting system considers as much of a user population as possible, but also that it incorporates features that will increase the system's general usability. The AIAP standard demonstrates a different approach to universal design, where the target system does not attempt to meet the needs of all users but lets users tailor it to their abilities. So, an interesting exercise is to use the hypothetical design of an AIAP-enabled mobile device to illustrate the Seven Principles of Universal Design.

*1. Equitable use:* The design is useful and marketable to people with diverse abilities. This is an AIAP device's key feature because it can take any form appropriate

# MOBILE ONE-WAY SIGN LANGUAGE TRANSLATOR

For the deaf community in the US, apartment hunting, communicating with a doctor, or even getting directions at the airport can be inconvenient and intimidating. Very few fellow travelers, landlords, or doctors "speak" American Sign Language, which is distinct from English with its own grammar, vocabulary, and visual puns.

One possible way for the deaf to communicate with the hearing is through writing. However, writing limits conversation to around 15 words per minute (both spoken and signed conversations are normally around 150 wpm). Additionally, many native signers have difficulty generating English text because English is a second language for them (recognizing a given English phrase is easier).

Georgia Tech is attempting to create a one-way translator for American Sign Language. The signer is limited to common phrases and queries that require simple responses, such as nodding yes or no, holding up a number of fingers, or pointing. For example, while interacting with a landlord, an apartment seeker might sign the equivalent of "How many bedrooms does the apartment have?" The system translates the utterance to English, shows it to the signer on her display for approval, and then speaks it to the landlord. The landlord then responds by holding up two fingers to indicate that the apartment has two bedrooms.

Figure A shows the current prototype hardware. A camera mounted in the cap's bill watches the signer's hands. Accelerometers worn on wrist bands provide additional features for sign recognition. A CharmIT Pro wearable computer executes the sign recognition software, and the signer views the potential English translations on a MicroOptical head-up display. A speaker in the cap announces the selected English phrase.[1,2]

Our translator is limited in its scope, similar to the tasks addressed by the early speech recognition community. Yet, if we can demonstrate our approach's feasibility, we might interest other researchers in the field.



**Figure A. Prototype of an American Sign Language recognition apparatus.**

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2. T. Starner, J. Weaver, and A. Pentland, "Real-Time American Sign Language Recognition Using Desk and Wearable Computer-Based Video," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol. 20, no. 10, Dec. 1998, pp. 1371–1375.

for the user. One person might have a sophisticated system integrated into his or her wheelchair that uses eye tracking for control, while another might prefer a cell phone with a headset for voice control and audio display. So, all users can access the ideal interface for their needs.

**2. Flexibility in use:** The design accommodates a wide range of individual preferences and abilities. Although users can personalize an AIAP device, designers must still consider flexibility. When interactions will occur in a mobile environment especially, the user's interaction needs could vary, and the device must allow for this flexibility. For example, the user might normally prefer audio display except when he or she has privacy concerns in a crowd. In this case, a dis-crete graphical display of information on a head-mounted display would be preferable.

**3. Simple and intuitive:** The design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level. This principle is the goal of all interactive systems but achieving it can be difficult. A simple and intuitive interface is especially important in a mobile setting, where the user might be focusing on other tasks. Designers must also consider cognitive impairments when developing a device for the disabled population. The designer must be aware of the limitations of memory, recognition, and understanding that can accompany various cognitive disabilities.

**4. Perceptible information:** The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities. For a system to be effective, a user must be able to comprehend its state. Again, in a mobile environment, ensuring that the user is receiving the necessary feedback from the device can be difficult. The user might miss the icon showing an error if he or she is driving a car or concentrating on crossing the street. A common problem with current mobile devices is their reliance on only one output mode for important information, thus making them unusable by people with disabilities. For example, cell phones often rely heavily on visual displays for output and use, making them inaccessible to blind users.
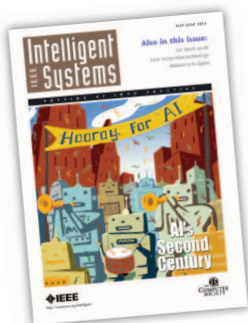
**5. Tolerance for error:** The design minimizes hazards and the adverse consequences of accidental or unintended actions. Designers must always allow for easy recovery or error avoidance in an interactive system. In a mobile environment, error tolerance is even more important because the incidence of error will increase due to environmental factors and changing focus of attention. With the AIAP device, the user might be interacting with critical systems, such as an ATM, where a poor error tolerance could cause serious consequences. The ideal solution keeps the user from making errors by providing a simple and intuitive system, but the system must at least allow for easy recovery from inevitable user mistakes.

**6. Low physical effort:** The design can be used efficiently and comfortably with minimum fatigue. A device's necessary physical requirements certainly factor in when a target user could suffer from impaired dexterity. For example, an elderly user might have trouble depressing buttons that require excessive force. In wearable computing, physical effort is always an issue when devices might require the user to wear equipment or use an interface that can be fatiguing or require excessive strength and dexterity. When designing a product such as an AIAP device, the developer must evaluate the required physical effort for carrying and interacting with the system throughout the day in various situations (carrying groceries, climbing stairs, or walking the dog, for example).

**7. Size and space for approach and use:** The design provides appropriate size and space regardless of users' body size, pos-

ture, or mobility. One problem with trying to make systems such as ATMs accessible to everyone is the size and space issue. Often these public devices are too high for a user in a wheelchair or too low for a tall person, or perhaps the space around the system is difficult for a user with a walker to navigate. Letting users access these public systems from their own portable devices offers an easy solution to the problems induced by system placement and allotted physical space.

The universal design principles we discuss hint at how wearable computers might address disabled populations' needs. At the same time, the seven principles also provide useful guidelines on how wearable computer interface designers can broaden their systems' appeal in the general population. Perhaps if we are very fortunate,

our pursuit of better interfaces will lead to a device with mass appeal, as with Alexander Graham Bell's invention of the telephone while pursuing the concept of a hearing aid for his deaf wife. 🄿

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