An Overview of the International Symposium on Wearable Computers 1998

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Structure and Background of ISWC'98

October 19, 1998: Over 300 attendees converge on the Pittsburgh Sheraton Station Hotel for the annual, two day International Symposium on Wearable Computers (ISWC'98). Registration opens, and a sense of enthusiasm can be felt as researchers greet each other and introduce new members of the community. Academia, industry, commercial vendors, government representatives, and the military mix as the audience forms for the opening session. Since attendees are encouraged to wear their latest wearable computer designs, spontaneous demonstrations already dot the hall. In some cases, the wearable computer is so subtly woven into an attendee's garb that it takes a practiced eye to know to ask for a demonstration. Fortunately, the researchers and, in some cases, independent inventors are proud of the year's accomplishments and seek to elicit the questions, criticisms, and compliments from the community at large.

After a series of academic and commercial workshops, the largest of which was hosted by Boeing in 1996, ISWC premiered in October, 1997 as one of the most successful new conferences in IEEE history. Sponsored by the IEEE Computer Society Task Force on Wearable Information Systems in cooperation with ACM SIGMOBILE, ISWC'98 provides a formal, refereed forum with a published proceedings for those interested in the difficulties and potential for placing computation on the body. ``Wearable computing forces us to not only address the substantial engineering challenges, but also the social and design challenges of how we make devices and information improve, not degrade, our quality of life," states the message from the program chair, Randy Pausch. The message from the general chair, Alex Pentland, presents the goal of ``improving intelligence ... by augmenting the items we wear all the time: glasses, wristwatches, clothes, and shoes." Paging through the conference digest shows the diversity of the wearables community, with paper presentations on augmented reality, power harvesting, design, recovering user context, wireless displays, and case studies, including one from a large commercial implementation. In order to properly review the submissions, the conference adopted the reviewing style of SIGGRAPH and UIST, calling on the skills of over 50 additional reviewers to supplement the nine person program committee. In addition to the paper sessions, ISWC'98 consists of invited talks, poster presentations, paper sessions, an exhibition hall, and a panel session on privacy. As a ``bonus" third day to the official two day track, Carnegie Mellon University offers special events and an insider's tour of their research laboratories, following a tradition started by last year's host, MIT.

While the attendees settle in for the opening remarks, a surprise greets them as they scan the proceedings. Previously unpublished details on what is probably the first wearable computer, constructed by Edward O. Thorp and Claude Shannon in 1961, are presented in an invited paper. Designed to predict roulette, the cigarette pack-sized machine yielded an expected gain of 44 percent when betting on the most favored octant of the wheel. Unfortunately, minor hardware problems prevented sustained serious betting when used by the Shannons and Thorps in a Las Vegas casino. [1]

Contextual Awareness

During the first sessions, context and collaboration become the dominant themes in this year's conference. By locating computation on the body, wearable computing provides a unique potential for sensing the user and the surrounding environment. The recovered data enables new interface techniques and allows the interactive construction of augmented realities where ``virtual" information is situated in the context of the physical world. As an example, Jun Rekimoto of Sony Computer Science Labs demonstrates an ``Augment-able Reality" where colleagues leave virtual annotations for each other in the workplace. Infrared beacons inform the wearable computer of its real world location, and the wearable gathers any messages associated with that location through a wireless network. Appropriate messages appear in the wearer's head-up display (HUD). For example, if a desktop user changes the location of a meeting, he may leave a virtual message at the old room through the use an email or web interface. Thus, when a wearable computer user enters the old room, the message appears in the user's field of view indicating the new location of the meeting. In addition to sensing location, the wearable computer senses individual objects through infrared beacons or through a two dimensional printed identification code recognized by a video camera mounted on the HUD. Wearable computer users use these anchors to attach voice or image annotations to the objects through a hand-held, mouse-driven interface. These techniques demonstrate situated communication by combining digital and physical spaces in a manner accessible to both desktop and wearable users.

As the first sessions continue, several presentations demonstrate novel methods of gathering and utilizing user context. Thad Starner presents the DUCK! system which recognizes user actions and location through two small head-mounted cameras: one looking forward and one looking down towards the wearer's hands and feet. By monitoring color and luminance changes in the floor's surface, the view ahead, and lighting off known surfaces, the system determines the location of the wearer through previously trained hidden Markov models (HMM's). Using a method established by Bernt Schiele together with HMM's, the system infers user actions from recognized hand gestures. Similarly, Brian Clarkson uses HMM's to infer if the user is in a conversation based on the ambient sound environment; this information allows the wearable to determine if the user can be interrupted for a message. Jennifer Healey demonstrates ``StartleCam," which represents a completely different class of context, that of the user's physiological state. This wearable computer system monitors skin conductivity changes to identify when a user is surprised, triggering an electronic camera to take a picture automatically whenever such events occur. On a more global scale, Bruce Thomas presents the ``map-in-the-hat" system which uses a differential global positioning system (GPS), digital compass, and HUD to provide an outdoor navigational aid. While these papers and posters are quite diverse in their specifics, they all hint at the more intimate and immediate interfaces made possible by wearable computing.

Presentations by Gerd Korteum and Jason Pascoe emphasize that context aware applications require a new type of software infrastructure. Particular locations or objects may be associated with entire software applications or environmental sensors instead of just visual or audio annotations. In addition, such applications, information, and sensors might be accessed locally or remotely. Managing such resources requires a common architecture - an object-oriented object system for lack of a better term. Kortuem demonstrates a service discovery and binding mechanism that allows a wearable computer to download and run the client portion of an application associated with a particular object or location dynamically. Kortuem also addresses some of the caching issues for such services. Similarly, Jason Pascoe introduces his work-in-progress, the Contextual Information Service, which maintains a dynamic model of contextual information, providing a common access medium to the current context for any program, service, or user that is associated with the wearable computer. Pascoe develops his points by referring to his experiences with an electronic assistant for ecologists studying giraffes in a Kenyan game reserve.

Collaboration

Wearable computers enable new types of remote and face-to-face collaboration. As collaboration tools become more common on the desktop, some of those same tools can be adopted for wearable computers to support collaboration with mobile colleagues. For example, Martin Bauer describes the NETMAN project that uses Microsoft's NetMeeting to enable a remote expert to see through the head-mounted camera of a local wearable computer user. The NETMAN system supports the collaboration functions of remote awareness, remote presence, remote presentation, remote pointing, and remote sensing. In addition to the camera and microphone, NETMAN uses infrared sensors for detecting user location, an iButton electronic tag scanner for object identification, and a packet sniffer for measuring network traffic. With this equipment, a remote expert assists a wearable user in network system administration tasks as they roam about campus buildings. Asim Smailagic from CMU presents a similar system developed for collaborative maintenance of the Adtranz light rail system at Pittsburgh International Airport. Using a wireless network, engineers collaboratively view and annotate documents, talk to each other using internet telephony, and share images taken with a Connectix Quickcam. In addition, CMU presents the Mobile Inspection Assistant (MIA) that helps bridge inspectors collect multimedia in the field to produce inspection reports.

Li-Te Cheng presents a paper showing how head-mounted cameras can be used for collaboration. With this system, images from a field worker's head worn camera form a high field-of-view image mosaic which a remote expert views and uses to annotate the worker's environment. Thus, the

1. *footnote{Those interested in reproducing this experiment should know that the 1985 Nevada devices law was signed as an emergency measure to prevent the use of such gambling aids.}*

remote expert can annotate the remote environment regardless of the current viewpoint of the worker in the field. Precise registration and calibration ensure that the annotations appear locked to real world locations when the worker turns to the annotated part of his environment; however, since the system is image-based, the user cannot move objects in the real world and expect the annotations follow.

Wearable computers can provide spatial audio and visual cues to aid collaboration. Mark Billinghurst describes work from the University of Washington and British Telecom on a wearable spatial conferencing space. This system provides spatialized three-dimensional graphics and audio cues to help identify and track the participants in an augmented reality communication space. Audio-enabled avatars of the remote collaborators surround the user in the virtual space. Through spatial cues and a sense of place, the system can support representations of dozens of simultaneous participants, providing a distinct advantage over current multi-party phone or video conferences.

Usability Studies, Design, and Interface

Commercial wearable computers demand careful attention to ergonomics, usability, and robust design to be successful. Stephen Ferrero discusses Symbol's efforts in developing the WSS-1000 wrist worn barcode scanner and computer. More than 30,000 WSS-1000 computers have been sold by Symbol to package handling and inventory companies such as UPS. In order to achieve this success Symbol spent almost 10 million dollars in research and development, including over 50,000 hours in user tests. In Ferrero's view, ergonomics is the biggest challenge, referring to the many tables summarizing the results from their usability testing. In addition, units that perform well in the laboratory are broken in the harsh conditions of field trials, and components require many design iterations. For example, the sleeve that holds the computer required 50 iterations, while the battery clips required 15 attempts. Once the device is developed there may be significant user resistance to overcome. In this case, allowing users to work with the previous hand held scanners solves the problem as they realize the huge comfort and performance improvements of the wearable version.

The paper ``Design for Wearability" by Francine Gemperle and others from CMU's Institute for Complex Engineered Systems further emphasizes the importance of ergonomics. Current body worn devices are not typically designed for wearability. For example, pagers and cell phones protrude from the body and have inorganic and rigid forms. To address this issue, the paper describes 13 guidelines for designing wearable devices, including unobtrusive placement, using a humanistic form language, accounting for size variation, accessibility, and aesthetics. In addition, their studies show the most unobtrusive areas of the body for placing wearable components, and their prototype wearable form shows their design principles in practice. A CD-ROM containing the group's findings will be made available in 1999.

Jennifer Ockerman's ``Preliminary Investigation of Wearable Computers for Task Guidance in Aircraft Inspection" distinguishes between situations where instructions are followed verbatim, such as a piloting reviewing a complete checklist of discrete possible failures, and situations where higher-level awareness and evaluation are necessary, such as a pilot survey to find rare or undocumented failures. She suggests that current interfaces are well suited for the former but require more work to encourage independent thought for the later.

Over the two days of the conference, the sessions cover a wide gamut of wearable input and output devices. Steven Lewis reports on Honeywell's development of innovative displays for the military. A 53 Mbit/sec wireless radio link drives their 16 color, 640x480 pixel, forearm mounted display, which is viewed through an eye cup similar to a camcorder viewfinder. While the display is meant to be coupled with a waist mounted computer, it can be driven from any VGA-equipped computer up to fifteen feet away. Another variant incorporates a 486-based computer with four PCMCIA slots and a see-through display in a pair of binoculars.

Steve Mann shares his experience with designing and using wearable cameras. Mann discusses the desireable traits of an optimal apparatus, details current constraints, and provides lessons from using wearable cameras for informal, lived experiments. He discusses how to align cameras and displays such that the view of the camera matches that of the eye. Continuing on this track, Mann reveals how to design a two camera, foveated view recording and display system.

Nitin Sawhney's Nomadic Radio paper presents an interface design for an audio only wearable computer. Nomadic Radio uses speech input and output from pre-recorded audio and synthesized speech to enable a user to access remote information and communication services. Spatialized audio assists the user in browsing and scanning messages, while ambient auditory cues indicate system events, such are the arrival of new email or voice mail. The system tailors the number and presentation method of notification messages according to usage, ranging from highly obtrusive voice messages to barely noticeable ambient cues.

Marshal Linder of Lifecor presents an invited talk detailing the design issues of ``Wearable Defibrillators." These devices monitor the heart status of an active, mobile patient and, if need arises, provides an electrical shock to correct life-threatening muscle spasms in the heart. Dave Akin of the University of Maryland provides yet another extreme in designing wearable computers in his invited talk on ``The Design of Astronauts' Spacesuits." With the proposed mission to Mars, more human monitoring, power assist, and telepresence capabilities are planned for future spacesuits, which raises many practical design and interface issues for handling such harsh environments. Lieutenant Colonel Bob Serino furnishes yet another dimension to the design space by describing ``The Army Soldier Project." The United States military has long been a driving force in mobile technology to support the vision of superior information transfer on the battlefield to lift the ``fog of war." Wearables provide the most immediate front-line component of that vision.

Several posters announce work on control and feedback for wearable computers. Robert Rosenberg presents a prototype cursor control system using bioelectric control, and Aaron Toney shows a joint motion sensing system using a glove outfitted with air pressure sensors. Addressing the navigational needs of the visually impaired, Jennie Sharf shows her ultrasonic and pyroelectric sensor aid which can help locate and distinguish between animate and inanimate objects, and Sevgi Ertan and others at the MIT Media Laboratory describe their wearable tactile display system, consisting of a 4-by-4 array of micromotors mounted across the back in a vest. This display system indicates directions for travel by vibrating the motors in pre-defined patterns to create illusions of moving contact across the back.

Overcoming physical and network limitations

Due to their size, mobility, proximity to the body, and the need for continuous availability, wearable computers challenge conventional computer designs. Joseph Paradiso describes and contrasts three working prototypes for generating power from the user's walking in an effort to lessen electronics' dependency on batteries. While the conversion and recovery efficiency can be improved for each device, the current generators produce from 1 to 250 milliwatts of power on average and are shown driving hand-held radios and identification transmitters. Another challenge for many mobile computers is heat dissipation. Thad Starner suggests several novel methods of heat management and describes the potential advantages of coupling the device to the user.

In his invited talk, Carl Waldspurger of Compaq/DEC describes the Itsy research platform, which tries to avoid both the heat and power problems with its low power usage. Running Linux and X, the Itsy provides full desktop capability in the size of a pack of cards with only two AAA batteries for power. Features include a 200MHz StrongArm processor, 16MB RAM, LCD panel on one side, audio CODEC, microphone, speaker, IrDA and serial ports, and an open architecture for adding daughterboards. Demonstrations include speech recognition, displaying real-time MPEGs, and playing the video game ``Doom" using a tilt sensor daughterboard.

Many mobile applications require communication with companion devices in the environment or current computer networks. In an invited talk, Dalibor Vrsalvic, Senior Vice President at AT&T, detailed his company's interest in creating an open IP service software platform called GeoPlex to address issues of authenticity, authority, and ownership in networking. Such issues will become critical as AT&T invests in mobile hardware platforms which allow personal and location-aware authoring and retention of data. In the poster session, Jie Yang describes a prototype system which dynamically selects its network service based on cost and performance requirements. In addition, Yang illustrates how multimedia applications can be decomposed so that processing is shared between the mobile and remote device based on current network bandwidth. For more fine-scale networking, Philip Neaves describes the benefits of near-field radio. These wireless links have low transmit power, well defined reception range, 0.3 Mbit/sec - 1 Mbit/sec bandwidth, and are license exempt. Such characteristics enable socially graceful peripherals for wearables, such as a companion flat panel display which becomes active when the user grasps it or a digital camera that, when used, automatically downloads images to the wearable.

A quick trip through the vendors

One of the pleasures of ISWC is visiting the growing number of vendors. Unfortunately, space permits only the most cursory glance of current and upcoming products on display. Boeing, through its recently acquired McDonnell Douglas section, displays its concept for a wearable with distributed modules connected via a 1394 bus. The core processing module will contain four 250MHz StrongArm processors. Via shows its Via 3, an upcoming belt-sized and shaped wearable computer. Interactive Solutions shows its Mentis wearable that provides informational assistance with automotive repair. HandyKey unveils an updated version of its one-handed, chording keyboard and mouse, the Twiddler 2. Improvements include a wireless connection, a mini-joystick mouse, and the ability to connect to keyboard, mouse, or USB ports. Finally, a quick detour to the MicroOptical booth again reveals why this company is causing a stir with displays incorporated into pairs of normal-looking eyeglasses.

Privacy, Wearable Computers, and Recording Technology

The afternoon of the second day brings the Privacy Panel, organized by Henry Strub and Kim Johnson of Interval. Members include Anita Allen, Victoria Bellotti, and Thad Starner. The panel addresses the growing concerns that current and upcoming consumer-grade technology may be used to observe and record people's actions in both public and private life.

Strub provides an introduction and asks if an individual ``owns" his own image or what he says. How does an individual know when he is recorded? Strub also makes the point that, once data is recorded, intentions towards that data can change days or even years afterwards. Allen, drawing from her recent book on privacy cases, provides perspectives from history and the law in defining physical, informational, proprietary, and decisional privacy. Taking questions from the audience, Allen notes that broadly-worded state torts are often the only recourse in privacy cases currently. Bellotti and Starner provide perspectives from ``lived experiments," ubiquitous computing use at Xerox Parc and Europarc and the wearable computing community at MIT, respectively. Social expectations and feedback on the use of a new technology are a reoccurring theme in the presentations. For a new sensor or communication system to be accepted, the users must know who can connect to the sensors and what can be done with the data. Bellotti suggests that the intended functionality might be made clear in the design and affordances of the system. Starner proposes that, instead of concentrating sensors in the environment, most desired functions can be achieved with purely on-body infrastructure, in which each user explicitly controls the information that is recorded and made available to the world. While the panel gives no final answers, it highlights some of the issues and points to resources for further study.

The future

As the conference finishes, several organizers gather to share their impressions and begin planning for next year's conference in the San Francisco area. The general perception is that the presentation quality at ISWC'98 was high and that the proceedings provide a benchmark for progress. In addition, the organizers feel that the annual conference and small workshops, such as the ones organized for CHI'97 and VRAIS'98, provide a real sense of community and openness for the field. However, the wearables community feels the need for continued support from its HCI contingent, especially internationally, as the conference continues to define itself. As part of this process, the authors encourage the reader to visit http://iswc.gatech.edu, where the ISWC call for papers resides as well as on-line video and pointers to the proceedings from this year's sessions. We look forward to seeing you at ISWC'99!

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Thad Starner, an Assistant Professor at Georgia Tech, is known for his preference for using his wearable computer over his desktop for everyday tasks - including authoring this report.

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