Wearable Communities: Augmenting Social Networks with Wearable Computers

Wearable communities—social networks based on computer-augmented face-to-face encounters—present both social and technical design challenges. Our WearCom design methodology permits rapid prototyping of wearable community systems to facilitate community building.

Gerd Kortuem
Lancaster University

Zary Segall
University of Oregon

Wearable computers enhance personal computing with continuously worn, intelligent assistants that augment memory, intellect, creativity, communication, and physical senses.[1–3] As wearable computing technology pervades our daily lives, we must ask how it influences social behavior. Will it merely make people "smarter" by providing seamless, context-aware access to information, or will it also enrich their social interactions?

To advance the wearable computing paradigm for personal computing, we must carefully consider this technology's social mechanisms, potential, and constraints. Some important research questions we must consider include

- What social potentials do wearable computers have?
- What system requirements and characteristics will realize these potentials?
- How can we systematically and effectively build such systems?
- What are this technology's social impacts?

The preliminary state of wearable computing technology and the low number of systems in active use keeps us from satisfactorily answering all these questions. To advance the wearable computing paradigm, however, we must start investigating these issues and develop a socially acceptable vision of wearable computing. This article presents a framework for wearable technology support for social networks. Our WearCom wearable community design methodology facilitates application creation and provides a framework for investigating the social and technical issues involved.

Wearable communities

We use the research framework of computer-mediated communities[4–6] to investigate wearable computers' social potential. *Wearable communities* denote the social networks that might emerge when enough people use wearable computing technology throughout their daily lives.[7] Using a particular technology, namely wearable computers, defines such a community just as Internet use defines an online community. Like online communities, wearable communities are multiparty conversations organized around affinities and shared interests, bringing together people who don't necessarily know each other personally. Unlike online communities, however, they are based on embodied, real-world human encounters augmented by wearable computers.

The combination of wearable computing devices and wireless personal area networks presents interesting opportunities.[8] WPANs such as Bluetooth enable seamless ad hoc communication over short-range radio links (up to 10 meters) and let people's wearable computers communicate during face-to-face encounters. This permits new forms of spontaneous social interactions among collocated people.

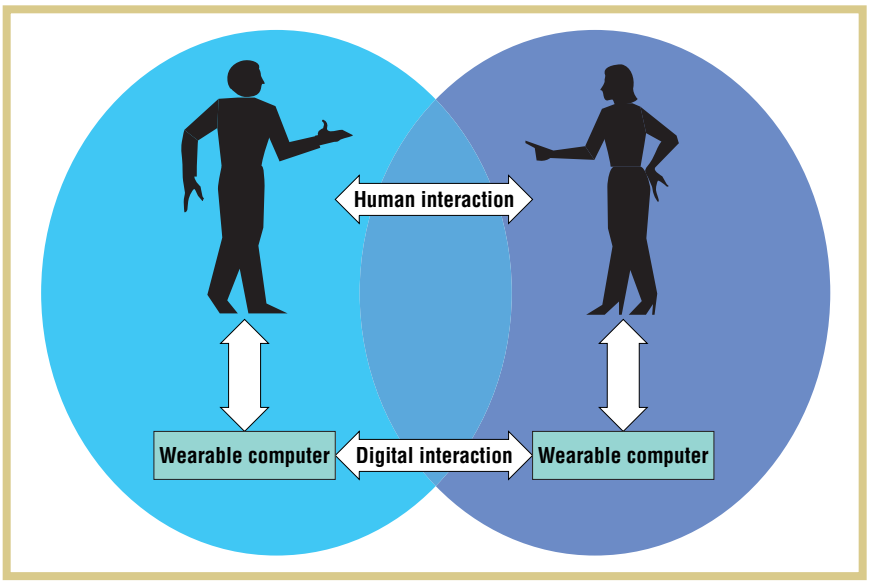


Figure 1. Augmenting social space with wearable computers.

Unfortunately, wearable computing research generally ignores the crucial interplay between technology and social behavior. Current systems and applications emphasize intellectual and sensory capabilities over interpersonal interactions and social competence. The danger of this trend is that wearable systems may end up inhibiting interaction. We'll eventually overcome some of the potentially negative social implications that stem from their current state (such as bulky head-mounted displays), but others are inherent to the wearable computing paradigm. By attending to the device and the information it presents them, wearable users have less time and attention to offer people nearby. Such behavior can negatively influence outsiders' views of wearable computers and their use.

Augmenting social space

The idea of wearable communities is based on the notion of *augmented social space*, where WPANs generate a sphere-like digital field that envelops a wearable computer and its user (see Figure 1). Social space defines the space in which humans interact. Edward Hall suggests four distinct interpersonal communication proximity levels—*intimate*, *personal*, *social*, and *public* space[9]—each defining a region around the body with invisible boundaries determined by the body's spatial characteristics, cultural conditions, and social relationships. Touch happens in intimate space, conversation in personal space. Groups of people set up social distances, usually 10 feet or less; public space extends beyond this.

Information broadcast by the wearable computer fills a *digital social space* whose size depends on the wireless transceivers' transmission range and can range from a few inches to several feet. The human eye can't see the digital field, but the wearable computers can. When two computers' digital social spaces overlap, they become aware of each other. We see the digital field as the alter ego of human social space: just as the concept of social space describes factors that influence interpersonal activities, the concept of digital social space describes factors that influence interactions between wearable devices. Interactions in the social realm can initiate interactions in the digital realm, and vice versa.

Based on the notion of augmented social space, we define a wearable community as a social network that people create or maintain using wearable computing devices. A collection of users becomes a community when enough people use their wearable computers to form webs of personal relationships. This notion of wearable communities acknowledges and is based on the unique value of random encounters and face-to-face interactions. We believe community building depends on fully embodied "human moments." While the Internet and online communities have separated physical place and social space, our work on wearable communities tries to reunite them—rather than replacing face-to-face interactions, we intend to augment them.

For example, when two people conversing exchange electronic business cards between their PCs, social interaction leads to digital interaction. On the other hand, interactions between wearable devices can facilitate or even augment social interactions. For example, wearable computers can inform their users about another person's presence nearby, autonomously exchange information, quietly gather information about encounters, or suggest a conversation topic of mutual interest. They might even speculate and inform the user about affinity relationships from repeated encounters.[10]

Applications

To illustrate the interactions that might take place within a wearable community, we describe several implemented applications.

Genie. We designed this simple application to improve knowledge exchange within a dispersed group of wearable computer users—for example, students attending the same college. Genie makes the group's combined expertise available to every group member. Some might be soccer experts, others might be hobby gardeners with extensive horticultural knowledge; but someone who needs to answer a particular question often doesn't know who can help them. Genie members use their WPAN-equipped wearable computers to automatically find fellow community members who can provide just-in-time expertise.

Using Genie, each user defines a set of questions that are stored on the wearable device. Whenever two or more wearable users meet, their computers exchange questions. This might happen during informal chance encounters occurring throughout a day, for example, during lunch or at a coffee shop. After receiving a question, the device displays the question and asks the

user whether he or she knows the answer and is willing to provide it to the other user. Genie relays the response from one computer to the other in real time. The system transmits only an indication of a person's willingness to engage in a conversation, not the answer itself. After a successful exchange, the users can approach each other and discuss the topic of interest face to face. To help users identify each other, the computers also exchange personal information such as user names or photos.

Although simple in many respects, this example illustrates many important aspects of wearable communities. First, interactions in wearable communities are *situated* and involve a rich *social context*: users are aware of whom they are interacting with and thus can observe important social cues such as sex, appearance, and gestures. The addition of social context shapes people's willingness to engage with strangers and the particular manner in which they interact.

Second, wearable communities may or may not be built on top of existing social networks. In particular, wearable communities can facilitate face-to-face interactions between strangers. The only prerequisite for a wearable community is a group of wearable users willing to cooperate through automated interactions of their respective wearable computers, regardless of preexisting social ties.

Third, you cannot implement wearable community applications with traditional mobile devices such as laptops and PDAs. They require devices that are

- *Constant*: always on and running
- *Presence-aware*: aware of the presence of nearby devices and people
- *Communicative*: able to communicate with other collocated devices
- *Proactive*: able to perform tasks autonomously and proactively without requiring explicit user intervention (although interactivity might also be supported)

This definition is consistent with previous definitions of wearable computers[1–3,11] but adds important functional requirements. Specifically, it emphasizes the ability to communicate with nearby devices and replaces a generic *context awareness* with a more specific *presence awareness*.

Other examples. Genie is a simple application that encourages direct, face-to-face interaction. We have also built several applications in which digital interactions occur implicitly—that is, without users' knowledge but with their consent.

The Piraté collaborative music guide[12] borrows ideas from peer-to-peer file-sharing applications such as Napster and moves them to the wearable domain. Piraté lets users exchange MP3 playlists and music recommendations during brief random encounters. Serendipitously exchanging and accumulating information throughout the day helps users discover new music based on the playing habits of those they meet most often, provides awareness of the community's favorite music titles, and lets users discover with whom they share a common taste in music. In contrast to Genie, members of the Piraté community do not engage in direct face-to-face interactions: exchanges occur implicitly whenever two or more people come physically close. Users aren't aware of interactions between their wearable computers.

The WALID (Wearable Augmented Task-List Interchange Device) community application digitizes the timeworn tradition of borrowing butter from your neighbor.[7] You help others because you know that one day they will return the favor. With WALID, two people use their wearable devices during random encounters to negotiate and exchange real-world tasks, such as dropping off someone's dry cleaning, buying stamps at the post office, or returning a library book. WALID uses personal-agent software to find nearby community members and negotiate the exchange of favors. The agents maintain a user's task list, becoming fully aware of the locations and activities involved. When an encounter occurs, the agents produce a negotiation. If both users approve, a deal is struck. In a negotiation, the agent evaluates the value of favors and keeps scores: having to run across town just to drop off someone's mail compares unfavorably with buying milk for someone if the grocery store is just a block away. Agents employ ideas from game theory to ensure that negotiation results are mutually beneficial: they cooperate only if doing so enhances the users' goals.

> The notion of wearable communities acknowledges and builds on the unique value of random encounters and face-to-face interactions.

We envision many other wearable communities:

- *Computing communities*: Members share computational resources such as network bandwidth and computing cycles.
- *Helper communities*: Members pledge to assist each other when in distress.
- *Bargain-hunter communities*: Members collectively search out sale items in local stores.
- *Marketplace communities*: People exchange goods without money.
- *Job market communities*: Free applications offer services to passersby.
- *Knowledge communities*: Members collectively accumulate information to create shared understanding.
- *Political communities*: Members create new forms of instant democracy and local activism.

From online to wearable communities

Wearable communities have precursors in other types of computer-mediated communities. One of the most powerful features of today's Internet is its ability to enable total strangers to interact on a personal and sometimes even intimate level. People who have never met (and are unlikely to ever do so) use the Internet to discuss personal matters related to health,

Supporting Face-to-Face Communication

The notion of wearable communities defines a research framework for investigating computer support for face-to-face social interactions. Such interactions are often spontaneous (driven by chance encounters of mobile people) and situated (embedded in the real-world context in which people interact). Several recently developed systems support such interactions. These include match-making technologies (LoveGety[1]), awareness devices to give roaming groups a sense of connectedness (HummingBird[2]), ad hoc games that incorporate real-world group mobility into digital entertainment (Pirates,[3] Pervasive Clue[4]), systems for education and exploratory learning (Geney[5]), collaborative augmented-reality systems,[6] and messaging devices that adopt "word-of-mouth" metaphors for proximity-based information passing (ThinkingTags,[7] MemeTags,[8] iBalls[9]).

These systems represent important precursors of wearable community systems, yet key questions remain unexplored. First, except for Richard Borovoy,[8] few have investigated this technology's social implications over time. Most systems are one-off prototypes that have seen little or no real deployment, so we don't really know how augmenting face-to-face interactions affects personal relationships and communal behavior. Second, we have no systematic engineering process for such systems. Developers have no infrastructures or tools to leverage but must build each system from the ground up, in a manner dictated by the underlying network technology and device platform. Many systems thus have a limited feature set and cannot evolve to accommodate design changes.

REFERENCES

1. CNN, *Japan's Lonely Hearts Find Each Other with "Lovegety,"* www6.cnn.com/WORLD/asiapcf/9806/07/fringe/japan.lovegety.
2. L.E. Holmquist, F. Jennica, and J. Wigström, "Supporting Group Collaboration with Interpersonal Awareness Devices," *Personal Technologies*, vol. 3, no. 1, 1999, pp. 13–21.
3. S. Björk et al., "Pirates! Using the Physical World as a Game Board," *Proc. 8th IFIP TC.13 Conf. Human-Computer Interaction* (Interact 2001), Laxenburg, Austria, 2001; http://viktoria.informatik.gu.se/groups/play/publications/2001/pirates.interact.pdf.
4. J. Schneider and G. Kortuem, "How to Host a Pervasive Game: Supporting Face-to-Face Interactions in Live-Action Roleplaying," *Proc. Ubicomp 2001 Workshop Designing Ubiquitous Computing Games*, 2001; http://www.cs.uoregon.edu/research/wearables/Papers/how2host.pdf.
5. A. Danesh et al., "Geney: Designing a Collaborative Activity for the Palm Handheld Computer," *Proc. Conf. Human Factors in Computing Systems* (CHI 2001), ACM Press, New York, 2001.
6. M. Billinghurst et al., "Experiments with Face-to-Face Collaborative AR Interfaces," *Virtual Reality J.*, vol. 4, no. 2, 2002.
7. R. Borovoy et al., "Things that Blink: Computationally Augmented Name Tags," *IBM Systems J.*, vol. 35, nos. 3 and 4, 1996; www.research.ibm.com/journal/sj/mit/sectionc/borovoy.html.
8. R. Borovoy et al., "Meme Tags and Community Mirrors: Moving from Conferences to Collaboration," *Proc. ACM Conf. Computer Supported Cooperative Work* (CSCW'98), ACM Press, New York, 1998, p. 159.
9. R. Borovoy et al., "Folk Computing: Revisiting Oral Tradition as a Scaffold for Co-Present Communities, *Proc. Conf. Human Factors in Computing Systems*, 2001; http://web.media.mit.edu/~borovoy/papers/folk-computing.pdf.

raising kids, romance, and many other topics of shared interest. In effect, the Internet provides the connectivity for the "global information community" that J.C.R. Licklider envisioned in 1968 as being "not of common location, but of common interest."[13] Howard Rheingold, who coined the term "virtual community,"[14] described the Internet as a place that enables a new type of social network, mediated by computer terminals and networks. He defined virtual communities as "social aggregations that emerge from the Internet when enough people carry on public discussions long enough and with sufficient human feeling to form webs of personal relationships."

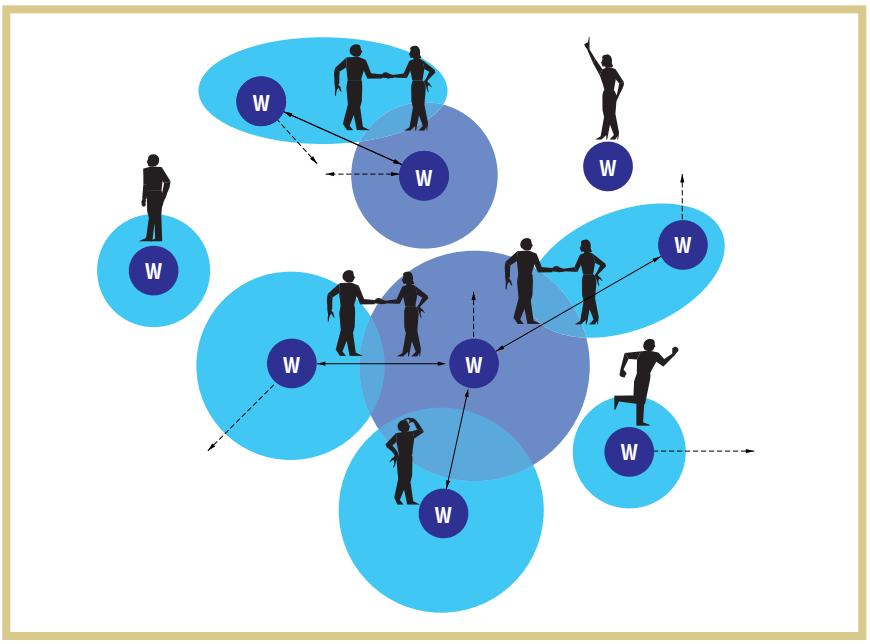
Technologies such as mobile phones and Internet-enabled PDAs have begun to extend online communities' reach to mobile users. For example, online community sites such as eBay give users access to community tools from their mobile devices, letting members stay in touch with their community at any time from any place. Also, *mobile communities* are proliferating in which interactions between members happen exclusively with mobile devices (mostly through SMS messages and mobile phones). Examples of mobile communities include Upoc, mopilot, and cosmiccupid.

Despite their widespread and successful adoption, however, mobile phones and Internet-enabled PDAs have serious flaws as enablers of new communities. They don't support many-to-many communication very well and don't facilitate random encounters (either virtual or real). Consequently, it is difficult to create new relationships using mobile phones. Moreover, the use of traditional mobile devices can potentially decrease real-world random encounters and face-to-face interactions: by attending to people located elsewhere, mobile users possibly reduce the amount of time and attention they pay to strangers nearby. These factors make current mobile technologies well suited for maintaining existing community relationships but less apt at creating new ones.

How wearable communities differ

Like online and mobile communities, wearable communities consist of webs of relationships that grow from computer-augmented social interactions. (See the sidebar "Supporting Face-to-Face Communication" for current wearable com-

Figure 2. A wearable community system.



munity examples.) They differ from traditional online communities, however, in three important ways:

- *Social context*. Wearable communities are based on direct encounters rather than indirect, remote interactions. WPAN exchanges must occur over short distances—when people come face to face or are at least within close physical proximity. Communication partners thus can usually see whom they're interacting with and observe such important social cues as gender, clothing, and gestures. They might even be able to talk to each other. The addition of social context shapes people's willingness to engage with strangers and how they interact.
- *Usage context*. People use wearable devices in different contexts than they use stationary computers at home or work. User attention becomes scarce because, instead of sitting in front of a computer where they can pay full attention to the computer and its operation, wearable computer users also engage in real-world tasks such as driving, operating a machine, or simply conversing with other people. Time also becomes a critical resource—when surfing the Internet at home or at work, people have more patience with delays because they can shift their attention to another task. This no longer holds true when exchanges occur spontaneously between people who happen to meet during their daily activities.
- *Technical context*. WPANs offer limited bandwidth and reliability compared to wired networks. Piraté showed us that we should therefore design systems to exchange low-fidelity data or meta-information such as song recommendations rather than large MP3 files.

When does a collection of individuals become a wearable community?

A community isn't a perfectly organized group where everyone who participates gains equally. Among other things, people's individual actions primarily serve their own interests. How people deal with conflicting interests determines whether a community is successful. We've identified several factors that influence people's behavior in wearable communities:

- *Identity*. Our sense of whom we're interacting with shapes all interactions, even those with strangers. Our clothes, voices, bodies, and gestures send messages about status, power, and group membership. Wearable technology lets people define and broadcast *digital identities* that might not be their true identities. In contrast to online communities, these digital identities *augment* rather than replace a person's true identity, as both are visible at the same time. Because observers can match the digital identity to a person's appearance and behavior, people in wearable communities can't easily switch identities.
- *Privacy*. Unlike security, which deals with keeping information away from unauthorized users, privacy gives people the right to control collection and use of their personal information, including when, how, and to what extent information about them is communicated to others. Most wearable communities require members to disclose certain personal information.
- *Trust*. This aspect of human interaction differs when people interact in person versus across the Internet. Being able to look at someone, observe gestures, and mimic them tells you a lot about another person. People place much importance in a handshake when completing a transaction because it signals commitment and mutual trust. No equivalent of a handshake exists in online communities.

Wearable community systems

Unlike online communities, which have a mature and proven technological foundation, wearable communities require complex, less mature technologies such as wearable devices, wireless ad hoc networks, spontaneous networking mechanisms, and context technologies. To bring wearable communities together, we must build reliable wearable community *systems*—collections of wearable devices, distributed software infrastructure, and application software that let people interact with fellow community members (see Figure 2). *System* refers to software and hardware that set the context for interaction, and *wearable* indicates the devices' wearable nature and implies that they're always on, communicative, proactive, and presence-aware.

Within a wearable community system,

a WPAN that enables seamless connectivity among collocated devices establishes communication. Thus, a wearable community system is a highly dynamic, loosely connected, potentially large-scale distributed system made up of wearable hosts. To support the formation of wearable communities anywhere, anytime, such a system must be independent of external communication and computing infrastructures, relying solely on device capabilities. System- and application-level software performs essential functions, such as discovering nearby devices and users, initiating interactions across wireless links, managing user identities, and handling user input and output. Because of the environment's complexity, developing effective systems presents a fundamental challenge to building wearable communities.

An exploratory design approach

In wearable communities, social concerns become difficult to separate from technical practices. To design a wearable community, we must simultaneously consider technology and social interactions because wearable communities, like all communities, result from people's self-organizing behavior. Relationships emerge from interactions over time; we cannot construct them following a simple recipe.

Successful community design often hinges on what Etienne Wenger calls *minimalist design*,[15] which starts with a provisional design and facilitates community growth over time. Designers must identify the attributes that make communities successful and design technology that embodies these attributes. When building wearable communities, we face the following fundamental problem:

> *Wearable communities require hardware and software to support them, but without real-world experiences we do not know what success factors to look for and how to design systems to embody them.*

Solving the engineering problem and making it easier to develop wearable community systems will help us create and investigate these communities.

To solve this problem, we developed the WearCom design methodology.[16] WearCom supports an exploratory design approach based on rapid prototyping of wearable community systems. Rapid prototyping has proved useful for creating several generations of the Vu-Man wearable computer.[17] Our work extends this by taking a systematic approach to designing an entire sociotechnical wearable computing system.

The WearCom methodology integrates social and technical concerns and guides designers from scenario development to implementation. WearCom provides

- A *design language* that allows the specification of important design decisions
- A *design process* that outlines an iterative sequence of individual design activities, each of which generates a specific design artifact (specifications and software components)
- The *Proem software platform*,[18] which supports the implementation and execution of proactive, presence-aware wearable community applications

WearCom specifies three design elements. A *user profile*—a typed data item that defines a user's identity within a community—contains information the user discloses willingly to other community members along with that deemed useful or necessary for community purposes. A *community protocol* defines how wearable computers interact when people meet. Protocols deal with communication content, not mechanisms, and in essence formalize rituals of engagement. A *community agent*—an executable software component that implements the community protocol—runs on the wearable device and functions as intermediary between user and community (see Figure 3).

Case studies

We performed several case studies to test our hypothesis that an exploratory design approach facilitates wearable community building. Between spring 2001 and spring 2002 we taught three software engineering courses at the University of Oregon in which students used the WearCom methodology to design and implement wearable community applications. In total, 35 students divided into 10 project teams worked on four projects:

- mClique, a community system designed to improve awareness among mobile users by determining groups (cliques) of mutually connected friends

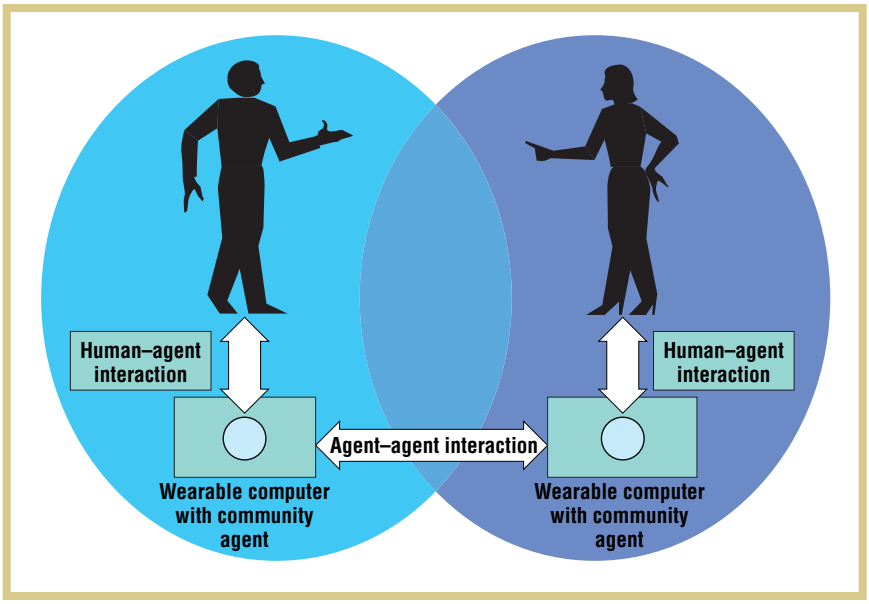


Figure 3. Community agents and community protocol in WearCom.

- mBazaar, a wearable community system that brings together buyers and sellers of goods
- Piraté, a collaborative music guide that creates community awareness (discussed earlier)
- Infomediation, a peer-to-peer information publishing and access system that lets collocated users collaboratively compare prices at online bookstores

WearCom proved successful in guiding the student teams' design activities. During the projects, we tracked data relating to learning time, development time, complexity of developed applications, and support requirements. Within 10 weeks, students learned to design wearable communities, implement applications, and experiment with the initial prototypes. It typically took students less than a week to learn the methodology and write their first application using Proem. After a design phase of about three weeks, students took five weeks using an iterative process to develop application prototypes. Teams deployed the applications on a testbed consisting of laptop, handheld, and wearable devices. The Proem platform not only simplified implementation but also made it possible to run applications on diverse hardware platforms.

For each project, we tracked support instances (how many times teachers aided students) and, on average, counted fewer than 3 instances per 10-week course. Contributing to this surprisingly low number was that we had encouraged students to share their expertise across teams. In sum, we found that the WearCom methodology effectively supported rapid prototyping of wearable community systems.

Despite this success, the overarching goal of building successful wearable communities remains elusive. A true community emerges over time and with regular technology use, and practical considerations limited our experiences with the applications developed. A major obstacle is the lack of adequate hardware—wearable computers that are constant, proactive, communicative, and presence-aware aren't yet available in large enough quantities to reach the critical mass necessary for community building. This has limited us to highly experimental systems confined to small groups of people at our lab and has prevented us from systematically analyzing the communities' social dynamics. The projects have, however, given us insight into what does and doesn't work when building such communities.

Design principles for wearable communities

Sociologists have extensively researched the successes and failures of online[19,20] and face-to-face communities.[21] Although we haven't empirically studied wearable community dynamics, we have identified six preliminary design principles that contribute to successful wearable communities. Developers can apply these guidelines to evaluate existing designs, guide the design process, and educate designers about the characteristics of successful wearable community systems.

Principle 1: *Make users aware of the hidden benefits of random encounters*. This principle guided design of the WALID community application. When two people meet, they usually aren't aware of each other's activities and, unless they talk about their respective errands, will never find out that they could benefit from a trade. WALID's community agents look for possible trading partners and alert their respective users if a mutually beneficial trade opportunity arises. Once users become aware of this, they can act on or ignore the agents' advice.

Principle 2: Reward users for social interactions. The frequency of social encounters per person should be proportional to the gain a user receives from using the system.

Principle 3: *Help people to recognize each other*. Without identity and mutual recognition, a group of people will always remain strangers. Promoting altruistic behavior and cooperation necessitates a social feedback mechanism that lets users evaluate and track others' behavior. Such a feedback mechanism requires identity and mutual recognition.

Principle 4: *Support expressiveness*. Live-action role-playing games have gained widespread international popularity. Such games become social events, bringing together people who have taken on imaginary identities based on historical or mythical characters, and the social interactions contribute much to players' enjoyment. Similarly, wearable communities let members invent digital identities to augment their true identities. Wearable communities should promote such creativity and artistic expressiveness as much as possible.

Principle 5: *Use knowledge about past encounters to enrich present interactions*. An important aspect of social encounters is our ability to recognize other people and to remember if, when, where, and under what circumstances we met someone before. Wearable computers can track both the user's current context (defined by other people's presence) and his or her *interaction history*. Applying this knowledge in wearable communities can enrich interactions in significant ways.

Principle 6: *Include social feedback loops*. Any community has disruptive or unruly members—in newsgroups, some people consistently and inappropriately flame others; on eBay, some members cheat by not paying for items they purchase. Successful communities can police their members' behavior not by giving some members extraordinary powers but through social feedback. For example, eBay uses reputations (aggregated signed opinions from eBay users on a buyer's or seller's transaction history) to let members rate and judge other members' trustworthiness. The community thus virtually excludes disrupting members. (Jay Schneider[22] presents a good discussion of trust and reputation in wearable communities.)

William Gibson described cyberspace as a "consensual hallucination experienced daily by billions of legitimate operators, in every nation."[23] Wearable communities present an alternative model of human communication that relies not on shared imagination but on real-world encounters and first-hand experiences. Mobile communication and computation

technologies have sufficiently permeated our society to shape social behavior, norms, and conventions. As mobile computers evolve into wearable computers—constant, aware, communicative, and proactive—we can expect to see even more dramatic changes. We believe that properly designed wearable computing technology can indeed beget community by facilitating social networks based on augmented interactions and face-to-face encounters.

Wearable communities face sociological as well as technical problems, which are difficult to separate—they interact and coevolve intimately. We plan further empirical research on wearable communities and the social networks this technology creates. P

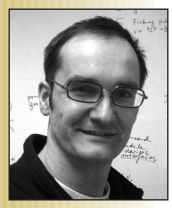
ACKNOWLEDGMENTS

This work was performed at and supported by the University of Oregon's Computer and Information Science Department.

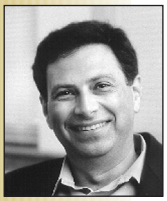
REFERENCES

1. T. Starner, *Wearable Computing and Contextual Awareness*, doctoral dissertation, Mass. Inst. Technology, Cambridge, Mass., 1999.
2. S. Mann, "Wearable Computing: Toward Humanistic Intelligence," *IEEE Intelligent Systems*, vol. 16, no. 3, May/June 2001, pp. 10–15.
3. B. Rhodes, "The Wearable Remembrance Agent: A System for Augmented Memory," *Personal Technologies*, vol. 1, no. 4, Dec. 1997, pp. 218–224; www.bradleyrhodes.com/Papers/wear-ra-personaltech/index.html.
4. N.K. Baym, "The Emergence of Community in Computer-Mediated Communication," *CyberSociety*, S. Jones, ed., Sage Publications, Newbury Park, Calif., 1995, pp. 35–68.
5. P. Kollock and M. Smith, eds., *Communities in Cyberspace*, Univ. Calif. Press, Ewing, N.J., 1998.
6. J. Preece, *Online Communities: Designing Usability, Supporting Sociability*, John Wiley & Sons, New York, 2000.
7. G. Kortuem et al., "When Cyborgs Meet: Building Communities of Cooperating Wearable Agents," *Proc. 3rd Int'l Symp. Wearable Computers*, IEEE CS Press, Los Alamitos, Calif., 1999, pp. 124–132.
8. *IEEE 802.15 Working Group for Wireless Personal Area Networks*, http://grouper.ieee.org/groups/802/15.
9. E.T. Hall, *The Silent Language*, Anchor, Garden City, N.Y., 1973.
10. M. Terry et al., "Social Net: Using Patterns of Physical Proximity over Time to Infer Shared Interests," *Proc. 2002 Conf. Human Factors in Computing Systems* (CHI 2002), ACM Press, New York, 2002, pp. 816–817.
11. G. Kortuem, Z. Segall, and M. Bauer, "Context-Aware, Adaptive Wearable Computers as Remote Interfaces to 'Intelligent' Environments," *Proc. 2nd Int'l Symp. Wearable Computers* (ISWC '98), IEEE CS Press, Los Alamitos, Calif., 1998, pp. 58–65.
12. G. Kortuem et al., "When Peer-to-Peer Comes Face-to-Face: Collaborative Peer-to-Peer Computing in Mobile Ad-hoc Networks," *Proc. First Int'l Conf. Peer-to-Peer Computing* (P2P '01), IEEE CS Press, Los Alamitos, Calif., 2001, pp. 75–91.
13. J.C.R. Licklider, "The Computer as a Communication Device," *Science and Technology*, Apr. 1968; http://gatekeeper.dec.com/pub/DEC/SRC/publications/taylor/licklider-taylor.pdf.
14. H. Rheingold, *The Virtual Community: Homesteading on the Electronic Frontier*, Perseus Books, New York, 1998, www.rheingold.com/vc/book.
15. E. Wenger, *Communities of Practice: Learning, Meaning, and Identity*, Cambridge Univ. Press, New York, 1998.
16. G. Kortuem, *A Methodology and Software Platform for Building Wearable Communities*, doctoral dissertation, Computer and Information Science Dept., Univ. Oregon, Eugene, Ore., 2002.
17. A. Smailagic et al., "Very Rapid Prototyping of Wearable Computers: A Case Study of VuMan 3 Custom versus Off-the-Shelf Design Methodologies," *J. Design Automation for Embedded Systems*, vol. 3, nos. 2/3, 1998, pp. 217–230.
18. G. Kortuem, "Proem: A Middleware Platform for Mobile Peer-to-Peer Computing," to be published in *ACM SIGMOBILE Mobile Computing and Communications Rev.*, 2003.
19. M. Godwin, "Nine Principles for Making Virtual Communities Work," *Wired*, vol. 2.06, June 1994, pp. 72–73.
20. P. Kollock, "Design Principles for Online Communities," *PC Update*, vol. 15, no. 5, June 1998, pp 58–60.
21. E. Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge Univ. Press, New York, 1990.
22. J. Schneider et al., "Disseminating Trust Information in Wearable Communities," *Personal and Ubiquitous Computing*, vol. 4, no. 4, Aug. 2000, pp. 245–248.
23. W. Gibson, *Neuromancer*, Ace Books, New York, 1984.

the AUTHORS



Gerd Kortuem is a lecturer in computer science at Lancaster University, UK. His research interests include collaborative technologies, ubiquitous computing, wear- able computing, and soft-ware engineering. He received an MS in computer science from the University of Stuttgart and a PhD in computer science from the University of Oregon. He is a member of the IEEE Computer Society and ACM. Contact him at the Computing Dept., Lancaster Univ., Lancaster, LA1 4YR, UK; kortuem@comp.lancs.ac.uk.



Zary Segall is the 2002–2003 Fulbright Distinguished IT Chair at the Royal Institute of Technology, Sweden, and professor of computer science at the University of Oregon. His research has focused on theoretical and practical methods and systems for parallel processing, highly dependable systems, fault tolerance, real time, binary-to-binary translation, networking, and wearable information systems. He is a fellow of the IEEE Computer Society. Contact him at the Computer Science Dept., Univ. of Oregon, Eugene, OR 97405; zary@zary.com.