



It's alive!

by A. Pentland

Inanimate things are coming to life. However, these stirrings are not Shelley's Frankenstein or Asimov's humanoid robots. This new awakening is more like Walt Disney's Sorcerer's Apprentice: the simple objects that surround us are gaining sensors, computational powers, and actuators. As a result, desks and doors, televisions and telephones, cars and trains, eyeglasses and shoes, and even the shirts on our backs—all are changing from static, inanimate objects into adaptive, reactive systems that are more useful and efficient.

If you imagine raising a child in a closed, dark, sound-proof box with only a telegraph connection to the outside world, you can quickly realize how difficult it is for computers to become intelligent and helpful. They exist in a world that is almost completely disconnected from ours, so how can they understand our desires?

To change inanimate objects like offices, houses, cars, or glasses into smart, active helpmates, the major change that must happen is that these devices need to begin paying attention to people and the surrounding situation the way another person would. They need to become aware of their *context*. In this way, they can begin to adapt their behavior to us, rather than the other way around. In the language of cognitive science, context awareness is the ability to solve the frame problem: it is being able to classify the current situation, so that you know what variables are important, and thus can take appropriate action. Once a computer has the perceptual intelligence to know who, what, when, where, and why, it becomes much simpler for the computer to determine what aspects of the situation are significant and to answer a wide variety of useful questions.

To realize this vision of helpful, context-aware environments, a series of experimental testbeds have been created at the MIT Media Laboratory. These testbeds can be divided into two main types. The first type are “smart rooms,” which typically try to act a little like a good butler—a passive observer who stands in the corner and is constantly looking for opportunities to help. The second type are “smart clothes,” which typically try to act as a personal assistant—a person who travels with you, sees and hears everything that you do, and tries to anticipate your needs and generally smooth your way. Beginning in the late 1980s, Media Laboratory research in this area quickly expanded into major research initiatives such as the Things That Think industrial research consortium. This section of the *IBM Systems Journal* special issue on the Media Lab presents a wide sampling of the ideas that have emerged from this research.

The section begins with a far-horizon technology focus. Maguire, Boyden, and Gershenfeld investigate scaling issues for computing using quantum effects. As they remark in their paper “Toward a Table-Top Quantum Computer,” “The dream of quantum computing is that quantum mechanics provides an untapped, scalable exponential resource.” Over time, work in the Media Laboratory has moved from a focus on smart rooms to an emphasis on smart clothes, both because wirelessly connected mobile devices offer a quicker, cheaper path toward ubiquity, and because of concerns over privacy. This emphasis on wearable devices can be seen especially in “E-broidery: Design and Fabrication of Textile-based Computing” by Post et al., in which computation elements

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are literally built into standard clothes. They compare textiles to existing flexible circuit substrates with regard to durability, conformability, and wearability, and they describe some unique applications enabled by their work.

The theme of context awareness dominates the papers in this section and is seen most clearly in the next three papers: Omojola et al.'s paper on interactive furniture, Selker and Burleson's paper on context-aware design, and Paradiso et al.'s paper on sensor systems. "An Installation of Interactive Furniture" by Omojola et al. is a report on a project that explored "emerging technologies for intuitive and unobtrusive information interfaces in a compelling setting"—interactive furniture at the Museum of Modern Art, New York. The authors describe the enabling technology and the design considerations necessary for building distributed, context-aware environments.

In their paper entitled "Context-Aware Design and Interaction in Computer Systems," Selker and Burleson argue that "As the human-computer interface becomes more pervasive and intimate, it will need to explicitly draw upon cognitive science as a basis for understanding what people are capable of doing." They go on to describe a user experience that is integrated into the computer system design process, taking into account situational awareness, e.g., "what and where the user task is, what the user knows, and what the system capabilities are." In "Sensor Systems for Interactive Surfaces" by Paradiso et al., the authors describe four different systems that they developed "for capturing various manners of gesture near interactive surfaces." In addition to describing the technology itself, they discuss applications that suggest how we might interact with simple animate objects.

The section concludes with an analysis of how people will interact with this new generation of devices. Ullmer and Ishii's paper entitled "Emerging Frameworks for Tangible User Interfaces" can be understood as a discussion of creating interfaces that have a richer, more specific context. They introduce an interaction model for tangible interfaces that relates physical models, digital representations, and system control. Their paper provides an abundance of examples of tangible user interfaces.

A theme that was touched upon in Omojola et al. is "quasi-local" rather than ubiquitous connectivity. Many of the early ideas about ubiquitous comput-

ing, e.g., Weiser's 1991 article in *Scientific American*, envisioned tight, continuous networking everywhere. But such networking entails the capacity to concentrate information, and so has an uncomfortable resemblance to George Orwell's dark vision of a government that monitors one's every move. Moreover, as Gershenfeld comments in his postlude to this section, the ability to guarantee reliability and security in such flat networks remains an open and possibly insoluble problem.

Instead, it appears that *local* intelligence—combined with relatively sparse, locally initiated connections—can provide most of the functional benefits of ubiquitous networking, while at the same time producing more reliable networks and making it more difficult for outsiders to track and analyze a user's behavior. Perhaps the emerging emphasis on using local intelligence is not surprising since naturally occurring network systems (such as the human brain) are not fully connected or under tight central control. Instead they are "lumpy," consisting of densely interconnected nodes that are only sparsely connected to other nodes. Biological brains—even those of humans—are better described as a collection of almost-disconnected local brains rather than as a unified network.

In looking over the trends that have emerged from this research—systems that use sensors to become aware of their context, that are mobile and always-on, and that are loosely networked "local intelligences"—it seems that the common objects that surround us are well on their way to "becoming alive." Perhaps they will next develop personalities, friendships, and emotions.

Alex (Sandy) Pentland MIT Media Laboratory, 20 Ames Street, Cambridge, Massachusetts 02139-4307 (electronic mail: sandy@media.mit.edu). Dr. Pentland is the academic head of the MIT Media Laboratory and cofounder and director of the Center for Future Health and the LINCOS Foundation. His research focus includes both smart rooms (e.g., face, expression, and intention recognition; word learning and acoustic scene analysis) and smart clothes (e.g., augmenting human intelligence and perception by building sensors, displays, and computers into glasses, belts, shoes, etc.). These research areas are described in the April 1996 and November 1998 issues of *Scientific American*. He is one of the 50 most-cited researchers in the field of computer science, and *Newsweek* has recently named him one of the 100 Americans most likely to shape the 21st century. Dr. Pentland has won awards from several academic societies, including the AAAI, IEEE, and Ars Electronica. See <http://www.media.mit.edu/~pentland> for additional details.