THE AGE of the INTERFACE

BY RICHARD YONCK

From processing codes punched out on cards to interpreting our brain waves, our computers are progressively learning how to read our minds. Future interfaces will help man and machine understand each other better.

MICHELE PIACQUADIO / ISTOCKPHOTO

DOMINIC HART / NASA AMES RESEARCH CENTER

Subvocal interface: When there is too much background noise to have a cell-phone conversation, you might opt for a subvocal speech-recognition system, as shown by NASA researcher Chuck Jorgensen. The system reads nerve signals in the user's throat and relays them to a remote computer that translates them into words.

Ever since we humans started building levers, wheels, and other tools, we've needed ways to interface with them — that is, to operate and control them. Initially the means of operating our devices were direct and highly intuitive. But as our machines grew in complexity over time, the controls became increasingly complex and more abstracted from the processes they managed.

The word *interface* is defined as a connection between systems, equipment, or people. It's most commonly associated with computing, but it is applicable to practically any human–machine activity. Interfaces exist to facilitate interaction. As Apple Computer put it, "The less alike two entities are, the more obvious the need for a well-designed interface becomes."

A properly designed and implemented interface not only facilitates system-to-system communication, but it also simplifies and automates control of otherwise complex functions. Interfaces let us operate on things that we can't otherwise deal with and peer into regions where we couldn't otherwise see. From steering aircraft carriers to moving atoms with atomic force microscopes, interfaces rescale our actions. They translate digital signals and invisible radiation into media that are readily accessible to our senses. In essence, they become our eyes, ears, hands, and even extensions of our minds.

As astounding and varied as our interfaces are today, they're on track to become much more so in the near future. Under development now are a range of new methods for interacting with our devices in ways that would have been inconceivable only a few years ago. With so many advances now on the horizon, we may someday look back on this period as the Golden Age of the Interface.

FORCES ACCELERATING INTERFACE DEVELOPMENT

Several factors are driving this wave of innovation. Continuous improvement in computing plays a particularly critical role. As microprocessors become faster and more powerful, there are more processing cycles to spare. This allows for designs that are more intuitive and user-friendly — for instance, by incorporating artificial intelligence to better anticipate user intentions. At the same time, circuits are shrinking in scale, allowing devices to be configured and located in ways they never could be before.

Smaller devices also need different input and display methods than those we typically use on the desktop. Smart phones with touch screens are already moving us away from the keyboard and mouse paradigm. As our computers shrink further, they will tend to disappear completely from view because they are embedded in our environments, woven into our clothes, or inserted underneath our skin, so we'll need whole new ways to control them.

The availability of relatively inexpensive, ever-present, two-way communication has already created an electronic ecosystem that has never existed before. In this environment, a broad ecology of networked devices and their supporting interfaces will rapidly develop. Cloud computing and software services will reduce the processing power required by users, resulting in potentially smaller and cheaper devices.

The marketplace is becoming as much a part of the positive feedback loop as the technology it sells. Several new interfaces have been feasible via existing technology for some time; they've simply needed the right combination of entrepreneurial spirit and market forces to bring them to fruition. This will probably continue to be true for many of the nascent or newly developing interfaces as they progress through the development cycle.

FROM PUNCHED HOLES TO GESTURES

The evolution of the computer-user interface has progressed from punch cards to today's graphic user interface (GUI). Now, we're beginning to shift to a new model: the natural user interface (NUI).

With punch cards, we had a means of input and output that was far from intuitive and only became productive through hours of training and experience. The GUI was more accessible to the untrained user, its rules more evident and easily acquired through exploration due to the visual feedback the GUI provided. With the natural user interface, the methods of control will be even more intuitive in that they're derived from natural actions and behaviors. For example, a user might zoom in and out of a photo on an iPhone or Microsoft's Surface just by pinching two fingers (i.e., multi-touch). Multi-touch, gesture, and motion are just a few of the many different approaches to implementing an NUI.

This isn't to say NUIs will completely do away with GUIs any more than GUIs eliminated the command line. Each will continue to be used for those tasks for which it's best suited. It's an evolutionary progression that will eventually result in a new paradigm that becomes the dominant choice over the old.

This progression isn't likely to end with NUIs. As our devices become more intimately integrated with our bodies, the organic user interface (OUI) will come into its own. Biometric sensors, skin displays, and eventually brain-computer interfaces are just a few of the potential implementations of OUIs. As with earlier interfaces, many OUIs will probably be more intuitive to work with than their predecessors, even to the point where we'll be entirely unconscious of them.

SHAPES OF INTERFACES TO COME

Some of the technologies that follow would fit reasonably well under headings of "input" or "output," while others bear elements of both. Still others are essentially amalgams of two or more technologies. One day it might even be possible to combine different elements from different vendors on the fly, much as is done in programming with software toolboxes.

All these interfaces will be useful for an incredible variety of applications. Vehicle control, augmented reality, emergency services dispatch, global disease monitoring, telemedicine, architectural design, and traffic flow modeling are just a few of the possibilities.

- **TOUCH SCREENS.** The touch concept is being embraced on larger scales. Microsoft Surface is a multiuser computer that's fast developing into a medium for a wide variety of uses, such as a conference room tool, a classroom education platform, a product catalog, or a multiplayer game board. Multi-touch kiosks are starting to provide new ways for travelers and shoppers to find information quickly and efficiently.

- **FLEXIBLE SCREENS.** Screens that are ultrathin, lightweight, and flexible are coming out of the labs and will soon hit the streets. Many observers refer to them as the future of paper. There are a number of different technologies being used to develop a truly flexible display. These include emissive displays such as OLED (organic light-emitting diodes), reflective displays such as E Ink's electrophoretic imaging technology (used in Amazon Kindles and Sony Readers), and transmissive displays such as LCD (liquid crystal display).

Because of differences in the technologies, each will likely fill a different market niche. For instance, OLEDs offer faster refresh rates while E Ink's products tend to be many times more energy-efficient than the other technologies. The opportunities to place video displays in everything from newspapers and magazines to clothing and wraparound wall displays will result in a vast number of new ways to distribute information.

- **3-D DISPLAYS.** 3-D movies have been with us for nearly ninety years, but adding a third dimension to video display is only now beginning to become a reality. Sony, Panasonic, and other companies will be bringing 3-D televisions to the home market in 2010. The new devices will still need users to wear special glasses, but the technology has come a long way since the iconic red and cyan anaglyph glasses of 1950s sci-fi and horror movies. The different manufacturers use either "active shutter 3-D glasses" or polarizing glasses, though as yet there is no industry standard. Format wars like that between Blu-ray and HD-DVD players may be ahead for 3-D TV.

While the industry is betting that the success of recent 3-D movies shows the home market is ready for this move, it remains to be seen if the average viewer will want to routinely watch hours of television while wearing these special glasses. In the meantime, industry represent-

Electrotactile stimulation: A person who is blind or visually impaired might gain vision with this BrainPort Technologies Vision Device. The system's sensors translate visual images into electronic signals that stimulate the user's tongue. The user's brain will input the sensations and extrapolate images for itself.

atives have suggested that 3-D displays that won't need glasses may be on the market sometime around the end of the decade.

• **RETINAL DISPLAYS.** Retinal displays project images directly onto the user's retina using low-level lasers or LEDs. This concept was invented nearly a quarter century ago, but technological advances have recently made various aspects of the system more feasible. For instance, edge-emitting LED technology, which has more optical power than surface-emitting LEDs and lower power requirements than lasers, could provide a brighter, lower-cost alternative to using lasers to create the display.

Because a much larger percentage of photons contact the retina, the brightness-to-power ratio is much higher than in conventional displays, resulting in considerably lower power requirements. Put another way, battery life in devices like cell phones could be greatly extended.

Retinal imaging has many potential uses, such as heads-up displays of operations manuals for vehicle repair, optimal path and tactical information for military operations, overlays of patient scans and vital statistics during surgery, immersive gaming, and augmented-reality displays. Recently, Japan's Brother Corporation announced plans to release a commercial retinal imaging display using red, green, and blue laser diodes sometime in 2010.

• **GEOSPATIAL TRACKING.** Geospatial tracking is only beginning to make its impact felt and will see considerable improvements in the next few years. GPS, directional compasses, and accelerometers in smart phones provide enough information to determine the approximate location, direction, and orientation of the user. As location precision improves, either through GPS improvements or possibly the addition of supplemental localized data, tracking will eventually become accurate to within fractions of a millimeter.

Many of the new augmented-reality applications being created for smart phones utilize geospatial data, providing contextual information based on the user's location. This will allow for location-based marketing, travel assistance, and social networking applications, to name just a few possibilities. This market should see tremendous growth for the next several years, especially as location precision improves and wireless network speeds increase.

• **GESTURE RECOGNITION.** While most gesture-recognition development currently focuses on the face and hands, the field extends to posture, gait, and other behaviors. Gesture recognition is a developing technology that will begin to open up fields as diverse as wearable computing, immersive games, and affective computing, which is used to identify emotions. Controller-based devices, such as the Wii Remote, are already available at the consumer level. Just beginning to be used in hospital environments, gesture recognition will allow doctors to manipulate digital images without compromising sterility by touching a keyboard or screen. Future uses could include sign-language translation and stealth technologies.

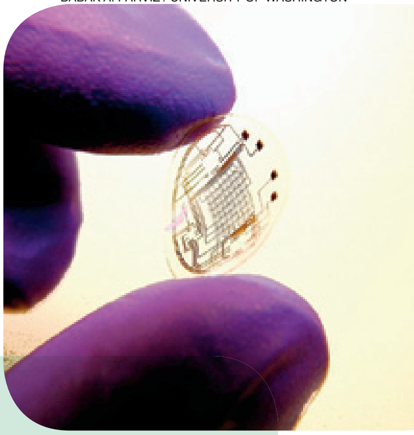
• **HAPTICS.** Haptic technologies interface with users through their sense of touch, providing a sense of presence that would otherwise be absent in a virtual setting. Since touch is built up from many different types of receptors (light touch, heavy touch, pressure, pain, vibration, heat, and cold), there are numerous approaches to synthesizing these sensations.

Because of the importance of tactile feedback in certain types of tasks, there are many areas where haptics will provide a helpful dimension of information. Virtual environments, telerobotics, and telemedicine are just a few areas that will benefit from work in this field. E-commerce will almost certainly put this technology to significant use as well. Imagine, for instance, the appeal to consumers of being able to feel fabric samples before buying an item of clothing online.

Eventually, haptics may even give us senses we've never had before. Haptic Radar, a project under development at the University of Tokyo, augments spatial awareness by sensing the environment within a few feet around the user and translating it into vibrations and other sensory cues. As a result, a blindfolded user is able to avoid colliding with objects as he or she comes within a few feet. Potential uses could include collision avoidance in hazardous environments and obstacle awareness for drivers and the visually impaired.

• **TANGIBLE USER INTERFACES.** This subset of NUIs is typically configured based on how users handle and position them. The "bar of soap" device from MIT Media Lab responds to how it's being held, reconfiguring itself into a camera, a cell phone, a PDA, a game pad, or a remote control. "Siftables," also initially developed at the Media Lab, are cookie-sized computers with graphical display, neighbor detection, motion sensing, and wireless communication. Based on their arrangement relative to each other, Siftables can become any number of interactive applications, such as a math game, a music sequencer, a paint mixer, a photo sorter, or a storyboard game. Interfaces like these lend themselves to a very natural learning process that could benefit even the youngest users.

BABAK A. PARVIZ / UNIVERSITY OF WASHINGTON



Bionic contact lenses: Computers might one day fit on contact lenses. Bionic contacts, now being developed by University of Washington electricial-engineering professor Babak A. Parviz, will provide "augmented reality"—you can have the lens give you instant background data on whatever you see, or alternative visual representations of the scene itself.

SAM OGDEN / COURTESY OF PRANAVMISTRY.COM

Gesture recognition: MIT engineer Pranav Mistry places a phone call using his prototype SixthSense gestural interface. A projector in the pendant around his neck emits a visual display of phone numbers onto the palm of his hand. Mistry "dials" the numbers, and the camera reads his gestures to process the phone call. Mistry's SixthSense interface will be capable of a range of functions: phone service, e-mail, display maps, clock display, and retrieval of information about recognized objects.

• **SPEECH RECOGNITION.** The ability to talk directly to our devices holds great promise for any number of fields. While no one would want to be at a large conference where everyone was talking to their smart phones, there are plenty of situations where this could be the interface of choice. Driving a car, cooking a meal, repairing an engine, and performing surgery are all activities that could benefit from hands-free interaction with different devices.

Already, speech is being used for tasks as diverse as call routing, home automation, voice dialing, and data entry. For the international traveler, speech-to-speech translators are beginning to enter the market. A real-time universal translator will probably be available by around the middle of the decade.

• **SUBVOCAL RECOGNITION.** Related to speech recognition but in a far earlier stage of development is subvocal recognition, the conversion of electrical signals from the throat into speech without the operator needing to utter a sound. This technology may one day be used by pilots, firefighters, SWAT teams, and special forces. It would be a useful means of input in noisy or harsh environments, underwater, and even in space. The device has also been tested as a way to control a motorized wheelchair and could be a highly efficient means of speech synthesis for people with speech impairments. It has potential recreational use, also: The gaming community will almost certainly take up subvocal controls once they become commercially available.

One subvocal system is currently under development at NASA Ames Research Center for eventual use in astronauts' EVA suits. The project's chief scientist, Chuck Jorgensen, has suggested that subvocal control technology could be available in commercial applications within only a few years.

• **EYE TRACKING.** In passive applications, eye tracking can be used for advertising and marketing feedback, gathering useful information about where a consumer's gaze (and attention) lingers. But even this use of the technology is likely to become much more interactive in time. For example, auto safety could be enhanced if the eye-tracking technology catches a driver looking away from a potentially dangerous situation.

At its most interactive, eye tracking is already allowing quadriplegics to work directly with computers, selecting letters and commands by fixing their focus on an appropriate region of the screen. Such interaction may also provide an excellent means of input control for wearable computers in the future.

• **ELECTROTACTILE STIMULATION.** Output and display technologies are developing at a rapid pace and are far from limited to visual media. One of the more unusual of these is electrotactile stimulation, which could allow the blind or visually impaired to "see" in a brand new way. BrainPort Technologies is currently developing a means of translating visual images into a matrix of electrotactile signals that stimulate the user's tongue. (Theoretically, fingertips or other regions of the body could be used, but several features make the tongue the optimum candidate.) Within a short time, through the wonders of the brain's neuroplasticity, the user learns to interpret the signals as if they had been received via normal visual channels. The result is a grainy but usable "image" that can allow the user to navigate a room, recognize shapes, and even identify letters. As resolutions are improved, such images may become more detailed and thus more useful. Potentially, images created from signals beyond the visual spectrum would allow for novel applications, such as low-visibility scuba diving work.

• **BIONIC CONTACT LENSES.** For decades, contact lenses have been used to correct vision, but what if they could do much more, such as double as a personal computer display? Babak Parviz, an associate professor of electrical engineering at the University of Washington, has been working on just that. Using self-assembly techniques to embed microscale components in a polymer lens, Parviz and his team are building prototypes of what may one day change the way we see the world.

Augmented reality, in which data is superimposed over the real world, will completely change the way we interact with other people and the world at large. Personal data, location-based statistics, and even alternative representations of the scene itself could all eventually be possible. Though the project presents numerous challenges, considerable progress has already been made.

Because the lens is in continual contact with bodily fluids, early versions may be used for noninvasive health monitoring. A glucose detector, for instance, would be a boon to diabetics. Parviz speculates that such monitoring may be possible within five to 10 years. If most of the necessary technology is in place by then, a full-fledged display could follow only a few years later.

• **BRAIN–COMPUTER INTERFACES.** In some ways the holy grail of interfaces — a brain–computer interface (BCI), or direct neural interface — would provide the most immediate means of interacting with our devices. Eliminating our intermediary senses, brain–computer interfaces would tie directly into the brain's neural system. There are both invasive and noninvasive methods of achieving this.

With invasive BCI, arrays of electrodes are placed in direct contact with the brain. To date, this application in humans has been limited to neuroprosthetics used to replace or restore a particular brain function. Retinal prostheses that partially restore sight and motor neuroprosthetics that restore or assist movement are examples of invasive BCI.

In noninvasive BCI, brain waves are read through external means, such as electrodes placed on the scalp to read electroencephalogram (EEG) activity. The quality of the EEG is typically better when electrodes can be carefully placed using conductive gel, but recent innovations have been able to obtain usable signals with less exacting placement. Magnetoencephalography and fMRI (functional magnetic resonance imaging) are other noninvasive methods that have been used in BCI research but are not easily used outside of special facilities.

The potential benefits of an effective BCI are considerable. Victims of locked-in syndrome, ALS, and quadriplegia could regain significant functions. Communication via computers and the control of wheelchairs and other devices would contribute greatly to many people's independence and self-sufficiency.

The potential applications for BCIs are almost limitless. They could make it possible to communicate and carry out transactions in complete privacy, improving financial security. Domotics, or home automation, could be set up to respond even to unconscious needs. A room's temperature might automatically adjust according to who is in it. A bedroom's lights might dim or turn off when a person inside is falling asleep. If the individual suffers a stroke or other medical emergency, the home system might instantly call paramedics to come help.

As is often the case, the gaming industry will probably be a driver of much initial development and consumer demand. The appeal of controlling a game or avatar using nothing but one's mind is considerable. Already, several developers are marketing helmets that they claim will give users on-screen control using only their minds.

As systems improve and become more reliable, the ability to communicate thoughts suggests something that has previously existed only in the realm of science fiction: telepathy. Yet, this might actually be possible in the near future. In April 2009, a biomedical engineering doctoral student at the University of Wisconsin–Madison used BCI to post a tweet on Twitter. The method used to compose the message was laborious but definitely shows the feasibility of outbound brain-based communication.

So far, much BCI research has dealt with methods of input, using thought to control an external device. The creation of sensations, words, or even thoughts in a receiving mind will be a much greater challenge. But as our understanding of the brain grows, this, too, will eventually become possible. Neuroprosthetics such as cochlear implants to improve hearing and artificial vision systems suggest ways we may one day link into our sensory system to generate sounds, images, and ultimately even thoughts.

Such an interface may one day give us instant, intuitive access to the sum of human knowledge. Likewise, it could provide a means of off-loading menial mental tasks to externally run processes. This idea of memory enhancement, an exocortex, has been developing ever since the first notched sticks and stone tablets. Printed books, computers, and the Internet continued the trend. Future interfaces will allow us even faster, better, and more complete access to all manner of information. But ultimately, it's the BCI that would give us a nearly transparent ability to interface with external stores of knowledge. While this idea may feel strange and foreign now, the right interface would make it seem so natural that in time we wouldn't even realize we were using it.

PUTTING IT ALL TOGETHER

The marks of a good interface are its intuitiveness, ease of use, and ability to handle tasks more efficiently. As interfaces have progressed, the trend has been toward ever more natural implementations, resulting in devices that can better integrate with the way people work and play. Over time, this progression will likely lead to organic user interfaces, which will allow our tools to become even more intimately part of our lives. Eventually, this may even lead to the development of a true exocortex, an additional aspect of our memory and processing that would exist outside of our bodies. The result would be a tremendous increase in our effective personal knowledge and the intelligence we could bring to bear on a given task or problem.

This age of the interface is far from complete, and there will no doubt be many novel and unexpected developments in the decades ahead. Many of the interface strategies described here may be merged into a single solution. One thing we can be fairly sure of, though, is that new interfaces will utterly change the way we interact with our machines, our world, and each other. ❑

About the Author

Richard Yonck is a foresight analyst for Intelligent Future LLC and has more than 20 years of experience as a computer systems programmer-analyst. He writes the futures blog The Foreseeable Future and is the founder of FutureNovo.com, a site about emerging technologies. E-mail ryonck@intelligent-future.com.