

## The Eyes Have It

*Eye-tracking control for mobile phones might lead to a new era of context-aware user interfaces.*

**H**UMAN-COMPUTER INTERFACES (HCIs) controlled by the eyes is not a novel concept. Research and development of systems that enable people incapable of operating keyboard- or mouse-based interfaces to use their eyes to control devices goes back at least to the 1970s. However, mass adoption of such interfaces has thus far not been necessary nor pursued by system designers with any particular ardor.

“I’m a little bit of a naysayer in that I think it will be very, very hard to design a general-purpose input that’s superior to the traditional keyboard,” says Michael Holmes, associate director for insight and research at the Center for Media Design at Ball State University. “When it comes to text, it’s hard to beat the speed of a keyboard.”

However, one class of user interfaces (UIs) in particular has proven to be problematic in the creation of comfortably sized keyboards—the interfaces on mobile phones, which are becoming increasingly more capable computational platforms as well as communications devices. It might stand to reason that eye-based UIs on mobile phones could provide users with more options for controlling their phones’ applications. In fact, Dartmouth College researchers led by computer science



“People tend not to point with their eyes,” notes Roel Vertgaal, associate professor of human-computer interaction at Queen’s University, who studies eye communication.

professor Andrew Campbell recently demonstrated with their EyePhone project that they could modify existing general-purpose HCI algorithms to operate a Nokia N810 smartphone using only the device’s front-facing camera and computational resources. The new algorithms’ accuracy rates, however, also demonstrated that the science behind eye-based mobile control needs

more refinement before it is ready for mass consumption.

### Eyes As an Input Device

Perhaps the primary scientific barrier to reaching a consensus approach to eye-controlled mobile interfaces is the idea that trying to design such an interface flies against the purpose of the eye, according to Roel Vertgaal, asso-

ciate professor of human-computer interaction at Queen's University.

"One of the caveats with eye tracking is the notion you can point at something," Vertegaal says. "We didn't really like that. People tend not to point with their eyes. The eyes are an input device and not an output device for the body."

Vertegaal says this basic incompatibility between the eyes' intended function and the demands of using them as output controllers presents issues including the Midas Touch, postulated by Rob Jacob in a seminal 1991 paper entitled "The Use of Eye Movements in Human-Computer Interaction Techniques: What You Look At is What You Get."

"At first, it is empowering to be able simply to look at what you want and have it happen, rather than having to look at it (as you would anyway) and then point and click it with the mouse or otherwise issue a command," Jacob wrote. "Before long, though, it becomes like the Midas Touch. Everywhere you look, another command is activated; you cannot look anywhere without issuing a command."

Another issue caused by trying to make the eyes perform a task for which they are ill-suited is the lack of a consensus on how best to approach designing an eye-controlled interface. For example, one of the most salient principles of mainstream UI design, Fitts's Law, essentially states that the time to move a hand toward a target is affected by both

the distance to a target and the size of the target. However, Fitts's Law has not proven to be a shibboleth among eye-tracking researchers. Many contend the natural accuracy limitations of the eye in pointing to a small object, such as a coordinate on a screen, limit its applicability. A lack of consensus on the scientific foundation of eye control has led to disagreement on how best to approach discrete eye control of a phone. The Dartmouth researchers, for example, used blinks to control the phone in their experiment. However, Munich-based researcher Heiko Drewes found that designing a phone that follows gaze gestures—learned patterns of eye movement that trigger specific applications, rather than blinks—resulted in more accurate responses from the phone.

"I tried the triggering of commands by blinking, but after several hundred blinks my eye got nervous—I had the feeling of tremor in my eyelid," Drewes says. "I did no study on blinking, but in my personal opinion I am very skeptical that blinking is an option for frequent input. Blinking might be suitable for occasional input like accepting an incoming phone call."

However, Drewes believes even gaze gestures will not provide sufficient motivation for mass adoption of eye-controlled mobile phones. "The property of remote control and contact-free input does not bring advantage for a device I hold in my hands," he says. "For these reasons I

am skeptical regarding the use of gaze gestures for mobile phones.

"In contrast, I see some chances for controlling a TV set by gaze gestures. In this case the display is in a distance that requires remote control. In addition, the display is big enough that the display corners provide helping points for large-scaled gesture, which are separable from natural eye movements."

### Steady Progress

Vertegaal believes the most profound accomplishment of the Dartmouth EyePhone work may be in the researchers' demonstration of a mobile phone's self-contained image and processing power in multiple realistic environments, instead of conducting experiments on a phone tethered to a desk-top in a static lab setting. Dartmouth's Campbell concurs to a large degree.

"We did something extremely simple," Campbell says. "We just connected an existing body of work to an extremely popular device, and kind of answered the question of what do we have to do to take these algorithms and make them work in a mobile environment. We also connected the work to an application. Therefore, it was quite a simple demonstration of the idea."

Specifically, Campbell's group used eye-tracking and eye-detection algorithms originally developed for desktop machines and USB cameras. In detecting the eye, the original algorithm produced a number of false positive re-

## Obituary

# Benoît Mandelbrot, Mathematician, 1924–2010

Benoît Mandelbrot, working largely outside the mainstream of mathematics and computer science, achieved international fame by introducing the term "fractal" to refer to intriguing mathematical shapes that display rough and irregular patterns found in nature. The mathematician died from pancreatic cancer on October 14 at age 85.

Mandelbrot, born in Poland, raised in France, and later a resident of Cambridge, MA, became interested in unusual natural patterns—including coastlines, plants, and blood

vessels—as a young man. He continued to focus on geometric complexities throughout his career. In the 1950s, Mandelbrot argued that it was possible to quantify the crookedness of complex objects by assigning a "fractal dimension." In 1982, he published *The Fractal Geometry of Nature*, a book that earned him widespread acclaim.

"His and other mathematicians' work on fractals helped to answer some nagging questions that had bothered mathematicians since the early 20<sup>th</sup> century," says Joe Warren, professor of computer

science at Rice University. In addition, Mandelbrot helped define the fields of computer science, geology, medicine, cosmology, and engineering. In 1979, he studied the Mandelbrot set that is now named after him.

"Movies such as *Avatar* and video games such as *Spore* utilize this method in building realistic creatures and natural environments as well as creating fantastic new creatures and environments," Warren notes. Today, "the study of self-similarity as occurring in fractals also spurred the idea of exploiting self-

similarity in other mathematical applications such as signal processing," says Warren.

In 1958, Mandelbrot was hired by IBM to work as a researcher. He served as a visiting professor at Harvard and Massachusetts Institute of Technology universities and accepted a full-time teaching position at Yale University in 1987. Mandelbrot received more than 15 honorary doctorates and served on the board of many scientific journals. He is frequently referred to as the "father of fractal geometry."

—Samuel Greengard

sults for eye contours, due to the slight movement of the phone in the user's hand; interestingly, the false positives, all of which were based on coordinates significantly smaller than true eye contours, seemed to closely follow the contours of the user's face. To overcome these false positive results, the Dartmouth researchers created a filtering algorithm that identified the likely size of a legitimate eye contour. The new eye-detection algorithm resulted in accuracy rates of 60% when a user was walking in daylight, to 99% when the phone was steady in daylight. The blink detection algorithm's accuracy rate ranged from 67% to 84% in daylight.

Campbell believes the steady progress in increasing camera resolution and processing capabilities on mobile phones will lead to more accuracy over time. "Things like changes in lighting and movement really destroy some of these existing algorithms," he says. "Solving some of these context problems will allow these ideas to mature, and somebody's going to come along with a really smart idea for it."

However, veterans of eye-tracking research do not foresee a wave of eyes-only mobile device control anytime soon, even with improved algorithms. Instead, the eye-tracking capabilities on mobile devices might become part and parcel of a more context-aware network infrastructure. A phone with eye-gaze context awareness might be able to discern things such as the presence of multiple pairs of eyes watching its screen and provide a way to notify the legitimate user of others reading over his or her shoulder. An e-commerce application might link a user's gaze toward an LED-enabled store window display to a URL of more information about a product or coupon for it on the phone. Campbell says one possible use for such a phone might be in a car, such as a dash-mounted phone that could detect the closing of a drowsy driver's eyes.

Ball State's Holmes says such multimodal concepts are far more realistic than an either/or eye-based input future. "Think about how long people have talked about voice control of computers," he says. "While the technology has gotten better, context is key. In an open office, you don't want to hear everybody talk to their computer. Voice command is useful for things like advancing slide

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show, but for the most part voice control is a special tool. And while I can see similar situations for eye gaze control, the notion that any one of these alternative input devices will sweep away the rest isn't going to happen. On the other hand, what is exciting is we are moving into a broader range of alternatives, and the quality of those alternatives is improving, so we have more choices." ■

### Further Reading

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### Career

## CS Grads Are Well Paid

As the U.S. economy limps toward a recovery, there's some good news for students launching careers in computer science and engineering: the starting pay for college graduates in those fields is well above that of many other disciplines, according to a new report by *The Wall Street Journal*.

The study, conducted for the *Journal* by PayScale.com, shows that graduates with engineering degrees earned an average starting salary of \$56,000 in their first full-time jobs out of college. Computer science graduates were second, earning an average salary of \$50,000. By comparison, people who graduated with degrees in communications and English earned \$34,000 in their first jobs.

PayScale.com conducted the survey between April and June of this year, which included responses from about 11,000 people who graduated between 1999 and 2010. According to *The Wall Street Journal*, the reported starting pay was adjusted for inflation to make the salaries of graduates from different years comparable.

The survey was conducted as part of *The Wall Street Journal's* Paths to Professions project, which examined a selection of jobs in careers that were deemed to be satisfying, well paid, and having growth potential.

One of the advantages of having a technical degree is that it can be applied to a variety of fields, such as product marketing and advertising, which can increase the marketability of an engineer or computer science major, says Katy Piotrowski, a career counselor and owner of Career Solutions Group in Fort Collins, CO.

"You can't really wing technical skills, so if there's a technical product that needs to be promoted through a marketing activity, there's more confidence with someone who has a technical pedigree" to be able to understand how the product works, Piotrowski says. While technical skills are not valued in every field, such as social work, they do open a lot of doors, she notes.

—Bob Violino