Simple, low-cost device that affixes to a cellphone could provide quick eye tests

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Postdoctoral Associate Ankit Mohan demonstrates NETRA (Near-Eye Tool for Refractive Assessment). The user places the device to the eye and, using phone's keypad, aligns patterns in the viewfinder. These alignments provide the data needed to determine a prescription. Photo: Andy Ryan

There are two standard systems for determining a prescription for eyeglasses to correct refractive errors such as nearsightedness, farsightedness and astigmatism. One is to have the patient look through a large device called a phoropter, fitted with dozens of different lenses that can be swung into place in front of each eye in various combinations, while the patient tries to read a standard eye chart on the wall ahead. The other uses a more expensive system called an

aberrometer that shines a laser into the eye and uses an array of tiny lenses to measure its characteristics, with no interaction from the patient.

Now, a team at MIT's Media Lab has come up with a much quicker, simpler and cheaper way to get the same information — a method that is especially suitable for remote, developing-world locations that lack these expensive systems. Two billion people have refractive errors, and according to the World Health Organization, uncorrected refractive errors are the world's second-highest cause of blindness, affecting some 2 percent of the world's population; all these people are potential beneficiaries of the new system. The team is preparing to conduct clinical trials, but preliminary testing with about 20 people, and objective tests using camera lenses, have shown that it can achieve results comparable to the standard aberrometer test.

In its simplest form, the test can be carried out using a small, plastic device clipped onto the front of a cellphone's screen. The patient looks into a small lens, and presses the phone's arrow keys until sets of parallel green and red lines just overlap. This is repeated eight times, with the lines at different angles, for each eye. The whole process takes less than two minutes, at which point software loaded onto the phone provides the prescription data. The device is described in a paper by MIT Media Lab Associate Professor Ramesh Raskar, Visiting Professor Manuel Oliveira, and Media Lab student Vitor Pamplona (lead author of the paper) and postdoctoral research associate Ankit Mohan, that will be presented in late July at the annual computer-graphics conference SIGGRAPH.

"Our device has the potential to make routine refractive eye exams simpler and cheaper, and, therefore, more accessible to millions of people in developing countries," Oliveira says.

"People have tried all kinds of things, some very clever," as possible replacements for the heavy and expensive conventional eye-testing

systems, says Mohan. "The key thing that differentiates ours is that it doesn't require any moving parts." The technology takes advantage of the huge improvements over the last few years in the resolution of digital displays and their widespread proliferation on cellphones, even in some of the world's poorest countries — there are now some 4 billion cellphones in the world. Apart from the software to run on the phone, all that's needed is the snap-on plastic device, which Mohan says can be produced at a cost of about $1 to $2 today but could cost only a few cents in large quantities.

The device uses an optical system derived from one some team members developed last year as a way of producing tiny barcodes (called Bokode) that could provide a large amount of information. Raskar explains that he had demonstrated that barcode device to many people, but when he showed it to his wife she had trouble seeing its patterns. He quickly realized that others he had shown it to had been wearing their glasses or contact lenses, but his wife had been looking into it directly and it had revealed the imperfections in her vision. "I said, 'Wow, maybe you don't need such an expensive device'" as those presently being used to test people's vision, Raskar recalls.

Focusing at different depths

The prototype system Raskar and his group developed as a result of that insight has an array of tiny lenses and a grid of pinholes that, combined with the software on the phone, "forces the user to focus at different depths" so the eye's focusing ability can be measured. Essentially, Raskar explains, the test works by transforming any blurriness produced by aberrations in the eye into an array of separate lines or dots instead of a fuzzy blob, which makes it easier for the user to identify the discrepancy clearly. Rather than estimating which of two views looks sharper, as in conventional eye tests, the user adjusts the display to make the separate lines or dots come together and overlap, which corresponds

to bringing the view into sharp focus. The underlying principle is similar to that used by new "adaptive optics" systems that have recently allowed ground-based telescopes to exceed the performance of the Hubble Space Telescope; these sometimes use the same kind of Shack-Hartmann sensors used in eye testing aberrometers.

NETRA combines inexpensive optical elements with interactive software components to create a new, portable, and low-cost optometry system. Image: Tiago Allen

The team will be field-testing the device in the Boston area this summer and will later test it in developing countries. The team already has applied for a patent on the system, named NETRA (Near-Eye Tool for Refractive Assessment), and team members won a prize this year in MIT's annual IDEAS competition — a contest for inventions and business ideas that have a potential to make a significant impact in the developing world — and were semi-finalists in the 2010 student-run MIT $100K Business Plan Competition.

Chika Ekeji, a student at the MIT Sloan School of Management who joined the team to help with commercialization of the system, says the

group plans to launch production of the device as a for-profit company called PerfectSight, initially targeting parts of Africa and Asia. Ultimately, they also hope to produce a more advanced version that can incorporate its own higher-resolution display and be able to detect other conditions such as cataracts, which could be sold in the developed world as well. IT consultant Margaret McKenna is also assisting the team.

Mohan says the way new technology has made such a simple, inexpensive and portable eye-testing device possible is analogous to what has happened in the field of photography. A century ago, he says, to have a picture taken you would go to a special studio that had large, expensive equipment, and then you would wait days to see the resulting photograph. "Today, it's something everyone has in their pocket," he says.

By using high-resolution LCD displays with this system, it is potentially not only much faster than today's standard methods, but also "potentially more accurate," Raskar says, although that hasn't yet been demonstrated.

"I've tried it myself, and found it to be very impressive," says Ken Perlin, professor of computer science at NYU's Media Research Lab, who is not connected with the project. "I think they found a real sweet spot where the right software can allow a consumer device to perform an accurate measurement of optical acuity that formerly required extremely expensive equipment." And ophthalmologist Francis D'Ambrosio of Massachusetts-based D'Ambrosio Eye Care says that once it is proven though clinical trials, "I feel that this type of technology could go a long way to helping people who otherwise wouldn't have access to eye doctors and refractive eye exams."

More information: cameraculture.media.mit.edu/netra