Through the Glass, Lightly

I begin this article with the fundamental premise that wearable computing will fundamentally improve the quality of our lives [1]. I can make this claim because for the past 20 years I have been walking around with digital eye glasses (DEG), and I believe my life has been enhanced as a result. Perhaps I am biased about wearable computing, but like my EyeTap invention (www.eyetap.org) that computationally processes everything I see, I try to tell it like it is. I am of course, only a one person case study, but I know there are others out there who feel the same way as I do, and perhaps for very different reasons.

It is well known that when traditional optical eyeglasses were first invented, many wearers of these eyeglasses were treated poorly and discriminated against. But as time went on, society began to accept eyeglasses, even to the point where they have, in some instances, become fashion statements. Many people, who have no need for spectacles, will purchase zero prescription eyeglasses just to look smart. This says a lot about technological innovation and how society responds to it over generations of varying levels of acceptance.

Especially as we age, it is my prediction that many of us will choose DEG, which can correct for more than just focus (e.g., prescriptions can be adaptive and interactive). And the wearable computer becomes, in effect, like part of the brain itself: "Eye is a camera" and "mind is a computer" [2].

Over the past 34 years of living my life through wearable computing, I have found myself on the receiving end of some shocking behavior. I can only describe it as resistance to technology. My guess is that some people are frightened of the cameras that are necessary for the functioning of mediated, augmented, and augmediated reality. People are possibly frightened of being recorded, or just plainly frightened of how the video may be captured and used against them at a later date. In the vast majority of adverse situations I have found myself in, people belonging to large multinationals and government agencies have been the most heavy-handed with me about wearable technologies. It is ironic that those who are most frightened by my single camera, use numerous surveillance cameras throughout their establishments to

Mann's 1999 "EyeTap Digital Eye Glass"

My EyeTap invention (illustrated here at top of p. 10.) was inspired by the need to see better while learning how to weld in early childhood.

Although it has varied over the last 34 years, the basic idea is to cause the eye itself, in effect, to function as both a camera and display. The device gives the wearer the appearance of having a "glass eye;" this phenomenon is known as the "glass eye" effect [16]. Over the years the EyeTap has also therefore been known as the "Glass Eye" or "Eye Glass", or just "Glass" or "Digital Eye Glass" [17].
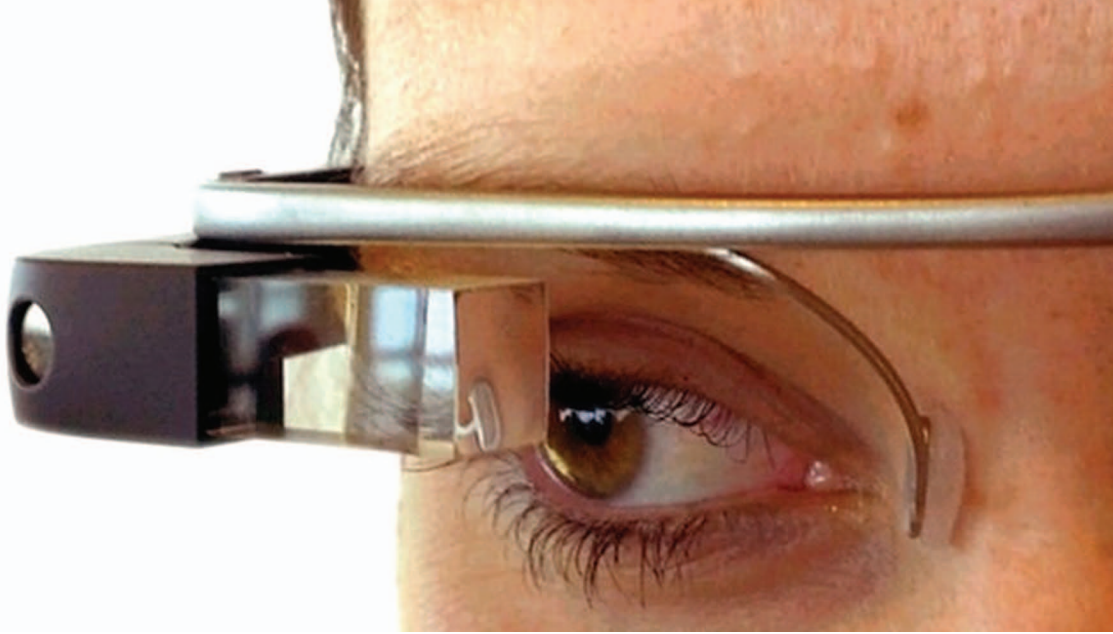
watch their employees, to watch their clients interacting with products, and to watch citizens just passing by the sidewalk going about their everyday business.

I am grateful that until now, objections about the EyeTap DEG I invented and wore nearly everywhere in my day-to-day life have been very rare. The majority of individuals that raise questions about my EyeTap are appeased when I provide them with a simple explanation of what the eyeglasses do, and how they help me. Basically individuals can work things through by running their own ethical assessment tests, some as basic as the *"if I were in his shoes would I do the same?"* But when a large organization has a policy against cameras, we have a fundamental problem that, on the surface, would seem to have a chilling effect on mass acceptance of DEG.

This Makes Us Ask: "What is a Camera?"
The word "camera" in Latin means "room" and it is usually an abbreviation for "camera obscura" which means "dark room." That is the technique that was used for developing pictures (and many paintings) since as far back as the days of Leonardo da Vinci. Cameras come in many forms. A cardboard box with a hole in it is a camera. The human eye is a camera, and taking this metaphor further, the human brain is a recording device. Someone who claims to have a photographic memory can see something and remember it for his or her own purpose. In short, this is to provide an eyewitness account. But if he makes a detailed painting of what he saw, and puts the painting on exhibit, he may be violating the privacy rights of others.

Today, my DEG captures 120 pictures per second, in groups of three: one that is underexposed, one that is normally exposed, and one that is overexposed. The computer then combines these together to help me see

Over the past 34 years of living my life through wearable computing, I have found myself on the receiving end of some shocking behavior.

better, using something that I invented in 1996 called High Dynamic Range (HDR) [3], [4].

In theory, if I see and remember something (whether in a temporary short-term image cache, or permanently), and keep it for my own personal use, I have not violated anyone's privacy. This issue has come up a number of times in various establishments, and we have generally been able to reach an agreement that my personal use of imaging is actually less of a violation of privacy than the surveillance cameras that are already present in most spaces, public or private.

Precedents have already been established from the days of audio recording: it is far more acceptable for a party to a conversation to keep a recording of the conversation, than it is for a third (non-participant) party to do so.
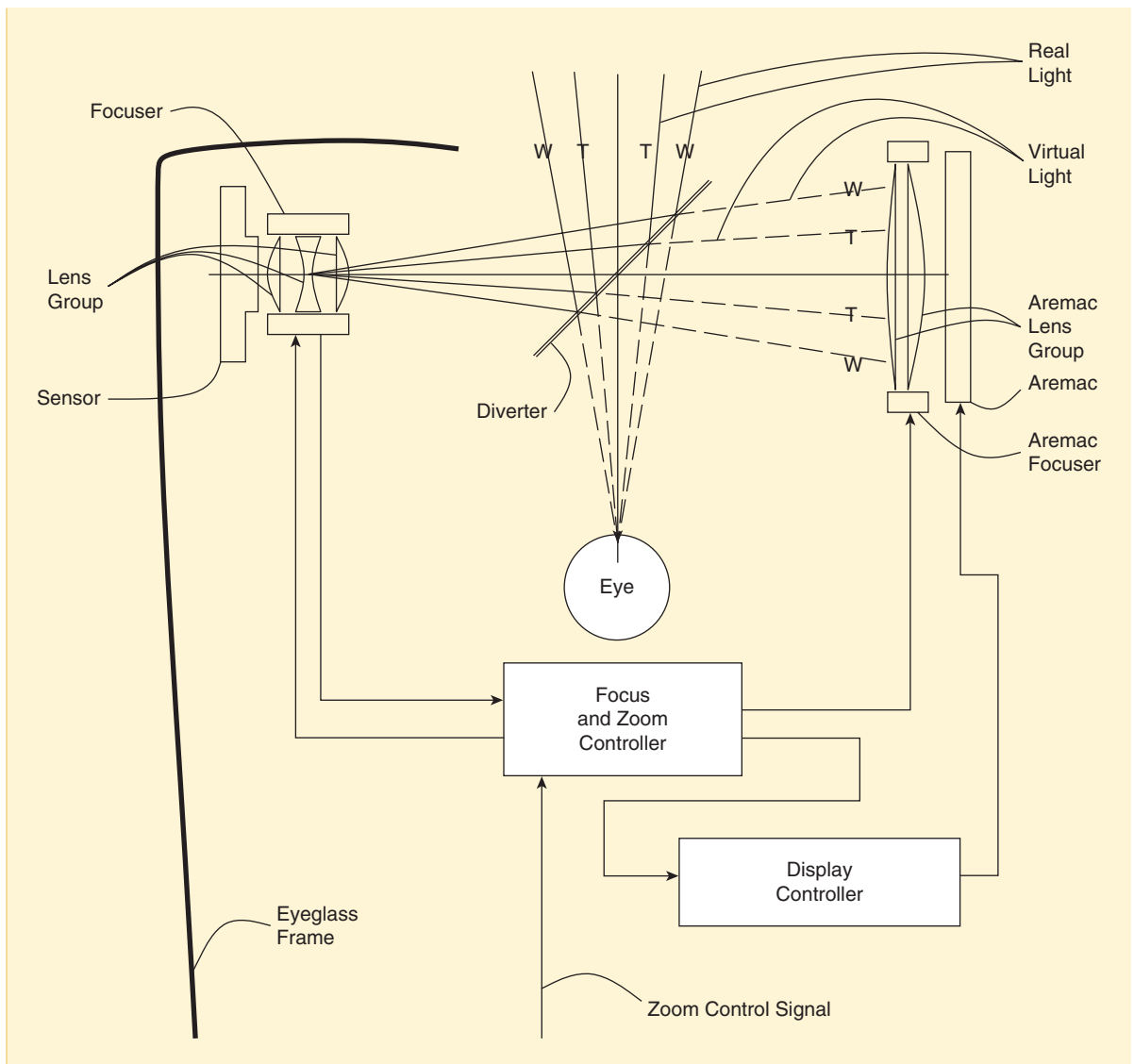
To try and stop people from taking pictures in public spaces in 2012 would be almost impossible. One can just look around and see how young people in particular are utilizing their smart phones. But there are even cheaper, completely covert cameras that can be purchased for less than US$40, such as covert eyeglass-based wearable cameras. Most smart phones today can surreptitiously take pictures. Some smart phone applications can continue to record even while making the phone look like it is turned off.

The camera is therefore easy to completely conceal. The part that is difficult to conceal is the part that functions as a seeing aid. So attacking someone with a seeing aid is pointless. If their only goal was merely to record without correction to their sight, i.e., without

2012, Google Glass

Shown above, top of p. 11.

Real
Light

Virtual
Light

Focuser

W T   T W

Lens
Group

W

T

Aremac
Lens
Group

Sensor

T

Aremac

W

Diverter

Aremac
Focuser

Eye

Focus
and Zoom
Controller

Display
Controller

Eyeglass
Frame

Zoom Control Signal

better vision, there already exist a plethora of technologies to do that recording, secretly and covertly!

Personally, I feel safer living in a world with so many smart phones around me, to counteract the otherwise one-sided effect of what could otherwise be a one-sided surveillance society.

Ubiquitous personal cameras have helped society evolve not so much into an Orwellian surveillance nightmare, but more into a "veillance" society where the boundaries between surveillance (watching from above) and sousveillance (watching from below) have become blurred [5]-[6]. In many ways this blurring of the boundaries is a good thing, to which David Brin refers to "The Transparent Society," for which "glass" is the perfect metaphor [7].

Moreover, an organization or agency that tries to mandate what kind of eyeglasses a person wears or does not wear, is overstepping their authority and liable for the possible consequences. For example, if a person trips and falls down the stairs because they were required to remove their eyeglass by their employer, or anyone else (e.g., a building owner or shopkeeper), then there would be a liability on the part of the employer (or building owner or shopkeeper, or the like). It should be underscored at this point that rules regarding eyewear are a far more fundamental intrusion than, for example, prohibiting people from wearing blue shirts in your establishment.

Additionally, EyeTap creates the possibilities of much stronger eyeglass "prescriptions," so requiring a person to remove or shut down their eyewear may be much more intrusive than merely making the world appear out-of-focus.

We need either a statutory declaration that a seeing aid is not a "camera," to be prohibited in this sense – or we need to accept the existence of DEGs, in the

same light that surveillance cameras are somehow not "cameras" according to the rules that prohibit cameras as well.

I wear such a computer vision system to help me see and understand the world around me [8]. I originally created this technology, and the HDR computer vision algorithms to help people who had issues with their sight, visual memory, or sensory integration issues. I have also assisted a number of blind and visually impaired (i.e., partially sighted) persons with various projects, and I continue to conduct research in this area. I was also part of the team that invented, designed, and built rehabilitation technology for the Canadian National Institute for the Blind (CNIB), and this technology continues to be used by the CNIB today.

The "Surveillight": See the Light … and the Light Sees You

If you are playing a video game, perhaps at home, while you might not know it, you are probably on camera, even if you are still in your underwear. Gesture-sensing cameras capture your every move – not so much to spy on you, but simply to respond to your movements.

Many of the new light-emitting diode (LED) streetlights also have a camera in each light fixture, and some have multiple cameras in the lamp, to get better coverage. Motion-sensing streetlights are a longstanding idea that only recently came to fruition because of new breakthrough techniques like image-based motion sensing. The old kind of ultrasonic or microwave motion sensors did not work well for outdoor lighting at the scale of a typical street. But new image-based motion sensors work much better in this application. The raw cost of a camera is less than US$2, which is even less than some of the older motion-sensing technologies. And the image-based motion sensor works better because it can determine the speed and direction of moving objects, as well as a rough estimate of the number and type of objects (e.g., how many cars, how many bicycles, and how many people). Many cities are installing camera-based motion-sensing streetlights as part of their energy savings efforts. These motion-sensing streetlights carry a small camera in each light that tracks street usage and reduces light output (but never turns the light completely off) when no one is on the street. When one light "sees" a car it determines the speed and direction of the car and sends messages to the lights up ahead to make a buffer of light maybe 10 lamp posts ahead of the car but only 2 or 3 behind the car, for example.

The cameras in modern streetlights are also used for urban planning and intelligent communities to name but a few applications, beyond merely controlling the lights in which they reside. Such systems have been installed in many European, Far East, and American cities. There are various companies installing vision systems in streetlights. In addition to the skyward pointing light sensor, there is an image array pointing downwards at the street. Some of these companies like Philips, and Tvilight are based in Europe, whereas others like KMW are located in the Far East, and there are others like SmartSite and Eco City Lights that are located in the United States. There is also a noticeable convergence of different applications using image-based sensing.

Table I shows three primary purposes for building one or more cameras in every streetlight.

Some groups have expressed privacy concerns about cameras in streetlights, but the energy savings alone will make it necessary to address these privacy concerns by technological means, much like the Privacy and Veillance (Priveillance™) technology being developed in my lab – rather than by removing or not installing the cameras.

Table I	
Reasons to Build Cameras into Streetlights	
Energy Management	Motion sensing, occupancy estimation, usage estimation, and other techniques, are used to automatically control the dimming of the lights. Such automated light dimmers, on average, represent a typical savings of 72% to 80% [9].
Public Safety	Many police forces already put cameras throughout a city. But the position of the camera relative to ambient sources of light such as streetlights varies. Some cameras have a light to the left, casting shadows to the right, or vice-versa. Other cameras have a light directly above them, whereas still others end up being positioned directly across from a light that is in their field of view (FOV) resulting in glare. By integrating streetlighting with surveillance, the picture quality from the cameras is much better because there are no shadows from the primary source of illumination (i.e., from the streetlight). Thus it is alleged that documentation of traffic accidents, emergency notification, and crime deterrence, prevention, and evidence-gathering could become greatly improved.
Civic Management	Citywide surveillance can answer questions like "how many cars were parked on this street or that street, and what is the peak utilization of this street or that street..." [10], [11]. This information can help civic planners decide which roads to enlarge or which roads to put on a "street diet" [12].

I have predicted for some time that before too long there will be a camera or at least a place to install a camera, in every manufactured streetlight. Moreover, as this technology is already widely used in streetlights, it is now moving to other lighting applications. Lighting Science Group, for instance, has recently released a new product that is a light fixture that has a camera in it [13]. Texas Instruments also now makes a camera-based occupancy sensor for use in "offices, classrooms, copy rooms, restrooms ..."

Should there be Surveillance in Private Places?

Just about anywhere you go in public you will likely be on camera. The average person living and working in London is recorded on dozens of cameras each day. In the past, some places were off limits to surveillance. Once upon a time, people who installed cameras in change rooms, toilets, or shower areas were arrested and charged with offenses against the person such as voyeurism. But more recently things have begun to change. Gym managers are even calling for change rooms to be rigged up with surveillance cameras, in full view of naked people changing and showering and dressing. Once upon a time Privacy Commissioners would frown upon locker room surveillance, but another recent headline read "Alberta Commissioner upholds cameras in locker rooms at health club" [14]. When such cameras are installed in change rooms for our so-called "safety" there is something very wrong.

A number of surveillance cameras have also been installed in washroom areas as well, and acceptance of this practice is growing. Moreover, as washrooms are automated with computer vision systems, cameras are being used to automate various plumbing fixtures. See for example Masco Corporation's use of charge-coupled device (CCD) cameras to automate plumbing fixtures [15]. There is always the possibility that surveillance installed for one purpose may be used for another. I refer to this effect as *conveillance*, i.e., concomitant usage that ends up being applied for surveillance. Is ubiquitous surveillance good for society? Perhaps this question is now redundant. It would seem that society has come to accept ubiquitous surveillance without questioning it.

Life in the "Glass Age"

Regardless of whether or not ubiquitous surveillance is justified, should those people who accept surveillance not also accept sousveillance? When we are surrounded by "smart lights," "smart toilets," "smart refrigerators," and the like, what is wrong with having "smart people?" That is, what is wrong with putting intelligence on people?

Many shopkeepers use surveillance cameras while prohibiting customers from bringing their own cameras into their shop. Does this suggest that merchandise is worth more than people? From the mere practical viewpoint, should a person (and their personal space) not be afforded the same protection as merchandise (and its premises)? In some sense, clothing is like a building designed for a single occupant. So wearable computing will likely evolve as a sousveillance system to protect the wearer. For example, upon finding the fire exits illegally chained shut, there is a moral and ethical duty to photograph this condition, as evidence of criminal activity, regardless of any rules against such photography.

Moreover, as building owners begin to embrace augmediated reality with QR codes and the like, they will embrace and facilitate wearable computing and the wearable computer vision systems that go along with it.

Author Information

Steve Mann is Professor in the Department of Electrical and Computer Engineering at the University of Toronto, Canada, and Director of the EyeTap Personal Imaging (ePi) Lab. Email: mann@eecg.toronto.edu.

References

[1] S. Mann, "Wearable computing," in *Encyclopedia of Human-Computer Interaction*, M. Soegaard and R.F. Dam, Eds. Aarhus, Denmark: The Interaction Design Foundation, 2012; http://www .interaction-design.org/encyclopedia/wearable_computing.html.
[2] "I AM A CAMERA: Humanistic Intelligence is the medium; our everyday living is the message," Keynote Address at the McLuhan Symposium on Culture and Technology, Many Dimensions: The Extensions of Marshall McLuhan, Oct. 23 - 25, 1998; http://wearcam.org/ mcluhan-keynote.htm.
[3] U.S. Patent 5828793.
[4] S. Mann, R.C.H. Lo, K. Ovtcharov, S. Gu, D. Dai, C. Ngan, and T. Ai, "Realtime HDR (high dynamic range) video for eyetap wearable computers, FPGA-based seeing aids, and glasseyes," in *Proc. IEEE CCECE 2012* (Montreal, Canada), 2012.
[5] "Sousveillance," Wikipedia; http://en.wikipedia.org/wiki/Sousveillance.
[6] S. Mann, "Sousveillance: Inverse surveillance in multimedia imaging," *ACM Multimedia,* pp. 620–627, 2004.
[7] D. Brin, *The Transparent Society.* Addison Wesley, 1998.
[8] "Eyetap Personal Imaging lab," *Eyetap*; http://www.eyetap.org, access Aug. 15, 2012.
[9] B. Coxworth, "Intelligent street light system uses 80 percent less electricity," *Gizmag*, July 12 2011; http://www.gizmag.com/motion-sensing-streetlight-system/19199/.
[10] Smart City. http://en.wikipedia.org/wiki/Smart_city
[11] http://ec.europa.eu/information_society/events/smartenergy/documents/joan_battle_montserrat-barcelona.pdf
[12] "Road Diet," *Wikipedia*; http://en.wikipedia.org/wiki/Road_diet, accessed Aug. 15, 2012.
[13] "Pixelview," Lighting Science; http://www.lsgc.com/pixelview/, accessed Aug. 15, 2012.
[14] D.T.S. Fraser, "Alberta Commissioner upholds cameras in locker rooms at health club," *Canadian Privacy Law Blog,* Mar. 22, 2007; http://blog.privacylawyer.ca/2007/03/alberta-commissioner-upholds-cameras-in.html.
[15] J. Iott, "CCD camera element used as actuation detector for electric plumbing products," U.S. Pat. Application 20060231782, 2007.
[16] S. Mann, "Mediated reality with implementations for everyday life," *Presence Connect*, 2002; http://wearcam.org/presence-connect/.
[17] A. Harris/Canadian Press, CBC News, Dec. 22, 2003; http://www. cbc.ca/news/background/tech/cellphones/mann.html.