Designing EyeTap Digital Eyeglasses for Continuous Lifelong Capture and Sharing of Personal Experiences

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ABSTRACT

Humans increasingly engage themselves in their computational world as much as the physical world. Following this need for constant connectivity, computing devices such as Personal Digital Assistants (PDAs) and camera phones have become more wearable. We introduce the EyeTap personal experience capturing system EyeTap digital eyeglasses cause the eye to, in effect, function as if it were both a camera and display, by mapping an effective camera and display inside the eye. Eyetap therefore captures images exactly as they were originally seen by the user. Since sight is a primary sense this interface becomes intuitive and easy to use for continuous capture and sharing of personal experiences. This paper will discuss the EyeTap's evolution over the last 30 years; some encountered design principles, the various EyeTap applications and future social aspects that may arise from EyeTap technology.

ACM Classification Keywords

H.5.2 User Interfaces: Input Devices and Strategies; H.5.1 Multimedia Systems: Artificial, augmented and virtual realities

Author Keywords

Lifelong Experience Capture, Cyborglogging, Design

INTRODUCTION

Vannevar Bush envisioned an age when storage would become so massive that it would allow us to record everything in our lives [2]. Later, individuals such as Gordon Bell followed up upon the vision, which later gave birth to the MyLifeBits project [5]. Engelbart saw that the computer could augment human intellect [4] through this storage ability and its computational ability. With the development of wearable personal electronics, such as smart phones or personal digital assistants (PDAs)Engelbart's vision has become closer to reality. Nowadays, it has become increasingly easier to capture and share our personal experiences with others, as seen by early mobile phone bloggers such as Joi Ito [6]. Unlike image capture devices before, these camera phones and other similar devices are becoming increasingly *continuous* in nature, recording large amounts of data at any point of the day. Many have described our growing integration with these continuously connected personal experience capture devices as the "cyborg" era [11]. There has been a large interest recently in continuous archival and retrieval of personal experiences, especially with wearable head-born or eyeglasses born systems. Dickie et al. "eyeblog" eyeglass based video archival tool uses eye contact to edit the large amount of footage obtained from a continuous video capture system records upon eye contact from others with the user [3]. Meanwhile Aizawa et al. have explored efficient video retrieval of large archived life logs based upon context and content from a head mounted video system [1].

Personally driven to explore new ways of seeing, EYETAP eyeglass devices have been invented, designed, built and used over the last 25 years [9]. Long term usage in day-to-day life has led to greater insights into some of the issues normally undiscoverable in a controlled lab setting. These design issues include not only the possibilities offered by the device or its long-term effects, but also some sociological and humanistic factors such as how others react to such devices.

BACKGROUND

Traditional Lens-based 'Analog' vs EyeTap Electric 'Digital' Eyeglassess

Traditional optical (analog) eyeglasses have been limited to modifying light by refraction of light. "EyeTap" electric (digital) eyeglasses could also modify light computationally. With EyeTap eyeglasses, for example, instead of having to get new lenses ground, our eyeglass prescriptions could be downloaded over the Internet.

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Traditional lens based eyeglasses have corrected various optical disorders, but they have also extended some of our visual abilities. Sunglasses or welding glasses allow us to see very bright scenes while magnifying lenses (such as a jeweler might use), allow us to see very small objects. In contrast, EyeTap electric eyeglasses merge all of these different analog visual aids into a single device enabling it to perform in a variety of situations. These "digital" eyeglasses could one day provide users with many enhancements over traditional eyewear, where each one of these aids used alone will not suffice. As analog eyeglasses resyntesize light by a refractive optical element, EyeTap digital eyeglasses computationally resynthesize light through the EyeTap arrangement as seen in Figure 1.

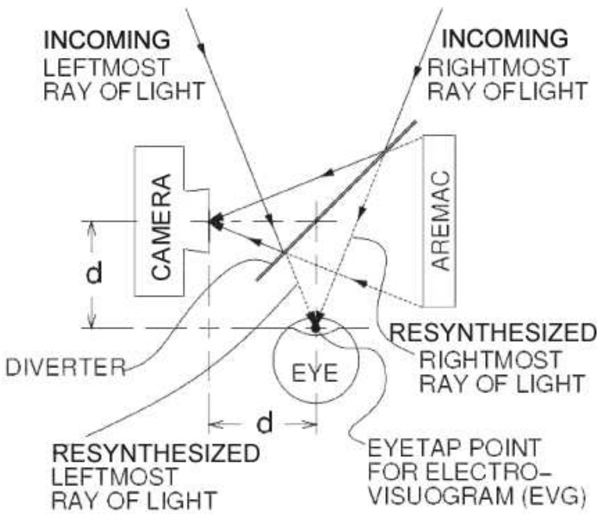

Figure 1: Shows the EyeTap arrangement that allows for merging the real world with the computer world. Incoming light rays are reflected into a sensing element, such as a camera, by a 'diverter, an optical element coated on both sides in reflective or semi-reflective material. These diverted light rays are digitized by the sensing element and then the light data is computationally processed. The resynthesized light data is then outputted by the "AREMAC", a kind of micro-display, which projects the resynthesized light back onto the diverrter which then reflects the beams into the eye. It is important to note that the resynthesized light is colinear to the original incoming light, this creates a merging of virtual and real light known as the 'illusory transparency effect.'

Computer Enhanced Vision & Mediated Reality

The EyeTap's ability to computationally resynthesize incoming rays of light before they reach the user, allows for a number of powerful possibilities. Many eye disorders, which require some form of seeing aid beyond traditional eyewear could be addressed through a computer enhanced vision algorithm to make simple tasks such as reading easier for the visually impaired.

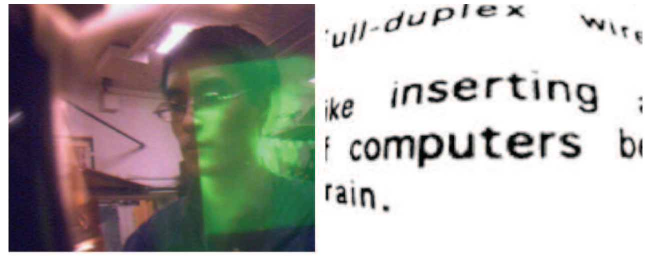

Figure 2: (left) An actual view looking out of the EyeTap eyeglasses. The image on the AREMAC micro display is reflected from the diverter as a rectangular mediation zone. As seen from the image, the subject matter has been computationally enhanced and mediated in this area. Also note, the subject matter is collinear with the virtual image due to the EyeTap setup, creating an 'illusory transparency'. (right) EyeTap can act as a computational seeing aid for the visually impaired in tasks such as reading.

EyeTap enables for mediated reality, the ability to computationally augments, diminishes, or alters visual perception in day-to-day situations in real time. The EyeTap can help us identify faces by comparing an incoming image to a collection of stored faces. Once the wearer confirms a match, the the eyetap mediated reality system inserts a virtual name tag into the wearer's field of view, creating the illusion that a person is actually wearing a name tag. The name tag will stabilize on the person even though the image field moves using the "video orbits" homography algorithm [10].

Figure 3: Shows a valid use of an EyeTap tool to label faces with virtual name tags to augment memory

Cyborglog: Continuous Capture & Sharing of Personal Experiences

Important features of EyeTap devices however, have no analog in traditional eyewear. The name EyeTap itself implies that we are able to "tap" into the user's eye, much as a phone tap intercepts a phone conversation. This unique configuration makes the EyeTap ideal for lifetime capture of personal experiences, particularly visual ones, because it captures the image at the point of entry to the user, the human eye. A camera worn on the shoulders, or neck, or other places on the body would not be ideal since images captured from these areas would not be relevant since they do not capture images as visually experienced by the user. The EyeTap configuration as seen in Figure 1, causes the eye to, in effect, function as if it were both a camera and display, by mapping an effective camera and display inside the eye.

Wearing EyeTap digital eyeglasses can help us remember better, through what is called a lifelong "cyborglog" or 'glog, for short. A 'glog uses continuous lifelong video capture to record exactly what our eyes see over an entire lifetime. Essentially, a 'glog is a recording of an activity made by a participant in the activity. EyeTap's hands-free nature makes it easy for day-to-day use, and ideal for 'glogging. As opposed to other forms of blogging, glogging is a continous process in which there is effortless image capture.

The advantages of 'glogging with a device such as an EyeTap is never missing the most important aspects of one's life. A living and permanently installed/instilled photographic perspective allows the bearer to capture the birth of a newborn, or to capture baby's first steps, as shown in the Figure 4.

By digitizing the world around us, EyeTap empowers the user with the data management capabilities of modern computers. By mapping the display into the eye, the user does not have to move from the line of sight to see the digital content. This allows unobtrusive personal retrieval of digital information, such that others are unaware that personal archives or any other data are being accessed at all. Thus, EyeTap enables seamless recall of anything we have seen with perfect clarity in a natural and intuitive way, by seeing the captured experience exactly the way we originally saw it. This on-demand photographic memory aid offloads our own mental resources.

Figure 5: Shows the birth of a newborn (Christina Mann, as documented in Christina's 'glog at URL, http://christinamann.com), and a little over a year later, Baby's First Steps

Vicarious Soliloquy: Eye am a Document Camera

The EyeTap enables others to "Enter your shoes and see the world from your perspective" page. The demonstration of this technique has seemed to be typically quite surprising to many different types of audience. Demonstrations, such as keynote addressses, involved an EyeTap wearing lecturer,making illustrative notes, walking amongst the audience, and talking to people one–on–one, transmitting their conversation to the projection television screen at the front. An excerpt from this reality stream as seen in Figure 5, shows how the audience was, in effect, able to "be" the wearer, rather than just see the wearer, from Eyetap's first–person perspective. There is an existential aspect here since it puts the audience, in effect, inside wearer's head to share their viewpoint. The EyeTap causes the eye itself to, in effect, function much like the document camera, which is common in many presentations.

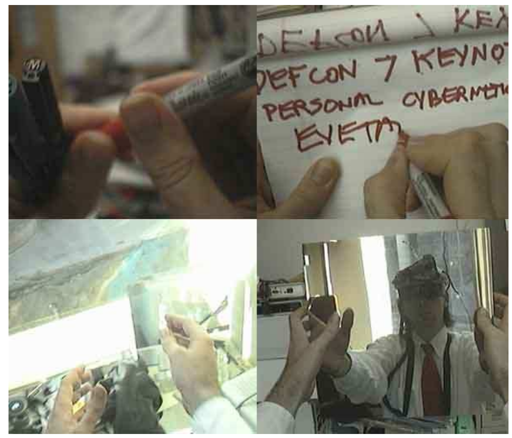

Figure 6: An example of the Vicarious Soliloquy genre was Manns Keynote Address at DEFCON 7.

History of Previous EyeTap Designs

Since the 1970s EyeTaps have been invented, designed, built, and worn as for the creation of electronically mediated environments. The EyeTap's design practise followed the evolution of the wearable computer systems as they were being used for computationally enhanced vision and personal experience capture.

Initially, during the early experimental days, EyeTap systems were used to visualize the mediated reality environments created in the visual art of 'Dusting'(Figure 7, left). During the 1970s, EyeTaps were crudely built with the cathode ray tube (CRT) salvaged from a video camera, as seen on the helmet in Figure 8. This early EyeTap could present both text and images.

Over the years the miniaturization of capture and display electronics has allowed for the EyeTap to shrink to an acceptable and weight for wearability. With the advent of consumer camcorders, miniature CRTs became widely available, making possible the late 1980s EyeTap design as shown in Figure 7. We used a 0.6-inch CRT facing down (angled back to stay close to the forehead). This apparatus was later transferred to optics salvaged from an early 1990s television set. Though still somewhat cumbersome, the early 1990s unit could be worn comfortably for several hours at a time. An Internet connection through the small hat-based whip antenna used TCP/IP with AX25 (the standard packet protocol for ham radio operators).

By the late 1990s, miniaturization had driven the devices to having a completely normal appearance. However, subsequent realization that covertness stigmatizes the activity, led to a more 'overt' approach.

Figure 7: (left) Lightvector painting of Brooklyn Bridge made with WearComp7 system. 'Dusting', similar to what traditional photographers describe as 'painting with light', differed in its use of combining of multiple exposures of a scene through quantigraphic image processing or lightspace rendering. This enabled the creation of long exposure images with a single handheld flash. At a photo shoot, users with an EyeTap could see the scene as it evolved through the 'Dusting' process initiated by the hand held flash lamp input device. (right) This version of the EyeTap, now being shown at the Smithsonian, is particularly illustrative of why miniaturization became so essential

Figure 8: The evolution of our invention for seeing everyday spaces in a different light

EYETAP DESIGN PRINCIPLES

The EyeTap's design has evolved considerably over the years with shrinking components making it more commercially feasible. There are already many head mounted displays (HMDs) in the market but the unique configuration of an EyeTap with a camera, display and diverter allows for it to not only merge your real world with the digital one it also enables precise lifetime personal experience capture. Also to be continuously worn, as a pair of spectacles or a wristwatch, the ideal design has to be such that the user forgets it is being worn at all. To acheive these thing, some critical points must be satisfied.:

- **The EyeTap distance**: Considering the EyeTap configuration of Figure 1, the distance from the diverter to the eye should be exactly equal to that space between the diverter and the camera or the display. This calibration is vital to achieve the illusory transparency as seen in Figure 2. for mediated reality and to effectively place the camera in the position of the eye for effective personal experience capture.
- **Ergonomics of the head**: Since the diverter must lie exactly in front of the eye, the design needs to fit different people irregardless of different head shapes, ear-eye distances or nose bridge heights.
- **EyeTap weight**: Humans these days wear enough electronic components, EyeTap must acheive its goals without burdening the user with excessive weight on the face or at least distributing this weight in a comfortable way.

Current EyeTap Prototypes

The early prototypes were quite obtrusive and often made people ill at ease, but recent prototypes have been gaining acceptance in social situations. This can be attributed partly to miniaturized smaller units, but also to dramatic changes in the attitude toward personal electronics. With the popularity of camera phones, bluetooth headsets, and so forth, such devices may even be considered fashionable.

The custom made injection moulded EyeTap, as seen in Figure 9,ensures that the EyeTap distance criteria is satisfied by use of a wrap around frame that ensures a snug fit around the user's head and precise positioning of the diverter, camera, and micro-display. A custom fitted eyepiece based upon the head ergonomics was created to fit according to the user's exact facial measurements. The head wrapped frame with a custom fitted eyepiece, ensured that weight was evenly distributed throughout and reducing stress on any single point.

Although experimental, a future EyeTap design in Figure 10, in which the frames come right through the center of the visual field, proves the possibility of using eyeglass frame itself as a mediating element. Eyeglass frames were assembled using standard photo-chromatic prescription lenses and modified to accommodate a break in the eyeglass frame along the right eyeglass lens. To miniturize the optical system further, fiber optic bundles were bonded and concealed by the frames at the former position of the camera and display, and moved the actual camera and aremac to the back of the device. The camera and display then operated remotely by way of the fibre optics.

The frames do not block the user's vision, since they are slender enough (approximately two millimeters wide) do not appreciably interfere with normal vision, but more importantly since the frames have become a part of the mediating element, as seen by the EyeTap's illusory transparency effect as seen in Figure 2 they have essentially become computationally transparent. This brings about a role reversal of eyeglass frames and eyeglass lenses, in which the eyeglass lenses are a decorative design element, whereas the frames are what enables the seeing.

Figure 9: New injection moulded design. From this figure we see how the camera has been effectively mapped to the position of the human eye by the EyeTap configuration as outlined in Figure 1.

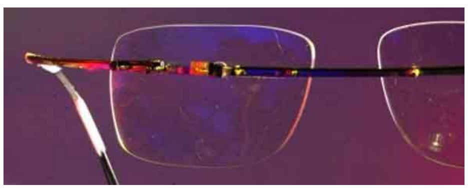

Figure 10: In one design prototype, the computational element of the eyeglasses is incorporated into the eyeglass frames

Future Social Aspects: Sousveillance

The Cyborglog can also be used for personal safety gainst criminal acts by allowing for trusted third party visual evidence in situations where the user may feel threatened. At the same time, these technologies are changing social hiearchies. Information is power, seeing is believing, and organizations believe in power – power over individuals. But the tables are turning. The very miniaturization that has made it possible for police to hide cameras in shopping-mall washrooms has also made camcorders small and light enough for average citizens to carry around and capture events like the Rodney King beating, and similar human rights abuses around the world. As with many problems, the problem of surveillance contains its own solution. Whereas the word "surveillance" derives from the French for oversight, "sousveillance" is a term coined which describes "seeing from below" [8]. In essence, sousveillance balances the forces of surveillance by providing a tool which watches the watchers.

CONCLUSION

The EyeTap electric digital eyeglasses have evolved considerably from headsets of the 1970s, to EyeTaps with optics outside the glasses in the 1980s, to EyeTaps with the optics built inside the glasses in the 1990s to EyeTaps with mediation zones built into the frames, lens edges, or the cut lines of bifocal lenses in the year 2000. As the need for continuous lifelong capture of experiences continues to become more widespread, with the development of camera phone devices and others it becomes more relevant that designers create devices which integrate into the user's life such that capture becomes effortless. We present EyeTap as one such device, and as the prevalence of such cameras becomes more available then the techno-sociological impact these devices bring also becomes more apparent.

REFERENCES

1. Aizawa, K. Tancharoen, D. Kawasaki, S. Yamasaki, T. Efficient retrieval of life log based on context and content. *In Proceeding in 1st ACM Workshop on Continuous Archival Retrieval of Personal Experiences.* Oct. 15, 2004 pp. 22-31
2. Bush, V. As We May Think. *Atlantic Monthly.* July 1945.
3. Dickie, C. Vertegaal, R. Chen, D. Fono, D. Cheng, D. Sohn, C. Augmenting and Sharing Memory with eyeBlog. *In Proceeding in 1st ACM Workshop on Continuous Archival Retrieval of Personal Experiences.* Oct. 15, 2004 pp. 105-109
4. Engelbart, D. Augmenting Human Intellect: A Conceptual Framework *Research Report AF)SR-3223.* Stanford Research Institute
5. Gemmell, J. Bell, G. Lueder, R. Drucker, S. Wong, C. MyLifeBits: fulfilling the Memex vision. *Proceeding of the tenth ACM International Conference on Multimedia.* Dec. 1-6, 2002, pp. 235-238
6. Ito, J. *Joi Ito's Moblog.* http://joi.ito.com/moblog/
7. Mann, S. *Intelligent Image Processing.* John Wiley and Sons, November 2 2001. ISBN: 0-471-40637-6.
8. Mann, S. Sousveillance: Inverse Surveillance in Multimedia Imaging *Proceedings of the 12th annual ACM international conference on Multimedia* 2004, pp. 620-627
9. Mann, S. and Fung, J. EyeTap devices for augmented, deliberately diminished, or otherwise altered visual perception of rigid planar patches of real world scenes. *PRESENCE*, Vol. 11, No. 2, 2002, pp. 158-175
10. Mann, S. and Fung, J. VideoOrbits on EyeTap Devices for Deliberately Diminished Reality or Altering the Visual Perception of Planar Patches of a Real World Scene." *Proceedings of the Second IEEE International Symposium on Mixed Reality,* March 14-15 2001, pp. 48-55
11. Mann, S. with H. Niedzvieck *CYBORG, Digital Destiny and Human Possibility in the Age of the Wearable Computer.* Randomhouse (Doubleday), November 6 2001 ISBN: 0385658257.