PREFACE

This book has evolved from the author's course on personal imaging taught at the University of Toronto, since fall 1998. It also presents original material from the author's own experience in inventing, designing, building, and using wearable computers and personal imaging systems since the early 1970s.

The idea behind this book is to provide the student with the fundamental knowledge needed in the rapidly growing field of personal imaging. This field is often referred to colloquially as wearable computing, mediated (or augmented) 'reality,' personal technologies, mobile multimedia, and so on. Rather than trying to address all aspects of personal imaging, the book places a particular emphasis on the fundamentals.

New concepts of image content are essential to multimedia communications. Human beings obtain their main sensory information from their visual system. Accordingly, visual communication is essential for creating an intimate connection between the human and the machine. Visual information processing also provides the greatest technical challenges because of the bandwidth and complexity that is involved.

A computationally mediated visual reality is a natural extension of the next-generation computing machines. Already we have witnessed a pivotal shift from mainframe computers to personal/personalizable computers owned and operated by individual end users. We have also witnessed a fundamental change in the nature of computing from large mathematical "batch job" *calculations* to the use of computers as a *communications* medium. The explosive growth of the Internet (which is primarily a communications medium as opposed to a calculations medium), and more recently the World Wide Web, is a harbinger of what will evolve into a completely computer-mediated world. Likely in the immediate future we will see all aspects of life handled online and connected.

This will not be done by implanting devices into the brain—at least not in this course—but rather by noninvasively "tapping" the highest bandwidth "pipe" into the brain, namely the eye. This "eye tap" forms the basis for devices that are being currently built into eyeglasses (prototypes are also being built into contact lenses) to tap into the mind's eye.

The way EyeTap technology will be used is to cause inanimate objects to suddenly come to life as nodes on a virtual computer network. For example, as one walks past an old building, the building will come to life with hyperlinks on its surface, even though the building itself is not wired for network connections. The hyperlinks are created as a shared imagined reality that wearers of the EyeTap technology simultaneously experience. When one enters a grocery store with eyes tapped, a milk carton may convey a unique message from a spouse, reminding the wearer of the EyeTap technology to pick up some milk on the way home from work.

EyeTap technology is not merely about a computer screen inside eyeglasses. Rather, it is about enabling a shared visual experience that connects multiple perceptions of individuals into a collective consciousness.

EyeTap technology could have many commercial applications. It could emerge as an industrially critical form of communications technology. The WearTel™ phone, for example, uses EyeTap technology to allow individuals to see each other's point of view. Traditional videoconferencing that merely provides a picture of the other person has consistently been a marketplace failure everywhere it has been introduced. There is little cogent and compelling need for seeing a picture of the person one is talking to, especially since most of the time the caller already knows what the other person looks like, not to mention the fact that many people do not want to have to get dressed when they get up in the morning to answer the phone, and so on.

However, the WearTel phone provides a view of what the other person is looking at, rather than merely a view of the other person. This one level of indirection turns out to have a very existential property, namely that of facilitating a virtual being with the other person rather than just seeing the other person.

It may turn out to be far more useful for us to exchange points of view with others in this manner. Exchange of viewpoints is made possible with EyeTap technology by way of the miniature laser light source inside the WearTel eyeglass-based phone. The light scans across the retinas of both parties and swaps the image information so that each person sees what the other person is looking at. The WearTel phone, in effect, let's someone "be you" rather than just "see you." By letting others put themselves in your shoes and see the world from your point of view, a very powerful communications medium could result.

This book shows how the eye is tapped by a handheld device like WearTel or by EyeTap eyeglasses or contact lenses, allowing us to create personal documentaries of our lives, shot from a first-person perspective. Turning the eye itself into a camera will radically change the way pictures are taken, memories are kept, and events are documented. (The reader anxious to get a glimpse of this should check the Electronic News Gathering wear project at http://engwear.org, and some of the related sites such as http://eyetap.org or run a search engine on "eyetap.") Apparatuses like this invention will further help the visually challenged see better and perhaps help those with a visual memory disorder remember things better. It is conceivable that with the large aging population of the near future, attention to this invention will be on the rise.

The book is organized as follows:

1. *Humanistic intelligence:* The first chapter introduces the general ideas behind wearable computing, personal technologies, and the like. It gives a historical overview ranging from the original photographic motivations of personal cybernetics in the 1970s, to the fabric-based computers of the 1980s, and to the modern EyeTap systems. This chapter traces personal cybernetics from its obscure beginnings as a cumbersome wearable lighting and photographic control system to its more refined embodiments. The motivating factor in humanistic intelligence is that we realize the close synergy between the intelligence that arises from the human being in the feedback loop of a truly personal computational process.
2. *Personal imaging:* This chapter ponders the fundamental question as to where on the body the imaging system should be situated. In terms of image acquisition and display various systems have been tried. Among these is the author's wearable radar vision system for the visually challenged which is introduced, described, and compared with other systems.
3. *The EyeTap principle:* This chapter provides the fundamental basis for noninvasively tapping into the mind's eye. The EyeTap principle pertains to replacing, in whole or in part, each ray of light that would otherwise pass through the lens of at least one eye of the wearer, with a synthetic ray of light responsive to the output of a processor. Some of the fundamental concepts covered in this chapter are the EyeTap principle; analysis glass, synthesis glass, and the collinearity criterion; effective location of the camera in at least one eye of the wearer; practical embodiments of the EyeTap principle; the laser EyeTap camera; tapping the mind's eye with a computer-controlled laser (replacing each ray of light that would otherwise enter the eye with laser light); the author's fully functional laser EyeTap eyeglasses; infinite depth of focus EyeTap products and devices; and practical solutions for the visually challenged.
4. *Photoquantigraphic imaging:* This chapter addresses the basic question of how much light is desirable. In particular, when replacing each ray of light with synthetic light, one must know how much synthetic light to use. The analysis portion of the apparatus is described. Since it is based on a camera or camera-like device, a procedure for determining the quantity of light entering the camera is formulated.
5. *Antihomomorphic vector spaces and image processing in lightspace:* This chapter introduces a multidimensional variant of photoquantigraphic imaging in which the response of the image to light is determined. The discussion of lightspace includes the application of personal imaging to the creation of pictures done in a genre of "painting with lightvectors." This application takes us back to the very first application of wearable computers and mediated reality, namely that of collaborative production of visual art in a mediated reality space.

6. *VideoOrbits:* The final chapter covers camera-based head-tracking in the context of algebraic projective geometry. This chapter sets forth the theoretical framework for personal imaging.

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