ELECTRONIC EXPANSION OF HUMAN PERCEPTION

by Warren Robinett

VIRTUAL REALITY, as its name suggests, is an unreal, alternate reality in which anything could happen. In its 1991 technological implementation, virtual reality is a 3D video game you can enter by strapping something onto your face that fools your senses into perceiving an environment that surrounds you on all sides. The thing strapped to your face is called a Head-Mounted Display.

The true potential of this new field comes from the ability of a Head-Mounted Display to induce a synthetic experience in its wearer. If experience can be captured and transmitted, you can "travel" instantaneously to a distant location and see the trees, feel the wind, hear the birds, and smell the flowers. If electronic instruments can sense things that you cannot perceive, such as the insides of opaque objects, then you can be shown images of these invisible things. If microscopes and tiny probes can scan and manipulate the microscopic world, then you can "shrink," like Alice in Wonderland, to enter into a three-dimensional world of palpable bacteria and Brontosaurian insects.

The true potential of the Head-Mounted Display is not that it allows you to enter into a fantasy world, but that it allows you new ways of perceiving the real world.

Expansion of Perception

Vision, hearing, touch, taste, and smell are the traditional five senses; in addition, you have the ability to sense temperature, vibration, acceleration of your body, the positions of your limbs, forces acting on your body, hunger, thirst, pain, and other sensations related to your body's internal state.

There are, however, things which are invisible to all of your senses. Among these are X-rays, infrared radiation, radio waves, magnetic fields, radio activity, ultrasound, electricity, the insides of opaque objects, microscopic objects, and events occurring too fast to see. Even though you cannot directly perceive these things, you can indirectly measure and observe them with various instruments and electronic sensors.

By linking electronic sensors to a Head-Mounted Display, it is now possible to create "sensory transducers," which will allow you direct perception of phenomena which are imperceptible without electronic augmentation. A v

Tools that extend human perception have created much of the world we inhabit today. The microscope opened a window on the previously invisible world of the infinitesimal, and thus made possible the germ theory of disease, which led to antibiotics and pharmaceutical technology. Telescopes opened a window on the invisible but long-fabled worlds of astronomical distances, and thus made possible a new view of the universe and the human place in the universe.

A few people are beginning to use virtual reality as a kind of microscope for the mind, extending the perceptions of chemists into the molecular realm, extending the perceptions of medical diagnosticians into the interiors of living human beings, extending

the perceptions of meteorologists and aircraft designers into the very complex.

For about ten years (about a century in Silicon Valley years), I've watched Warren Robinett build worlds you can climb around in and explore. In the early days of the video game boom, he created a graphic version of the first computer adventure game, Adventure, for the Atari game machine (his boss told him it was impossible to fit Adventure into the small memory of the game machine, so Warren did it anyway; the game sold a million copies). In 1983, Warren co-created Rocky's Boots, a nifty little Apple II game that taught Boolean logic to children. In the late 1980s, when I started poking around the world of virtual reality research, I discovered that Warren had been one of the principal cybernauts at NASA's Head-Mounted Display Project. He is now manager of the Head-Mounted Display Project at the University of North Carolina.

—Howard Rheingold

Ames Research Center

In addition to cameras slaved to the motion of your head, the Green Man also has robot arms slaved to the motion of your own arms. By putting on the gloves and headset that link you to the distant robot, your senses are transported into the robot body. If your eyes and hands are at a remote location, you're there

tion of the alphabet, spaces between words, the printing press, and standardized spelling. Writing is now a mature art, and the link between the sounds of speech and the black marks on a page of a book are quite abstract. Figure 2 contrasts (a) a sonogram, a straightforward way to visualize vocal sound, with (b) the much more abstract form of modern written language.

In a sense, reading is hearing with your eyes. This cross-sensory substitution is closely related to a sensory transducer for the imperceptible. For the deaf, the sound of human speech is an imperceptible phenomenon. If it were possible to make a device that converted speech to written text in real-time, this device would in effect allow a deaf person to hear. This capability — real-time, speaker-independent, continuous speech recognition — has not yet been achieved. It ought to be possible, nevertheless, to create some kind of real-time visual representation of the sound of speech that, when visually superimposed on the movements of the lips and face, is sufficient to allow a deaf person to comprehend what is being said.
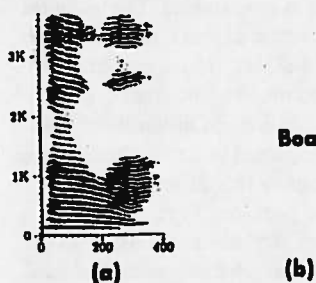

Figure 2: What does speech look like? (a) sonogram (b) English prose

What does computation look like? The step-by-step action of a computer as it manipulates data under the control of a program is a dynamic process that could be given an animated graphical representation, but there is currently no widely used or accepted depiction of the process of computation. Computation is currently invisible.

The electronic expansion of human perception has, as its manifest destiny, to cover the entire human sensorium. Ultraviolet rays that will cause a sunburn hours later might be mapped to an insistent vibration on the skin. Dangerous radiation which would kill you in a few minutes might be signaled directly with purposely induced pain. If each computer instruction were mapped to its own audible frequency, then each computer program would, because of its characteristic sequence of instructions, make its own recognizable sound.

Real-Space Databases

Information is often associated with location. Maps, inventories, and mailing lists are, in essence, lists of information about objects and features at specific locations.

Using a see-through Head-Mounted Display which tracks its location in the world, graphic data files could be spatially registered with the real world. A particular graphic object from the data file would be seen sitting at one spot in the world, and nowhere else. The data file would give the coordinates of the object's location — a very accurate latitude, longitude, and height above sea level — and only at that location

could it be seen. Michael Naimark, a San Francisco media technologist, has coined the term "real-space imaging" to describe graphics that are registered with the real world, just as real-time graphics are synchronized with events in the real world.

To find a specific item whose location in a company's huge warehouse is known, a huge red blinking arrow could appear in the air above the item, always remaining above it as you approached. Ghostly computer graphic labels could be attached to real-world objects and places. At specific places, you could leave notes to yourself that only you could see ("Don't eat at this place again"). You could leave warnings for others or scrawl rude graffiti.

The difference between these virtual labels and real physical ones is that everyone can see physical labels, whereas each virtual label exists in some spatial data file and can only be seen if you have loaded that file into your Head-Mounted Display. This means, unfortunately, that virtual billboards will probably not replace the physical ones that line the highways — they would be too easy to turn off. To guide you to her house, a friend might give you, not written directions or a map, but a spatial data file that had an orange stripe hovering ten feet above the road along the route from your house to hers. It would be difficult to miss a turn at an intersection where the orange stripe above you veered to the right.

Geographical information systems, which have become popular lately, are in essence computerized maps. Informa-
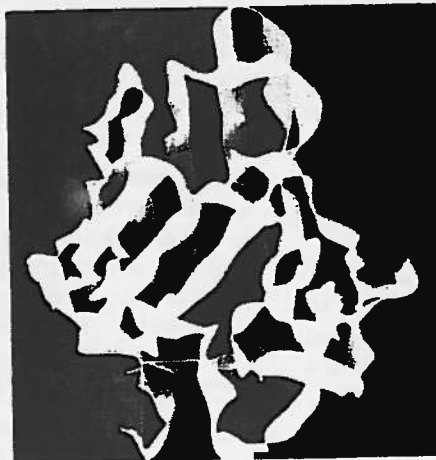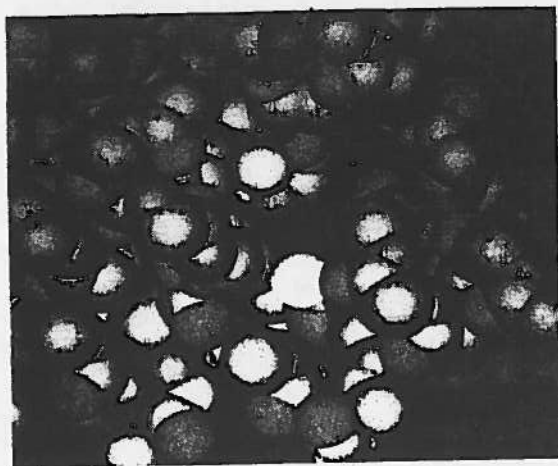

Figure 1: What does a molecule look like?

Two representations of dihydrofolate reductase: (a) touching spheres; (b) ribbon backbone.

and converse with another person in front of the robot. The person you talk to, however, would not see you, but rather a slimy green robot that was gesticulating and talking with your voice.

In a telephone conversation, each person has a microphone and a speaker in the telephone handset, with each microphone linked to the other person's speaker. The analogous setup for visual telepresence is for each person to wear a see-through Head-Mounted Display which is linked to a telepresence robot at the location of the other person. In such a conversation, you would see the other person's face superimposed onto the robot face which was physically there before you. You could thus have a "face-to-face" conversation with a distant person, making eye contact and observing one another's facial expressions.

The telephone allows electronic ventriloquism. It lets you throw your voice, at the speed of light, to any location where you can get someone to pick up the receiver. Likewise, visual telepresence will allow you to project your eyes, at the speed of light, to any location where a telepresence robot exists. This is instant travel. In ten minutes, an executive might do her daily tour of the warehouse, the factory, the lab and the accounting department, even though these places are thousands of miles apart.

The robot hands of the telepresence robot allow the human operator to manipulate objects at the robot's location. This goes beyond mere passive sensory "presence" at a remote location and therefore has a different name — "tele-operation." In extremely dangerous environments, mortal human beings can be replaced with human-controlled tele-robots. The Green Man was designed to work on the bottom of the ocean, too deep for divers. NASA may use tele-operated robots to construct its space station. Tele-manipulators are used to handle the radioactive fuel in nuclear reactors. Tele-operated robots are beginning to be used to fight fires and to defuse bombs.

Micro-Tele-Operation

Tele-robots don't have to be the same size as their human operators. Tele-robots the size of King Kong could be made, say, for constructing buildings. Tiny tele-robots could also be made. As operator of a micro-tele-robot, you

would have the perception that the ordinary world had expanded enormously, or equivalently, that you had been miniaturized. Operating at a 1-to-100 scale factor, the micro-robot would be two centimeters high and you would perceive a mouse to be the size of an elephant.

Some work has already been done in micro-tele-operation. A scanning-tunneling microscope can image individual atoms, detect surface forces as it probes these atoms, and move atoms around with its probe; IBM researchers have hooked up such a microscope to a force-feedback device to make it possible to "touch" atoms. Controlling micro-robots is one of the goals of Dr. Tachi in Tsukuba Science City, Japan, who is one of the leading researchers in one-to-one scale tele-operation.

With a microscope and micro-manipulator, you could effectively have your eyes and hands projected into the microscopic world. To perceive that the micro-world surrounded you, when you turned your head, the microscope would need to swivel around the specimen to achieve the right point of view. Another way to achieve quick changes of point of view in the micro-world would be to mount the specimen on an electrically controlled rotation stage beneath the lens of a fixed microscope.

This approach assumes a micro-world that is relatively transparent, such as a drop of water from a pond, so that any internal point of view can be achieved, even though the microscope looks in from the outside.

Scaled down by a factor of 100, you could reach out and tweak the antenna of a honeybee that you perceived to be four feet long. And it couldn't sting you.

An effective micro-tele-robot could be used for microsurgery. An adventurer could take a microscopic safari into an anthill to battle the furious hordes of ants. As people begin to work and play in micro-worlds, a need will arise for microscopic tools and devices which will perhaps be manufactured using micro-tele-robots.

Virtual reality will prove to be a more compelling fantasy world than Nintendo, but even so, the real power of the Head-Mounted Display is that it can help you perceive the real world in ways that were previously impossible. To see the invisible, to travel at the speed of light, to shrink yourself into microscopic worlds, to relive experiences — these are the powers that the Head-Mounted Display offers you. Though it sounds like science fiction today, tomorrow it will seem as commonplace as talking on the telephone. ∎

Head-Mounted Display Research At UNC Chapel Hill

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