bio-cybernetics
a biologically responsive interactive interface
DAVE WARNER, JEFF SALE, TODD ANDERSON, JO JOHANSON

"Adventures In the Next Paradigm of Human Computer Interaction"

The capacity of computers to receive, process, and transmit massive amounts of information is continually increasing. Current attempts to develop new human-computer interface technologies have given us devices such as gloves, motion trackers, 3-D sound and graphics. Such devices greatly enhance our ability to interact with this increasing flow of information. Interactive interface technologies emerging from the next paradigm of human-computer interaction are directly sensing bio-electric signals (from eye, muscle and brain activity) as inputs and rendering information in ways that take advantage of psycho-physiological signal processing of the human nervous system (perceptual psycho-physics). The next paradigm of human-computer interface will optimize the technology to the physiology — a biologically responsive interactive interface.

"BIOCYBERNETICS"

Interactive Information Technology

Interactive information technology is any technology which augments our ability to create / express / retrieve / analyze / process / communicate / experience information in an interactive mode. Biocybernetics optimizes the interactive interface, promising a technology that can profoundly improve the quality of real people or me today. The next paradigm of interface technology is based on new theories of human-computer interaction, which are physiologically and cognitively oriented. This emerging paradigm of human computer interaction incorporates multisense-rendering technologies, giving sustained perceptual effects, and natural user interface devices which measure multiple physiological parameters simultaneously and use them as inputs. Biologically optimized interactive information technology has the potential to facilitate effective communication. This increase in effectiveness will impact human-computer and human-human communication, "enhanced expressivity". Work in human-computer interaction is an ongoing endeavor in many areas. These efforts have captured the attention of several professional societies; the entertainment industry, the aerospace industry, communications and educational technologies industries, as well as medicine. These diverse areas will all be impacted in multiple ways by advances in technologies that enhance human-computer interaction.

Optimizing the human computer interface will rely on the knowledge base of physiology and neuro-science, that is, the more we know about the way we acquire information physiologically the more we know the optimum way for a human to interact with intelligent information systems. The next paradigm will see the "THINNING" of the human-computer interface to a biological sheer as the interface will map very close to the human body.

Physiologically Oriented Interface Design

Knowledge of sensory physiology and perceptual psychophysics is being used to optimize our future interactions with the computer. By increasing the number and variation of simultaneous sensory inputs, we can make the body an integral part of the information system, "a sensorial combinetric integrator". We can then identify the optimal perceptual state space parameters in which information can best be rendered. That is, what types of information are best rendered

to each specific sense modality, "a sense specific optimization of rendered information. Research in human sensory physiology, specifically sensory transduction mechanisms, shows us that there are designs in our nervous systems optimized for feature extraction of spatially rendered data, temporally rendered data, and textures. Models of information processing based on the capacity of these neurophysiological structures to process information will help out efforts to enhance perception of complex relationships by integrating visual, binaural, and tactile modalities. Then, by using the natural bioelectric energy as a signal source for input — electroencephalography, electro-occulography, and electromyography (brain, eye and muscle) — we can generate highly interactive systems in which these biological signals initiate specific events. Such a real-time analysis enables multi-modal feedback and closed-loop interactions.

"Biocybernetic Controller"

Interactive interface technology renders content-specific information onto multiple human sensory systems giving a sustained perceptual effect, while monitoring human response, in the form of physiometric gestures, speech, eye movements and various other inputs. Such quantitative measurement of activity during purposeful tasks allows us to quantitatively characterize individual cognitive styles. This capability promises to be a powerful tool for characterizing the complex nature of normal and impaired human performance. The systems of the future will monitor a user's actions, learn from them, and adapt by varying aspects of the system's configuation to optimize performance. By immersion of external senses and iterative interaction with biosignal triggered events complex tasks are more readily achieved.

This paradigm shift of mass communication and information technologies is providing an exciting opportunity to facilitate the rapid exchange of relevant information, thereby increasing the individual productivity of, persons involved in the information industry. Areas such as computer-supported cooperative work, knowledge engineering, expert systems, interactive attention training and adaptive task analysis will be changed fundamentally by this increase in informatics ability. The psychosocial implications of this technologically mediated human-computer and human-human communication are quite profound. Providing the knowledge and technology required to empower people to make a positive difference with information technology could foster the development of an attitude of social responsibility towards the usage of this technology and may be a profound step forward in modern social development. Applications that are intended to improve quality of life, such as applications in medicine, education, recreation and communication, must become a social priority.

Using Technology to Improve Quality of Life

The potential of this technological capability to improve quality of life can be best understood when it is actualized into the lives of real people with real needs. The Human Performance Institute at Loma Linda University Medical Center is an interdisciplinary research center leading the effort to utilize the latest in human computer interface technology to "make the world a better place". The primary research areas are in developing interactive interfaces, which enable severely disabled individuals to lead productive lives, and in the design of environmental systems, which support experiential interaction with information systems in such a way as to help maintain a state of general good health.

The following are real world cases that demonstrate the utility of this technology to change the future of disabled individuals.

— Crystal, an 18 month old "C1 quadriplegic" (complete paralysis from the neck down, requiring a respirator in order to breathe) was the first person to use this biocybernetic technology in a medical setting. Processing of electropotential changes along the eye and adjacent muscles into a biological signal enabled this child to interact in real time with the displays on the monitor, in short, "her eyes became her hands" in generating commands to the screen. The activity was direct, the implications profound: She was able to enter into a unified feedback loop where direct real time response to a physiological signal was used to modify and improve that psycho-physiological source. In this case, her capacity to learn and wilfully with the world was restored. Andy, a 10 year old C2 quadriplegic, whose speech is confined to the breathing patterns of his respirator to such an extent that it requires more than a minute to make a verbal request, found himself in a spatialized environment where commands from facial muscles enabled him to "fly around" in a 3-D computer environment. This was the first time in 5 years that he was able to wilfully control something in his environment without the aid of others.

— A 17 year old car accident victim who was motivated to rehabilitate his impaired psychomotor skills through an "air guitar" interactive system which converted the weak bioelectric signals from his impaired muscles into "rock and roll" music.

We have developed the BioCar, a primitive yet functional demonstration of telerobotic devices under direct biocybernetic control. The BioCar is a simple demonstration of how the biosignals can be used to control objects within an environment. For this demonstration a remote control car from Radio Shack was modified so that it can be controlled from the parallel port of a standard IBM compatible PC. Since there are only seven discrete functions (there is no proportional control) that the car can perform (forward, forward left, forward right, stop, reverse, reverse left and reverse right) it takes a minimum of three sets of electrodes to control all of the functions (2_ = 8). The BioCar software is responsible for interpreting the bioelectric signals from the user and sending commands to the remote control car.

— Michael, a 27 year old engineer recently paralyzed in an auto accident was able to navigate the BioCar through a very complicated course using the muscles of his face and arms. The same system that allowed him to control this toy car could be easily adapted to control his wheel chair or some type of robotic arm. The potential to empower the disabled to become functional members of society can be realized through biocybernetic interface design.

The next effort of our lab was to expand the utility of this biocybernetic controller. We modified a Nintendo game to accept commands from our system as if they were coming from the regular hand controller. This simple modification allows disabled children to use whatever muscle activity they have control of to play the same games as normal children. This generalized biocybernetic controller opens up an enormous resource of compelling games, which can be integrated into rehabilitative therapy. In this way we can achieve coordinated motion from patients at a much earlier stage. Instead of some arbitrary task, they can work with computer generated objects that have specific motions associated with them; getting the associated feedback of watching themselves pick up a virtual object even though they may lack the physical strength to pick up a real object.

Future efforts will focus on adapting the biocybernetic controller beyond games and toys to functional information systems. The capacity to operate interactive educational multimedia systems will open a whole new area where human expressivity can be optimized in applications that customize an educational environment to the capabilities of an individual.

Cybernetic Hedonism

The other focus of our efforts is in developing highly interactive, biocybernetic systems where biological signals can modify an environment chamber's parameters allowing the user to bioelectrically interface with spatialized environments. We believe that such physiologically modulated environment systems may have a health preserving function. Interfaces to control stimulation can adaptively utilize any biosignal. The result is the capacity to create a stimulus regime that accelerates relaxation and facilitates stress reduction. This is an application of wellness maintenance technology. "The Nirvana Express"

The Microscope of the Mind

The goal is to extend these environmental control systems into new methods of investigative research, such as a test of basic cognitive functionality or the capacity to maintain the attention focus necessary to complete an iterative series of cognitive tasks. Data fusion of sensor data with user interaction parameters will allow meaningful correlations to be made across various performance modalities. One goal of this application is to seek to identify a qualitative difference between the two performance/behavior states and then investigate various methods of quantifying that difference in a way that can be generalized.

It is postulated that a difference will be seen in the modulation of some of the natural rhythms. It is also postulated that a cognitively induced modification would be consistent in an individual but would most likely be different between individuals. The psycho-social-behavioral nature of individuals factors into initial assessment of their cognitive function. Other indicators of cognitive function are short-intermediate-long term memory, sound judgment and the ability to identify similarities in related objects. Performance of these cognitive functions is a strong indicator of the biologic health of the brain. Poor performance is highly correlated with organic brain dysfunction.

THE POTENTIAL OF THIS NEW PARADIGM OF BIOCYBERNETICS IS LIMITED ONLY BY THE IMAGINATION (and funding) OF THE USERS.

Send all responses to:
Dave Warner
Medical Neuroscientist
Human Performance Institute
Loma Linda University Medical Center
11406 Loma Linda Drive/Loma Linda Ca. 92354
909-799-6190 Voice/909-799-6106 Fax
davew@well.sf.ca.us Email

Special thanks to Dave Gilsdorf and Patrick Keller for their ongoing efforts in making the world a better place.