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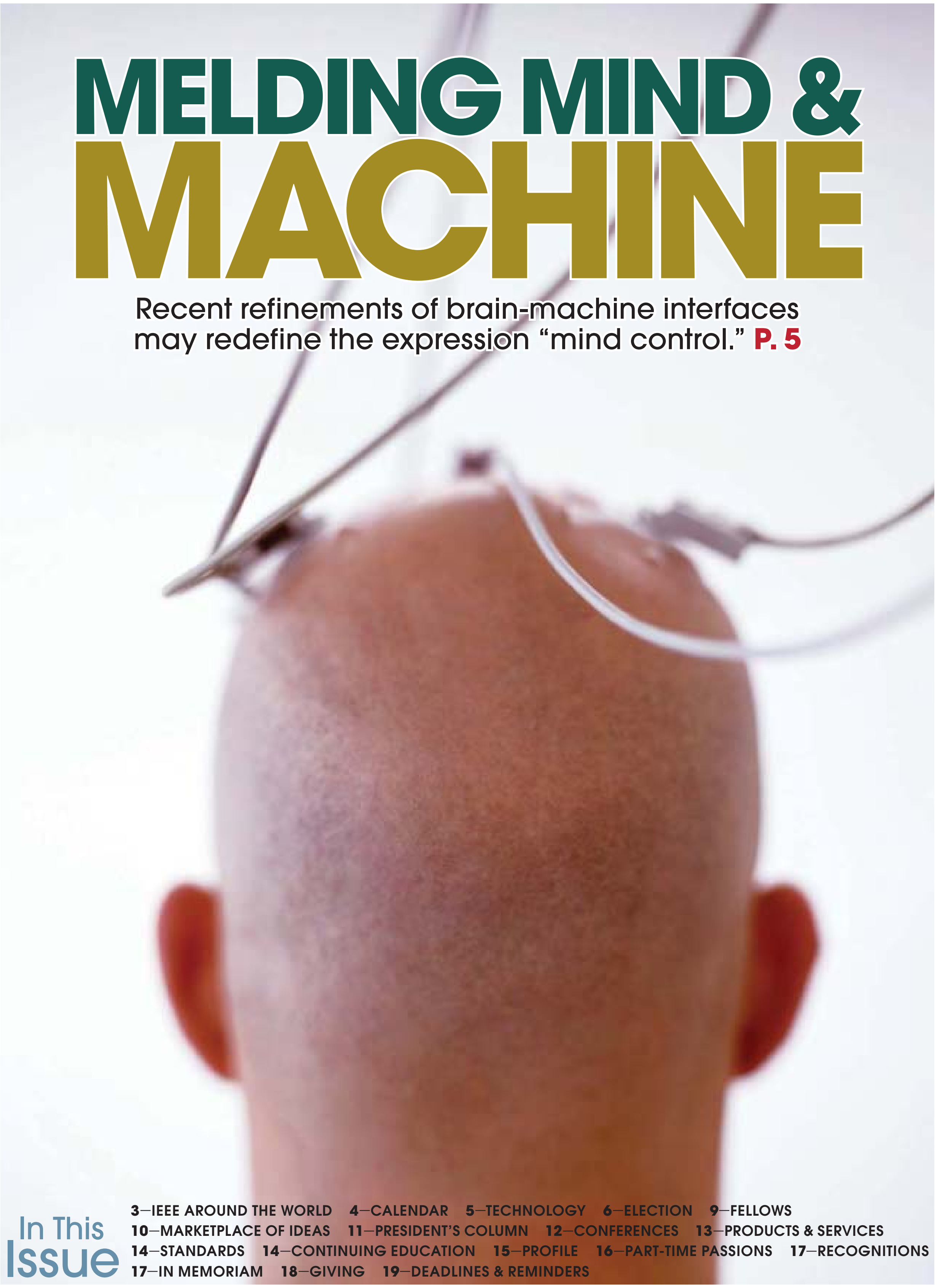
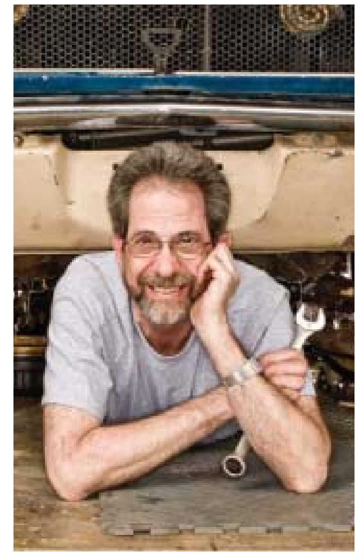


MELDING MIND & MACHINE

Recent refinements of brain-machine interfaces may redefine the expression "mind control." P. 5



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TECHNOLOGY

Melding Mind and Machine

Brain-machine interfaces could someday help people with severe paralysis move their limbs, walk, and use a computer BY MICHAEL J. RIEZENMAN

Mind control is generally regarded as scary—conjuring up *The Manchurian Candidate* and other depictions of brainwashing. But recent refinements of brain-machine interfacing (BMI) may redefine the expression to mean something totally different: control *by,* not *of,* the mind. It is a field that holds out the hope of allowing severely paralyzed people to communicate with the world, move their limbs, and even walk.

The basic idea is simple: paralysis is caused by a break in the neural pathway between the cognitive part of the brain, where the intention to make a movement is generated, and the muscles that do the moving. So an artificial system that senses the neural signals generated in the brain, analyzes what the brain is trying to do, and then moves the limbs mechanically can bypass the roadblock in the pathway and restore normal functioning. Such BMI systems are not just for moving limbs; for example, signals from the brain can be harnessed to move the cursor on a computer screen with no actual limb movement.

Of course, making that happen is far from simple. But laboratory experiments have proved the viability of the approach, and a number of IEEE members are working to develop solutions to the many practical problems that have prevented the idea from becoming a clinical reality.

Developed by Hitachi, this brain-machine interface analyzes slight changes in the brain's blood flow and translates them into electric signals, allowing the device's user to control everyday objects without lifting a finger.

SHIZUO KAMBAYASHI/AP PHOTO

ACCESS One problem is signal acquisition, specifically the design of the actual physical interface that taps into the brain's neural signals. The ideal would be to sense the signals noninvasively, through electrodes placed on the scalp. But signals obtained that way have poor signal-to-noise ratios compared with ones obtained by arrays of microelectrodes inserted directly into the cerebral cortex, the outermost portion of the brain, points out Member Justin C. Sanchez, a professor of pediatrics, neuroscience, and biomedical engineering at the University of Florida, Gainesville, and chair of the Gainesville chapter of the IEEE Engineering in Medicine and Biology Society. Moreover, microelectrodes can pick up signals from individual neurons, while external electrodes reflect the aggregate of many millions of neurons.

On the other hand, poking electrodes into the brain is a surgical procedure that risks infection as well as injury. As in many engineering situations, the name of the game is trade-off. Proponents of the noninvasive approach are constantly improving their signal-processing software to better extract every bit of information from the signals they collect. At the same time, those who favor microelectrodes are trying to lessen their impact by improving the electrode-tissue interface. Cyberkinetics Neurotechnology Systems of Foxborough, Mass., has developed a device that inserts an array of microelectrodes quickly. The procedure reduces tissue trauma because of the viscoelastic nature of neural tissue—that is, its ability to recover from mechanical stresses, provided they are of short duration.

Another method of accessing the brain's neural signals falls between those two. Sanchez's group is experimenting with an electrocorticographic (ECoG) technique that places an array of small electrodes on the cortex, each of which aggregates signals from a large number of neurons—many more than a microelectrode does but significantly fewer than an external electrode. Moreover, since the signals need not pass through the membrane surrounding the brain cortex, the skull, or the scalp before being sensed, ECoG signals suffer much less attenuation than EEG signals and exhibit a higher signal-to-noise ratio.

LESS POWER Minimizing power consumption is another major issue with BMI. Any permanently implantable device needs amplifiers, signal-processing circuitry, and a wireless transmitter. Therefore, using as little power as possible to minimize the heating of tissue and to prolong battery life is another important goal. One way is to minimize the bandwidth occupied by the data being sent from the implanted device to the outside world. Pursuing that goal, Member John G. Harris, a professor of electrical and computer engineering at the University of Florida, came up with a sampling scheme that samples more rapidly when the signal amplitude is large and more slowly when it is small. Since neurological signals are spike trains with a high amplitude only a small part of the time, that saves a lot of bandwidth. The price paid is a complex reconstruction algorithm performed in circuitry outside the body—where power limitations do not apply.

A team at Stanford University came up with a scheme that combines a variable-precision analog-to-digital converter with a spike-sorting subsystem that samples the neurological signal only when a spike is present and varies its resolution from 3 to 8 bits, depending on the quality of the signal. IEEE Student Member Michael D. Linderman, who is part of the Stanford team, says the subsystem can be trained by the signal shapes to identify individual neurons whose signals are picked up by the same electrode. That information is enough for the complex decoding algorithms to analyze and determine what action the person intends to take. BMI researchers are optimistic because, as Linderman and his colleagues explain in "Signal Processing Challenges for Neural Prostheses" [*IEEE Signal Processing Magazine,* January 2008], "many of the obstacles facing the prosthetics community as it develops a clinically viable implantable prosthetic processor are primarily engineering challenges." ■