Muscle Melodies and Brain Refrains

Turning bioelectric signals into music

By IVAN AMATO

Backstage a musician wraps fabric bands around her head and forearms. Silently, without any instrument, she walks on stage and begins playing. With every gesture of her hand, every flick of a finger, resounding notes emanate from the banks of speakers as though she were conducting an invisible guitarist. Now and then, mostly when she closes her eyes, an unseen piano accompanies the phantom guitar. She seems able to steer the sound in the direction of her gaze.

As patent applications come through, a rapidly evolving electronic system called Biomuse could soon usher a performance like this into reality, say the fledgling technology's inventors at Stanford University. Dime-sized electrodes hidden underneath the musician's headband and armbands would pick up electric signals from her brain and her eye, arm and hand muscles. A VCR-sized box of newly designed electronic circuitry would gather, filter and process the bioelectric signals so they could control a music synthesizer. To the audience, it might appear as though the music came directly from the musician's body, say physiologist Hugh S. Lusted and electrical engineering graduate student R. Benjamin Knapp, who consider their brainchild a new kind of electronic musical instrument.

Besides dazzling audiences at concerts, Biomuse might provide a means of self-expression to severely handicapped people, even nonverbal quadriplegics, note computer-minded music therapists. "This type of system is ideally suited for someone who has very little motor control," says Bradford Lowry, associate director of The Center for Electronic Music in New York City. The center's music therapist, Joseph Nagler, adds that Biomuse is user-friendly enough to enable many more disabled people to use music to build self-esteem and to communicate their feelings. In addition, Lusted, Knapp and others expect Biomuse to open novel creative vistas for composers, able-bodied or not.

The Biomuse system enables people to control standard music synthesizers with bioelectric signals from their own muscles, brains and eyes. Musicians need not press keys or pluck strings. Electrodes over the skull, near the eyes and over leg or arm muscles eavesdrop on underlying electrical activity in neurons and muscle cells. "The body is literally a symphony (or society) of electrical voices, sounding at different frequencies and intensities," the researchers said last November at a meeting of the Acoustical Society of America in Honolulu.

The electrodes continuously harvest biosignals and relay them to electronic circuitry, which amplifies, "cleans" and digitizes them. The signals then can feed into a signal processor, in this case the 320C25 made by Texas Instruments. Knapp and Lusted note that relatively inexpensive signal processors like this one have become available only within the last five years.

The preprocessor circuitry, which Knapp designed, and the commercially available signal processor form the talent of Biomuse. They translate the body's electric signals into an electronic language – the Musical Instrument Digital Interface (MIDI) code – that can drive standard electronic musical instruments. Go to nearly any contemporary music concert these days, and you'll probably hear a variety of MIDI instruments.

Knapp and Lusted tap into three types of biosignals, though they say future generations of Biomuses may use more. The largest signals come from muscles like the biceps. Physiologists call readings from muscle signals electromyograms (EMGs). As muscle tension increases, more and more motor fibers join in the action. An overlying electrode detects this as a smoothly graded increase in voltage output. A Biomuse user will be able to apply software, now under development by Knapp and Lusted, to program the processor to translate lower muscle tensions into, say, lower harpsichord notes, and higher tensions into higher notes.

Electrodes placed over the back of the skull near the brain's vision center (occipital region) pick up brain waves and feed them into electronic circuitry that arranges them as electroencephalograms (EEGs). A mere electrical whisper compared with muscle signals, brain waves flutter at about one-tenth the frequency of typical electrical oscillations in flexing muscles. Most people can control one type of brain wave – the alpha wave – simply by closing their eyes. Biomuse's processing circuitry can sift through the continuous and busy EEG signals and detect the onset of alpha activity. The Stanford researchers suggest using alpha waves to switch instruments – say, from harpsichord to flute.

Stanford Univ.

The electronic heart of Biomuse resides in the black box between Knapp and Lusted, who dons electrodes.

When the eyes move from side to side or up and down, the surrounding muscles produce another useful biosignal. Electrodes near the eyes can pick up these signals to produce an electrooculogram (EOG). Knapp's circuitry turns the EOG signals into electrical indicators of eye position. He and Lusted have programmed Biomuse to shunt the musical output between different sets of speakers depending on eye position. "Wherever you look, the sound is there," Lusted says.

"The startling thing about Biomuse is that you actually can listen to yourself, to your body, make music, and you can quickly learn to manipulate the sound," Lusted remarks. John Chowning, director of Stanford's Center for Computer Research in Music and Acoustics (CCRMA) and a professional trumpet player, quickly learned to produce specific signals just by flicking his finger.

"Being able to switch the sound from a string sound to a glockenspiel sound by changing from visual to nonvisual thought – that was really bizarre," says Lusted, who has the most on-line Biomuse experience to date. "I got good enough at this that I didn't need to close my eyes; I could just think black." In a future generation of Biomuse, the Stanford inventors would like to extract more subtle qualities from brain wave signals so that someone would be able to precisely control the music exclusively with thought. "The idea is to think violin and get violin," Knapp says. "But we're only a billionth of the way there."

At CCRMA on March 23, the scientists staged a demonstration performance of what actually is the second generation of Biomuse systems, though it's the first system that will work in nonlaboratory settings such as stages and therapy rooms. In 1987, only three weeks after Lusted and Knapp discovered their common interest in learning to play the body electric, they had in hand Biomuse I, an awkward-looking gizmo slapped together with parts lying around their laboratories. "It was a back-of-the-envelope mess," Knapp recalls. The electronics were so specialized that only Knapp could program the device. Moreover, it worked only intermittently and in extremely controlled places like laboratories. Anywhere else the input signals would fluctuate wildly, making it impossible for the electronics to make sense of them.

The two scientists since have developed Biomuse II, which they rate as far more stable and reliable. And anyone who has access to MIDI software for a personal computer will be able to program Biomuse II, Knapp says. Representatives from computer companies, electronic instrument companies and other organizations like the Center for Electronic Music attended the March 23 demonstration.

But CCRMA's computer music composers may be among the first to explore Biomuse's artistic possibilities. Instead of using fingers, breath and lips to play instruments, Biomuse "attempts to harness other bodily means of sound control," says CCRMA director Chowning. He expects its primary value for composers to rest in controlling sound features other than notes, things like the localization of sound source, overall loudness and timbre changes. "The ultimate applications probably are not obvious," Chowning adds.

Besides its musical applications, Biomuse technology may help disabled people get jobs by enabling them to control computers without needing fine motor control. "We're looking for alternate means by which patients can work using computer technology, but without needing complicated skills," says Nagler of the Center for Electronic Music. He and the Stanford inventors are considering using EOG signals to allow disabled patients to move the cursor around the screen like an "eye-controlled mouse."

"There are many things we have thought about doing with Biomuse but haven't tried yet," Lusted says. For one, he wants to hook Biomuse up to plants, which have their own brands of bioelectric signals. In animals, transforming bioelectric signals into musical analogs by hooking the animals up with the Biomuse might make for a painless window on their behavior, and would be especially intriguing with highly auditory animals such as dolphins, he suggests. In the world of dance, Biomuse-fitted performers soon might be able to produce sounds that follow their moves as closely as a shadow. "The possibilities are endless," Lusted says. "That makes it hard to decide what to try first." □

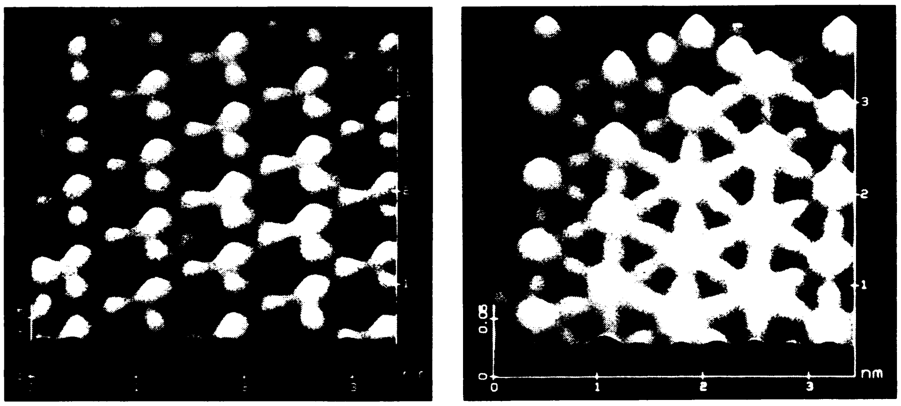
Continued from p. 201

enhances or hinders the material's superconductivity isn't clear yet.

Researchers have also used the scanning tunneling microscope to study the growth, dissolution or rearrangement of crystalline surfaces over the course of electrochemical reactions to gain a more detailed understanding of processes such as corrosion. In the Feb. 20 PHYSICAL REVIEW LETTERS, Dennis J. Trevor and his collaborators at AT&T Bell Laboratories in Murray Hill, N.J., report the results of an investigation of electrochemically induced changes at a gold surface.

The researchers looked at a crystalline gold sample immersed in perchloric acid. In their experiments, they gradually raised, then lowered, the voltage applied to the gold surface, first causing surface gold atoms to react with oxygen, then returning the gold to its pure state. After such a cycle, microscope images of what was originally a smoothly terraced surface reveal pits of various diameters, each usually only one gold atom deep. Within 20 minutes or so, terrace edges shift and pits gradually fuse together and join terrace edges, as gold atoms apparently rearrange themselves to smooth out the surface. The presence of chloride ions seems to speed up the smoothing, or annealing, process.

Recently, chemist Bruce C. Schardt and his colleagues at Purdue University in West Lafayette, Ind., observed the deposition of iodine on single crystals of platinum in air. They picked out two different packing arrangements into which iodine atoms settle on such a surface.



Schardt et al./SCIENCE

This pair of computer-processed images shows two different arrangements into which iodine atoms can organize themselves on a platinum surface.

On the basis of previous studies using other techniques, the researchers did not expect to find two such structures. "This study is a graphic illustration of the value of real-space imaging provided by the [scanning tunneling microscope]," they report in the Feb. 24 SCIENCE. It's also a striking example of the resolution obtainable with such a microscope operating in air.

The number of potential applications for the scanning tunneling microscope keeps growing. Physicists, engineers, chemists and biologists are starting to use this instrument for probing the structure of biologically important molecules such as DNA (SN: 1/28/89, p.53), monitoring the formation of thin films on metals (SN: 1/28/89, p.62) and many other purposes. Industrially, such microscopes guide the manufacture of magnetic recording heads and the production of nickel stampers used to make the tiny depressions carrying the information stored on compact disks.

In the scanning tunneling microscope, Pauli's devilish surfaces may have met their match. □