But rather than owning their music collections on a device, no matter how tiny, some fans will prefer to borrow their selections on demand from a streaming, cloud-based model that has been referred to as a "celestial jukebox."

Speaking with THE FUTURIST, author and cultural critic Douglas Wolk emphasizes that the ultimate streaming service would be a universal resource that is able to provide via a clean, elegant interface "immediate access anywhere, at any time, to any music that has ever been released to the public." In this case, the complete library of sound recordings would be hosted on external servers; there would be no need to download anything (although that option would still exist). He asserts that the demand—and the necessary technology—are here and that it's only a matter of time before somebody creates such a site, lawfully or not. In other words, the technological hurdles are not nearly as daunting as are the legal obstacles.

These options put the already beleaguered music industry in a quandary. Major labels and copyright holders have been quick to object to (and reticent to cooperate with) streaming services like Pandora, Rhapsody, and Spotify.

"As long as there are copyright ownership concerns, there's not going to be a single above-board mechanism by which people can have instant, ideally free access to any sound ever recorded and released," says Wolk.

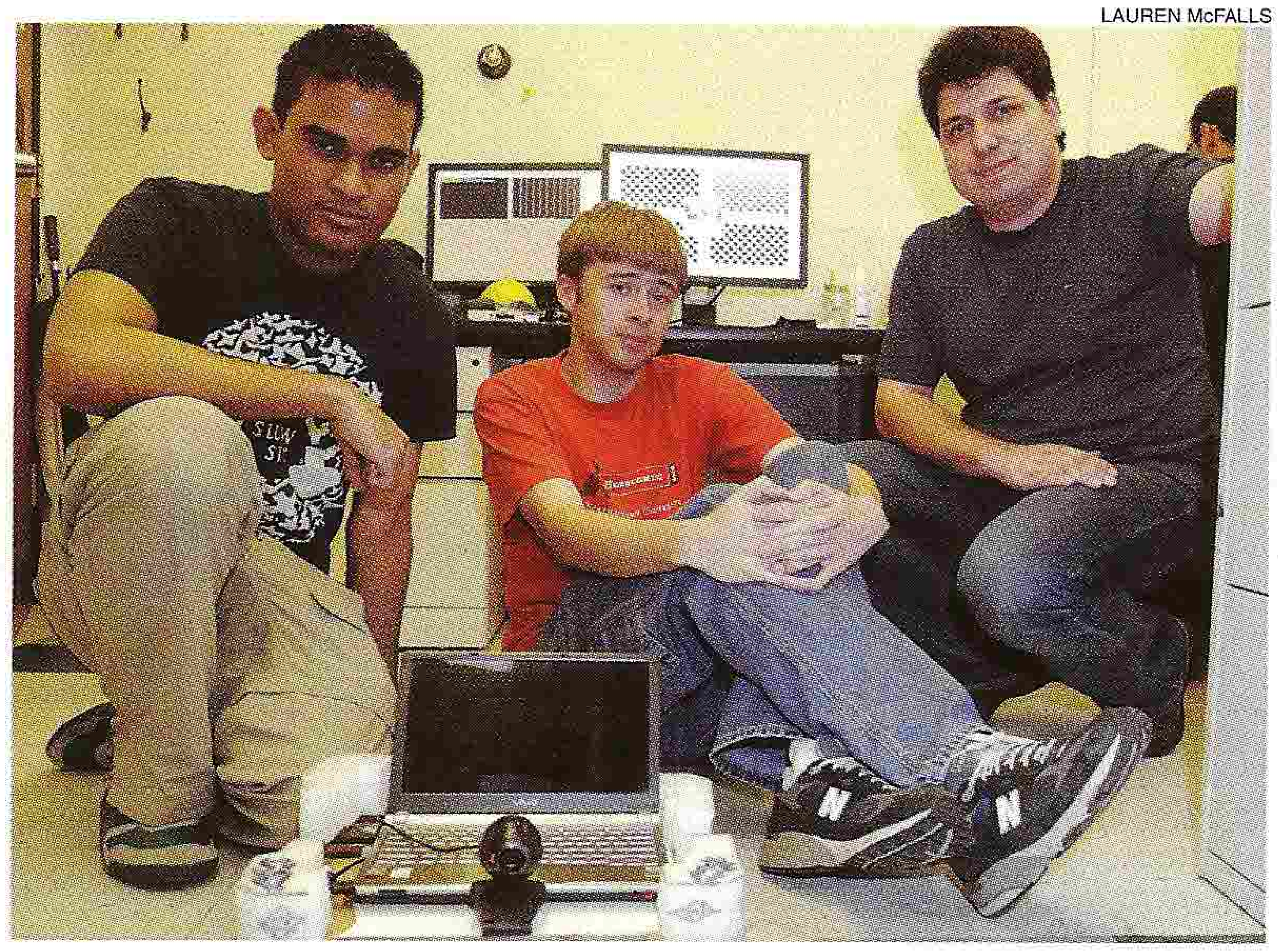
Music lovers sacrificing ownership to the convenience of celestial jukeboxes risk losing their music collections if the industry can't monetize the cloud. If the sites go out of business, the music will disappear.

Technology may eventually take things even further. Wolk and Pearlman, among others, forecast that the next level of listening "paradise" may be at the molecular scale, with the entire catalog of recordings available via a chip implanted in your body. In the future, you could control the soundtrack of your life—literally.

—*Aaron M. Cohen*

Sources: Douglas Wolk (interview), www.lacunae.com. "The Hell of Being Prolific" by Leonard Pierce, A.V. Club (March 17, 2010), www.avclub.com.

LAUREN McFALLS



Students at Northeastern University have successfully steered a robot via brain signals.

Cybernetics

Prospects for Brain–Computer Interfacing

Team uses brain waves to drive robot.

A group of undergraduates at Northeastern University demonstrated in June that they could steer a robot via thought. The subject in the experiment watched a computer screen and selected commands using his retina, causing electrical activity in the brain's visual cortex ranging from 4 to 100 hertz. The signals were then translated to a small robot, similar to the Roomba vacuum cleaner.

Electrical engineering professor Deniz Erdogmus, who oversaw the project at Northeastern, says that because the connection between the user and the robot is Internet-based (you can track the robot over Skype) an operator could control it from a considerable distance away.

"We could take the robot to Tahiti and the operator can take a webcam tour," says Erdogmus. "We are looking for volunteers to take the robot to Bora Bora."

The demonstration was the latest in a string of breakthroughs over the last decade, showing the growing viability of brain–computer interface, or BCI, technologies. Cybernetic research will advance far

MOTORLAB / UNIVERSITY OF PITTSBURGH

In 2008, a University of Pittsburgh team led by Andrew Schwartz taught a monkey to feed itself using a robot arm that the monkey controlled via implant. Researchers see brain–computer interface technology making considerable progress in the years ahead. Despite this, progress in robotic prostheses interfacing will lag brain–PC communication, perhaps by a decade or more.

more rapidly in the next few years, experts contend.

The Present and Future of Brain–Computer Interface Technology

Neural interface technology goes back half a century (and the larger field of cybernetics dates back to World War II), but advancement proceeded unevenly. The primary obstacle was, and remains, system compatibility; the delicate and complicated web of nervous tissue that is the brain doesn't communicate well with wires and electronics.

"If you put an array of sensors into a brain, there's a tissue reaction, namely scarring. The nervous tissue can no longer send a signal when there's scar tissue," says Klaus-Robert Müller, director of the machine learning group at Technische Universität in Berlin.

Previous studies have shown that linking mammalian brain matter with electric circuitry has a burning or melting effect on the brain. However, in the last two decades, advances in computation have enabled researchers to bypass this problem, somewhat, and rely more on devices that don't have to be surgically implanted to collect brain signals.

Electroencephalography (EEG), which the Northeastern University team used, is among the favored of these techniques. EEG uses a sensor array afixed to a subject's head externally, like a swimming cap. Because the signal from an EEG is weaker than the signal from a surgically implanted sensor, more guesswork is required to deduce what the brain is trying to communicate; that guesswork is aided through algorithmic math. Noninvasive BCI relies much more on algorithms and mathematic problem solving.

Erdogmus says that more funding agencies are seeing the potential of BCI, and this is having a positive effect across the field. "Technological and algorithmic advances allowed more groups to work on this problem for [less] equipment-wise," he says.

Müller agrees that shifting more of the burden to number crunchers (helped by the increase in computing power in recent years) has made a big difference. "We have put all the learning on the machine side. The computer learns to interpret your brain waves," he says. A few years ago, subjects would need to train for 300 hours to control their brain signals before those waves could be usable in BCI. Now, says Müller, you can achieve the same effect after about five minutes of training.

Brain-based control of conventional keyboards, allowing individuals to type without physically touching the keys, has been demonstrated at the universities of Wisconsin and Michigan. In the near future, brain e-mailing and tweeting will become far more common, say experts (though these interfaces remain extremely slow). BCI will also show up in some surprising places.

Other Applications for Brain–Computer Interfaces

In the near term, video-game makers could use BCI to develop gaming systems capable of reading and responding to a player's emotional state. Similar research could lead to new therapies for various neurotic disorders, enabling sufferers to see and potentially moderate their own brain patterns to reduce stress. Müller reports that a company called Pico has designed an iPhone application that allows users to see their own thought patterns on the iPhone. (He says the app is not yet commercially available, as it requires a surgical implant to operate.) Automobile manufacturers might use BCI to improve navigation systems.

"Say you're a carmaker; you are designing a new driver-assistance system," says Müller. "Normally if you were testing this system, you would have people come in, try the car, and you would survey them on their experience. But what if you wanted a highly accurate qualitative measure to see if cognitive workload was lower using one gadget over another? Or you wanted to see how people reacted emotionally to different designs? These things can be measured non-intrusively and quantitatively."

Erdogmus sees brain-controlled prosthesis and robots going mainstream within a few decades. There have been a number of startling demonstrations on this front in addition to the work at Northeastern. In 2008, a University of Pittsburgh team led by Andrew Schwartz taught a monkey to feed itself using a robot arm that the monkey controlled via implant. (A link to the video is available on THE FUTURIST's Web site.)

Researchers caution that they need much more information about the brain, particularly its feedback mechanisms and how it transitions between different states, before science can fulfill the more ambitious cybernetic visions of science fiction. Acquiring this information will be the most important application of BCI in the years ahead. *—Patrick Tucker*

Sources: Personal Interviews, Deniz Erdogmus (e-mail) Northeastern University, www.northeastern.edu. Klaus-Robert Müller, Technische Universität. Suggested further reading: *Toward Brain Computer Interfacing* edited by Guido Dornhege et al. MIT Press, 2007.

Health

U.S.–Canadian Health Disparities

Researchers seek reasons why Canadians are healthier than Americans.

Canadians are living longer and in better health than their American neighbors. The reasons may have more to do with economics and politics than with lifestyle and genetics, according to a study led by David Feeny of Kaiser Permanente Center for Health Research.

Examining data from the Joint Canada/United States Survey of Health 2002/03, Feeny and colleagues found that the average 19-year-old Canadian can expect to live 2.3 years longer than his or her American peer. Moreover, there is more equality in terms of health among Canada's richest and poorest members.

"The difference in health between the two countries seems to be associated with substantial differences in access to care as well as substantial differences in social and economic inequality," says Feeny.

Where the health disparity between Canadians and Americans shows up most noticeably is in middle age, when "the effects of access to health care and social and

Data Box: Chronic Health Conditions

Chronic Condition	U.S.	Canada
Angina	2.9%	3.7%
Arthritis	18.7%	16.8%
Asthma	11.4%	10.4%
Depression	8.7%	8.2%
Diabetes	6.7%	4.7%
Emphysema/COPD	3.6%	2.2%
Heart attack	3.0%	3.3%
Heart disease	6.0%	5.1%
Hypertension	22.7%	18.3%

Comparison of prevalence of chronic conditions among adults over age 18.

Source: Sanmartin, Ng, Blackwell, Gentleman, Martinez, and Simile, cited in "Comparing Population Health in the United States and Canada," Feeny et al.

Data Box: Health, Poverty, and Income Inequality

Indicator	U.S.	Canada
Infant mortality rate, deaths per 1,000 live births	7.0	5.4
Life expectancy at birth, in years	77.2	79.7
Life expectancy at age 19, in years	58.3	60.6
Poverty rate, in percentage	17.0	12.0
Poverty rate among elderly, in percentage	23.0	6.0

Source: OECD and other sources, cited in "Comparing Population Health in the United States and Canada," Feeny et al.