The not-so-digital future of digital signal processing

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Fungi processing audio signals. E. Coli storing images. DNA acting as logic circuits. It's possible, and in some cases, it's already happened. In any event, performing digital signal processing using organic and chemical materials without electrical currents could be the wave of the future — or so argue Sotirios Tsaftaris, research professor of electrical engineering and computer science, and Aggelos Katsaggelos, Ameritech Professor of Electrical Engineering and Computer Science, in their recently published "point of view" piece in the *Proceedings of the IEEE* (Institute of Electrical and Electronics Engineers.)

Digital signal processing uses mathematics and other techniques to manipulate signals like visual images and sound waves after those signals have been converted to a digital form. This processing can enhance images and compress data for storage and transmission, and such processing chips are found in cell phones, iPods, and HD TVs.

But over the past 10 years, scientists and engineers around the world have experimented with performing signal processing using different materials. In their piece, Tsaftaris and Katsaggelos describe these experiments while stirring the engineering community towards "a possible not-so-electronic future" of digital signal processing.

For example, scientists and engineers have shown that certain chemicals, when mixed in a solution, don't react until light is projected through them. So if you project light through a transparency image, these chemicals can record the image. When the chemicals are stimulated by light and controlled by the acidity of the mixture, basic image transformations like contour enhancement can happen.

But such processing tasks extend beyond chemicals to organic materials. Artist/scientist Cameron Jones found that out after he used audio CDs as substrates to grow fungi. He put the fungi-laced CDs in a CD player and found that the optically recorded sound was distorted by the fungi — and the fungi growth patterns were dependent on the optical grooves recorded on the CD.

“The bacteria reacted to the recorded information, and the audio track was ‘processed’ by the grown fungus,” Tsaftaris says. “That is essentially bacteria signal processing.”

Using bacteria to process signals has even spurred a competition – the International Genetically Engineered Machine Competition at the Massachusetts Institute of Technology, where undergraduate students compete to design biological systems that can perform simple computations. In 2005, a group modified E. coli cells to react to light, and the students created a layer of that bacteria that could perform edge detection of an image – a basic processing task.

Tsaftaris’s and Katsaggelos’s research includes studying the use of DNA for digital signal processing. DNA strands can be used as input and processing elements, and, it turns out, DNA is an excellent data storage medium. Digital samples can be recorded onto DNA, which can be kept in a liquid form in test tubes to save space. That DNA can also be easily replicated using common laboratory techniques, and such a database could be easily searchable, no matter how large it is.

“It becomes a very attractive solution,” Tsaftaris says.

Though science is still years away from this possibility, engineers have created useful algorithms in their pursuit of the technology. Such algorithms have been used, for example, to better detect disease. But Tsaftaris hopes for a day when organic digital signal processing will allow for the implementation of the so-called “fast Fourier transform” — a widely-used method of extracting useful information from sampled signals that Tsaftaris calls the “holy grail” of DNA signal processing.

“The cost and delivery time of DNA synthesis is being reduced exponentially, this making data input elegant and economical,” Tsaftaris and Katsaggelos write in the paper. But in the meantime, “don’t forget to feed the bacteria that nurture your precious jazz collection.”

Source: Northwestern University