Scientists develop biological computer to encrypt and decipher images

February 7 2012

Scientists have developed a “biological computer” capable of deciphering images encrypted on DNA chips. As a proof of concept, the scientists encrypted the Scripps Research and Technion logos on a single DNA chip and, using software, decrypted the separate fluorescent images. Credit: Image courtesy of the Kienan laboratory at the Scripps Research Institute.

Scientists at The Scripps Research Institute in California and the Technion–Israel Institute of Technology have developed a "biological computer" made entirely from biomolecules that is capable of deciphering images encrypted on DNA chips. Although DNA has been used for encryption in the past, this is the first experimental demonstration of a molecular cryptosystem of images based on DNA computing.

The study was published in a recent online-before-print edition of the journal *Angewandte Chemie*.

Instead of using traditional computer hardware, a group led by Professor

Ehud Keinan of Scripps Research and the Technion created a computing system using bio-molecules. When suitable software was applied to the biological computer, it could decrypt, separately, fluorescent images of The Scripps Research Institute and Technion logos.

A Union Between Biology and Computer Science

In explaining the work's union of the often-disparate fields of biology and computer science, Keinan notes that a computer is, by definition, a machine made of four components—hardware, software, input, and output. Traditional computers have always been electronic, machines in which both input and output are electronic signals. The hardware is a complex composition of metallic and plastic components, wires, and transistors, and the software is a sequence of instructions given to the machine in the form of electronic signals.

"In contrast to electronic computers, there are computing machines in which all four components are nothing but molecules," Keinan said. "For example, all biological systems and even entire living organisms are such computers. Every one of us is a biomolecular computer, a machine in which all four components are molecules that 'talk' to one another logically."

The hardware and software in these devices, Keinan notes, are complex biological molecules that activate one another to carry out some predetermined chemical work. The input is a molecule that undergoes specific, predetermined changes, following a specific set of rules (software), and the output of this chemical computation process is another well-defined molecule.

"Building" a Biological Computer

When asked what a biological computer looks like, Keinan laughs.

"Well," he said, "it's not exactly photogenic." This computer is "built" by combining chemical components into a solution in a tube. Various small DNA molecules are mixed in solution with selected DNA enzymes and ATP. The latter is used as the energy source of the device.

"It's a clear solution—you don't really see anything," Keinan said. "The molecules start interacting upon one another, and we step back and watch what happens." And by tinkering with the type of DNA and enzymes in the mix, scientists can fine-tune the process to a desired result.

"Our biological computing device is based on the 75-year-old design by the English mathematician, cryptanalyst, and computer scientist Alan Turing," Keinan said. "He was highly influential in the development of computer science, providing a formalization of the concepts of algorithm and computation, and he played a significant role in the creation of the modern computer. Turing showed convincingly that using this model you can do all the calculations in the world. The input of the Turing machine is a long tape containing a series of symbols and letters, which is reminiscent of a DNA string. A reading head runs from one letter to another, and on each station it does four actions: 1) reading the letter; 2) replacing that letter with another letter; 3) changing its internal state; and 4) moving to next position. A table of instructions, known as the transitional rules, or software, dictates these actions. Our device is based on the model of a finite state automaton, which is a simplified version of the Turing machine. "

Unique Biological Properties

Now that he has shown the viability of a biological computer, does Keinan hope that this model will compete with its electronic counterpart?

"The ever-increasing interest in biomolecular computing devices has not arisen from the hope that such machines could ever compete with electronic computers, which offer greater speed, fidelity, and power in traditional computing tasks," Keinan said. "The main advantages of biomolecular computing devices over electronic computers have to do with other properties."

As shown in this work, he continues, a wealth of information can be stored and encrypted in DNA molecules. Although each computing step is slower than the flow of electrons in an electronic computer, the fact that trillions of such chemical steps are done in parallel makes the entire computing process fast. "Considering the fact that current microarray technology allows for printing millions of pixels on a single chip, the numbers of possible images that can be encrypted on such chips is astronomically large," he said.

"Also, as shown in our previous work and other projects carried out in our lab, these devices can interact directly with biological systems and even with living organisms," Keinan explained. "No interface is required since all components of molecular computers, including hardware, software, input, and output, are molecules that interact in solution along a cascade of programmable chemical events." He adds that because of DNA's ability to store information, major computer companies have been extremely interested in the development of DNA-based computing systems.

More information: The first author of the study, "A Molecular Cryptosystem for Images by DNA Computing," is graduate student Sivan Shoshani of Technion. In addition to Keinan and Shoshani, authors include postdoctoral fellow Ron Piran of Scripps Research and Yoav Arava of the Technion. For more information on the paper, see

Angewandte Chemie at onlinelibrary.wiley.com/doi/10 … e.201107156/abstract

Provided by The Scripps Research Institute