News Releases

DNA Molecules Arranged to Act Like Infinitesimal Data Display

Computer scientist uses synthetic DNA to pattern computer displays

Monday, June 30, 2003 | DURHAM, N.C. -- Duke University computer scientists have induced DNA molecules to order themselves into the equivalent of a Lilliputian computer display. Using a synthetic DNA strand as input, the method caused the self-assembly of tile-like DNA structures displaying binary data 01101. By changing the input DNA, the method displayed a different value, 10010.

The researcher said his DNA patterning results might be used to position molecular electronic components to form molecular-scale computer circuits and memory. Such molecular computers could be far more compact and powerful than today's computers.

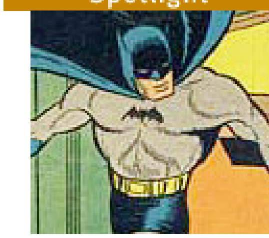
The researchers reported their results in a paper published in the online edition of the *Proceedings of the National Academy of Sciences* on June 23, 2003.

"Although we are far from creating a practical molecular computing machine, these experiments show progress toward that goal," said Professor of Computer Science John Reif. "We can create a nanoscale-patterned lattice representing binary data, we can reprogram the system to change the data, and we can display the data in a nanoscale visual readout that can be viewed with the aid of an atomic force microscope." The term nanoscale refers to objects and distances measuring only billionths of a meter.

The atomic force microscope reads the DNA-produced image by scanning the surface of the DNA tiles with an ultrasharp tip, detecting minute variations in height and then converting the variations into visual images of the scanned surface for display on a conventional computer monitor.

Reif said the DNA-based display of binary data resembled the front panels of some of the earliest computers. "Primitive electronic computers used lights that represented 1's when on and 0's when off. Reading the blinking patterns of 1's and 0's was a challenge. It took decades to get from those blinking panels to the graphical computer environments that are now in routine use.

"Our method uses the presence of a DNA hairpin loop to



represent a 1, and the absence of such a loop to represent a 0," Reif said. "Because of its minute scale, reading data displayed this way requires an atomic force microscope. Nevertheless, this is a visual output method for DNA computing, and having a visual output method would increase the read-out speed of DNA computers. The technique may also be useful for identifying gene sequences in DNA."

Reif stressed that the experiments also represented progress in the self-assembly of nanoscale structures using "bottom up" design methods. Conventional computers and electronic circuits are designed and fabricated in a "top down" method, he said. With the top-down approach, electron-beam lithography or x-ray lithography etches a circuit on a silicon chip in a series of steps, one after the other, as the beam moves along.

"The advantage of using bottom-up methods of self-assembly with DNA is that many steps can happen simultaneously, in parallel," Reif said. "However, self-assembly has been limited to creating relatively simple, regular, repeating structures. Furthermore, the assembly processes have not been reprogrammable. In this experiment, we created patterns that are aperiodic, or irregular, and we demonstrated that we can program DNA to create different patterns. These are necessary steps toward developing methods for self-assembly of more complex and varied nanoscale structures and devices such as nanoelectronic components, circuits, and functional nanodevices."

Programmability was achieved by using "directed nucleation," Reif said. "A preassembled input DNA strand encodes the required pattern of bits. DNA tiles are assembled around the input strand, which serves as a scaffold for the assembly."

Reif attributed the success of the project in large part to the strength and interdisciplinary nature of the team performing the work. "I am a computer scientist and the idea of programmable patterning has its roots in computer science. But the DNA nanostructure research we do necessarily involves drawing on knowledge and skills from a variety of disciplines well beyond computer science. My first co-author Hao Yan has a Ph.D. in chemistry, and another co-author Thomas LaBean has a Ph.D. in biochemistry. Both have done brilliant prior work on DNA nanostructures. Our lab assistant Liping Feng is highly trained in the required biochemical techniques. "

The self-assembly method could be used to create the layout for a random-access memory (RAM) circuit, the form of memory most commonly used in computers, Reif said. "A RAM circuit is a periodic lattice of memory elements coupled with a means to address any element in order to write or read a bit of data," he said. "Directed nucleation self-assembly can create lattices, and

A Campus Reflects

Audio & Video

Duke provides on-campus studio facilities to national and regional broadcast news media for live interviews of faculty, administrators, staff and students.

Information for Broadcast Media

the ability to create a variety of other patterns may permit the construction of more varied aspects of circuits to address memory elements, transfer data when it is read or written, and interface with other parts of the system."

Reif said recent experiments by his and other groups have demonstrated the ability to perform logical operations by assembling DNA tiles. "The challenge is to develop techniques to create DNA structures of increasing size and complexity in order to develop systems that can perform useful large-scale computations," he said. "Individual DNA computations are slow compared to electronic computers, but it may still be possible to achieve greater speed with DNA by performing vast numbers of operations simultaneously."

For additional information, contact:
Phil Lemmons
| phone: (919) 681-8061 | email: phil.lemmons@duke.edu