Decentralization May Prove Key to Smart Structures

A NEW APPROACH may finally make “smart structures” practical.

The early promise of smart structures—equipping spacecraft, aircraft, automobiles and ships with networks of sensors and actuators that allow them to respond actively to changing environmental forces—was that they would revolutionize design, construction and performance. That promise never materialized.

To today, however, recent advances in MEMS (microelectromechanical systems) and distributed computing appear to be overcoming these limitations. Reports by several groups indicated what could be a major clue in mysterious molecular processes that direct cells to the correct locations within a developing embryo.

In the first phase of the project, Frampton’s group prepared and ran a detailed computer simulation of the system that showed it should provide a degree of vibration reduction comparable to that of a centrally controlled system.

“The most important result of the simulation is that it shows that the embedded system is scalable,” says Frampton. “That means we should be able to build it as big as we need to and it should continue to function.”

In the older approach, all the sensors and actuators are connected to a central computer. It receives information from all the sensors, processes it, and then sends instructions to all the actuators on how they should respond. As the size of the structure and the number of sensors and actuators increase, the amount of wiring required increases. Difference in arrival times of information from the nearest and farthest sensors also increases. As this increases, the system takes longer to control the sensors and actuators, so it may simply not work.

The high noise and vibration inside rockets when they are launched increases the cost of manufacturing satellites and other equipment boosted into space. So a system that reduces these levels by even a small amount would cut payload development costs substantially.

In the first phase of the project, Frampton’s group used an embedded system. It contains one main computer that controls a group of modules, each of which is connected to the main computer as well as to its two nearest neighbors. Each module contains a small computer that monitors a group of sensors and actuators. Depending on how the system is set up, the processor also receives data from a number of the nearest neighbors so it can coordinate the actions of its actuators. Although each processor has less capability than that of a central computer, it has far less information to handle, and its workload does not increase as the system gets bigger.

“Embedded systems are also far more ‘fault tolerant’ than centrally controlled systems,” says Frampton. “If the central processor breaks down, the entire system shuts down. But a decentralized system will continue to work even when several microprocessors fail, although probably with slightly diminished capability.

The second step in Frampton’s project is to put a 100-node system into an actual rocket faring comparable to the simulated system. Then he will test how well it performs in the laboratory. This information will allow engineers to estimate the system’s performance and its weight and cost.

Discovery May Shed Light on Cell Movement During Development

B I O L O G I S T S at Vanderbilt and the University of Missouri have uncovered what could be a major clue in mysterious molecular processes that direct cells to the correct locations within a developing embryo.

Understanding the molecular basis of these processes and how they can go wrong could lead to treatments for birth defects such as spina bifida.

In the August issue of the journal Nature Cell Biology, researchers report the discovery that a single protein facilitates movements of cells within the developing embryo of the zebrafish. This protein plays an essential role in directing cell migration within the spherical egg to the head-tail axis where the body is beginning to take shape. Researchers found that disruption of the same protein inhibits normal migration of nerve cells within the developing zebrafish brain, a type of motion found in human brain development.

“Very little is known about how neurons move from one place to another,” says Lilianna Solnica-Krezel, associate professor of biological sciences at Vanderbilt, who led the study with Anand Chandrasekhar, assistant professor of biological sciences at the University of Missouri, Columbia. Solnica-Krezel’s research team included graduate student Florence Marlow, and research associates Jason R. Jessen, Jacek Topczewski and Diane S. Sepich.

Zebrafish have become important in studying development of vertebrates. Their eggs are transparent and develop outside the body, making them particularly easy to study. The zebrafish genome is currently being sequenced, which allows researchers to employ the powerful tools of genomics to unravel complex molecular processes involved in the development process. One of these methods is to examine the impact of specific mutations. In this case, researchers explored what takes place in a mutant called trilobite.

During development, cells begin converging from all sides of the spherical egg to the embryonic axis where the body begins to form. What begins as a disordered, chaotic motion changes into an orderly movement. Cells change from a round to an elongated, spindle shape. “It’s something like a mob transforming into an army,” says Solnica-Krezel.

Her research group discovered that trilobite embryos are a third of the trilobite embryos. Scientists concluded that the Strabismus/Van Gogh protein must have both cellular and extracellular effects.

The results of various tests suggest that the protein Strabismus/Van Gogh acts independently in mediating neuron movement. If this proves to be the case, then it provides an entry point to elucidate the molecular basis of this class of neuronal migration.

Microscopic view of two-day-old mutated zebrafish embryos. Disruptive activity of a specific membrane protein, called either Strabismus or Van Gogh, is shown in red. Somewhat later in zebrafish development, a number of motor neurons move from one part of the brain to another. “We don’t understand why they move because they can form the connections they need from their original location,” says Solnica-Krezel. But Chandrasekhar and his Missouri team discovered that this movement does not take place in trilobite embryos.

Researchers transplanted trilobite neurons into brains of normal embryos and normal neurons into trilobite brains. None of the normal motor neurons migrated when placed in a trilobite brain, whereas a third of the trilobite neurons migrated when placed in normal brains. Scientists concluded that the Strabismus/Van Gogh protein must have both cellular and extracellular effects. The results of various tests suggest that the protein Strabismus/Van Gogh acts independently in mediating neuron movement. If this proves to be the case, then it provides an entry point to elucidate the molecular basis of this class of neuronal migration.

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1. smart structures
2. decentralized system
3. embedded system
4. zebrafish embryos
5. Strabismus/Van Gogh protein
6. molecular processes
A mathematician at Vanderbilt and an expert in infectious diseases at the New York University School of Medicine have produced a mathematical model of how anthrax can be spread through the mail. The model was developed by Glenn F. Webb, professor of mathematics at Vanderbilt, and Martin J. Blaser, the Frederick H. King Professor of Internal Medicine, chair of the department of medicine, and professor of microbiology at the NYU School of Medicine.

Their model, which appeared in the May 14 issue of Proceedings of the National Academy of Sciences, simulates the recent outbreak of mail-borne anthrax deaths in the United States and demonstrates that all known cases of infection can be explained by contamination spread through the mail from six original envelopes.

Their analysis concludes that original anthrax-filled envelopes must have contaminated an additional 5,000 pieces of mail with significant but much lower levels of anthrax spores in order to account for the two deaths that appear to have occurred from such cross-contamination. In the case of any future attacks of this type, the model provides a framework that can be used for the rapid identification and containment of any further outbreaks.

Blaser was tapped in the days following the Sept. 11 terrorist attacks to participate in a task force on bioterrorism. He began bouncing ideas off Webb, a longtime collaborator and friend. The two agreed to try to develop a mathematical model that adequately explains the basic facts of the fall outbreak based on cross-contamination.

The model would not prove that the contaminated letters caused all the cases, but it would demonstrate that the explanation is feasible, the scientists say. “The other hypothesis—that original anthrax-laden letters passed through the postal system, either mailbox or post office—gets people better faster.” We believed earlier. “Only one of the deaths was the recipient of an original letter,” notes Webb. “The much greater danger is to postal workers and to the recipients of cross-contaminated letters. The threat is much greater than what people believed earlier.”

If their model is correct, “the rapid and widespread usage of antibiotics among postal workers and persons in the immediate environment of the received original letters probably averted a substantial number of cases,” Blaser and Webb write.

In the case of another mail-borne outbreak of anthrax, the model provides a framework that could help determine what is going on more rapidly than would otherwise be possible.

The mathematical model tracks contaminated letters through different “nodes” in the postal system. The first node is the point at which letters enter the system, either mailbox or post office. Then the letters move to local postal stations. From there they are transported to regional stations and back to local stations before delivery. Each node is assigned a different level of risk of spreading anthrax spores depending on how the letters are handled.

The scientists found that the model provides the best match for the fall outbreak when they assume that there were six original letters, each carrying trillions of anthrax spores. They calculate that these letters, although tightly sealed, contaminated about 5,000 other letters with much smaller numbers of spores, ranging from 10 to 10,000 apiece.

“Statistically, both cognitive therapy and medication were more effective than a placebo, and a brief course of cognitive therapy was better than a similarly brief course of medication in the yearlong continuation phase,” DeRubeis says. “These results suggest that even after termination, a brief course of cognitive therapy may offer enduring protection comparable to that provided by ongoing medication.”

For more information on the stories in Bright Ideas, visit Vanderbilt’s online research journal, Exploration, at http://exploration.vanderbilt.edu