From social networking to swarm intelligence

Research shows how complex systems rule everyday life

A new area of research — fittingly called "complexity science" — embraces the notion that an ant colony and the human brain, the stock market and Facebook all have something in common. All are complex systems, basically huge networks made up of individual components whose behavior is difficult to predict.

Hiroki Sayama

A deeper understanding of these systems' role in nature — and the emergence of computer science tools sophisticated enough to analyze them — offers scientists a more realistic framework for solving today's most vexing problems, from global warming to ethnic conflict.

"The rise of complexity science is not driven by researchers, but actually from the complexity in people's lives," said Hiroki Sayama, an assistant professor in the Department of Bioengineering at Binghamton University. "Ten years ago, a network didn't make much sense."

Today networks and complex systems are everywhere, and there are several university-based centers and journals devoted exclusively to their study.

"It's a fundamental conceptual shift," Sayama said.

It's a different world

At Binghamton, an interdisciplinary group founded in 2007 to study the collective dynamics of complex systems goes by the name CoCo. Perhaps the most striking characteristic of the group is that instead of talking about an interdisciplinary approach, it lives and breathes it.

"There are many people who claim to be interdisciplinary — it's the computer scientist working with the electrical engineers," Sayama, CoCo's director, said with a laugh.

Of course there are plenty of computer science- and engineer-types in CoCo, but they work alongside faculty such as Shelley Dionne, an associate professor in Binghamton's School of Management. She's an MBA-PhD who got her first taste of management not as a budding Wall Streeter, but during a dietetic management rotation toward a degree in nutrition.

"Each one of us is a unique mix," she said.

She was eager to join the group, but quickly discovered that when they finally got face to face, all that interdisciplinary *joie de vivre* didn't come baggage-free.

"We had no idea how to talk to each other," Dionne said.

In other words, they had swarm intelligence while she had SWOT, that classic business tool of identifying strengths, weaknesses, opportunities and threats.

Other members came to the table with similar diversity: Research interests include public administration, biomimetics and environmental toxicology.

It took time, Dionne said. And, it turned out, a lot of office supplies. "Week after week, drawing pictures on white boards until we were out of ink," she said.

What emerged was a shared passion for understanding group dynamics. The

computer scientists might be happily creating swarm simulators or explaining the latest in agent-based modeling, but, she too, could dive headfirst into creating ways for businesses to survive the shift from Dilbert days to dynamic global leadership.

"Gone are the days I sit in my cubicle alone for eight hours a day," she said, describing today's corporate environment. "Gone."

It is exactly that rapid-fire change of today's business climate that has shown the pressing need for a new framework, said Ken Thompson, a United Kingdom-based expert in the area of bioteaming, swarming and virtual enterprise networks and teams, which draws heavily on the understanding of complex systems in nature. His most recent book is *Bioteams: High Performance Teams Based on Nature's Most Successful Designs.*

Traditional business teams rely too heavily on a single dominant structure — command and control, also known as individually led teams, he said, drawing from the military. Such an approach "served us well in the era of mass production when costs, consistency and compliance were everything," Thompson said.

But that model falls well short in today's world full of "networks, dynamic alliances, virtual collaborations — where agility, innovation, added-value and responsiveness are king," he said. "We urgently need to find a new model which recognizes that organizations are not predictable systems, like clocks, but unpredictable ecosystems, like living things. The natural place to look for this model is nature itself with its numerous examples of self-organizing systems and teams in ants, bees, dolphins, wolves, geese and many more."

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One of Sayama's research goals is to create some way to self-organize heterogeneous swarms with several distinct types of particles into specific spacial patterns so one can evolve the internal mechanism. He envisions a system in which, collectively, robots can spontaneously create behaviors.

“Gone are the days I sit in my cubicle alone for eight hours a day. Gone.”

— Shelley Dionne

“That’s the key idea of any complex system,” Sayama said. “It’s very hard to predict.”

But what’s not difficult to envision, especially for the younger generation, is the concept that groups react differently than individuals when part of a network, he said.

Think of today’s college students, Sayama said. They get up, check Facebook, send e-mails. Their lives are all about connection.

“They are already aware that everything is networked,” he said. “They already understand they are part of something bigger.”

From ‘fringe’ to center stage

David Schaffer, a member of CoCo and a visiting research professor in the Department of Bioengineering who also works as a research fellow at Philips Research, connected with Sayama through their shared belief that the concepts from modern complexity theory have something to offer societal problems. It’s an idea that didn’t seem to get much traction in the wider world until recently, he said.

So it must be satisfying for scientists such as Schaffer, whose dissertation was on genetic algorithms — something once considered on the “lunatic fringe,” he said — to see their ideas get so much respect. Today evolutionary computation is seeping into every aspect of engineering and more applications are on the horizon, he said.

“I’m kind of the utopian thinker,” Schaffer said. “I think we can do better than we are doing.”

CoCo’s research focus is both “new and old,” said Yaneer Bar-Yam, professor and president of the New England Complex Systems Institute, a Cambridge-based nonprofit research and education institute. Sayama did his post-doctoral work there and they still collaborate.

It’s as old as the groundbreaking economic theory of Adam Smith’s “invisible hand,” put forth in the 1700s, and evolution itself, which of

course didn't happen by one piece, Bar-Yam said.

What's new are the computer science-based tools available for understanding and analyzing these ideas.

"And Hiroki is one of the pioneers in the field," Bar-Yam said.

A recent National Science Foundation grant of more than $550,000 confirms that view and provides CoCo at Binghamton with the resources the group will need to explore and expand its evolutionary perspective on collective decision making.

David Sloan Wilson, a distinguished professor of biology and anthropology at Binghamton, a member of CoCo and the director of the interdisciplinary Evolutionary Studies (EvoS) program at Binghamton, said it is CoCo's "combination of evolutionary theory and complexity theory that is so special."

So, too, is its emphasis on using its research to solve real-world problems.

Wilson is part of the Binghamton Neighborhood Project, a collaboration among Binghamton faculty and community partners that uses CoCo to help make neighborhoods stronger.

Think of SimCity, Wilson said, referring to the popular computer game that challenges users to create a city. You create infrastructure, both physical and social, and see the consequences unfold, some unforeseen.

It's much the same in the real world.

"Patterns develop within cities based on people making personal decisions — leaving neighborhoods if they can, or staying if they can't," Wilson said. "We are all interacting with each other."

The Neighborhood Project has been able to map seemingly intangible — but utterly familiar — neighborhood characteristics. One part of its research found a correlation between high marks for caring neighbors and the level of holiday decorations in a neighborhood.

The juxtaposition of high science and holiday displays is nothing new. "Binghamton has always valued integration," Wilson said, mentioning the University's Languages Across the Curriculum program. "I think it's one of the great things about the University. In order to have integration, you have to have a common language — one is the common language of evolutionary theories and complexity."

And that relatively new addition of evolutionary theory to the study of complexity science means a great deal more landscape for great thinkers to explore together. ■

— Kathleen Ryan O'Connor

Shelley Dionne