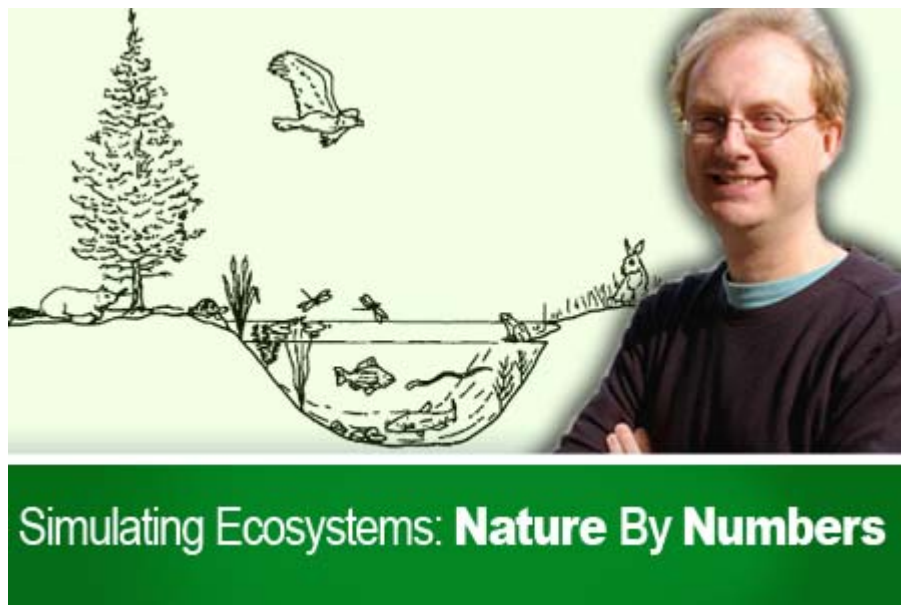


Research Profiles



Nature by Numbers: Simulated Ecosystems Provide Answers to Biological Questions

What drives evolution? How does one species become two? Where will organisms disperse and why?

Theoretical questions about the way natural ecosystems function have been puzzling biologists for years. Now a University of Windsor professor of computer science is providing the solutions with a complex and unique virtual ecosystem simulation.

Prof. Robin Gras, who also holds the Canadian Research Chair in Probability Heuristics and Bioinformatics, created the simulation to accurately represent the behavior of real world ecosystems.

His simulation is the first to model the fact that individual behaviours can affect the evolutionary course of the entire species.

To achieve this realism, Gras relies on the computational power of SHARCNET.

“Because we take into account the perceptions and behaviours of every individual in a species, our data gets quite large,” says Gras. “In fact, each time we run our simulation it takes between 5 or 6 weeks of computational time. We really rely on SHARCNET’s resources.”

Gras collaborated with biologists to gather the background data for the virtual simulation. Although it’s not based on any one specific living system, it was designed to model situations and problems that many real world ecosystems face, such as limited food resources, invasive species and disease.

At the beginning of the simulation, two species exist: one predator, the other prey. Throughout the simulation, new species can emerge in either class. Regardless of species, each organism in the simulation has the ability to perceive and make decisions about its environment. This allows them to feel basic needs and high level desires, from hunger and reproductive drive to curiosity, fear and happiness.

A mathematical concept called “Fuzzy Cognitive Map” (FCM) makes this possible. An individual organism experiences its environment, and then the FCM model transforms the data in some way to simulate the individual’s interpretation of its surroundings. This means the information perceived by the individual isn’t the exact information that comes from its environment – and the imprecision caused by individual perception makes the simulation more realistic. This model also integrates emotions and desires which, coupled with the perception of the agent, have influence on its decision of action.

Then there's virtual offspring. When two virtual organisms reproduce, their offspring's genetic information is a combination of the parents. Because the behavioural model for the organism is encoded in the genome, both the mother's and father's behavior will be represented in the offspring.

As in nature, chance genetic mutations are possible. So, the offspring could end up with new genetic variations that lead to totally new behaviours. They may be able to avoid predators or find food in different ways, and this could eventually result in "speciation": a new species emerging.

Gras and his team manipulate their simulated ecosystems to see if they can affect phenomenon like speciation and migration.

"We try, for example, to integrate a new source of food into our system to see if it accelerates the way the species emerge or dedicate themselves to one food source or another," says Gras.

By adding virtual obstacles, they can restrict the movement and breeding opportunities of a group of organisms. This models a very important biological paradigm, where a reduction in gene flow leads to more speciation events.

The researchers can also integrate virtual diseases into the simulation and study how individual interactions are linked to the disease's spread. Just like diseases, invasive species can diffuse throughout an ecosystem. In the virtual ecosystem, Gras can examine how a foreign species survives in a new environment, and how its survival impacts the native organisms.

Gras uses a special program to analyze the results of all these simulations. The program itself takes several days of computation with SHARCNET resources, and gives the researchers a clear picture of what's going on.

"We can compare what we observe with real biological data, and we see the same kind of patterns, the same kind of high level behaviours as we see in nature," says Gras. "We have the ability to observe what, at the individual level, leads to the cause of these emerging patterns—so we have the whole chain of representation."

Collaborators include Prof. Melania Cristescu, Great Lakes Institute for Environmental Research, University of Windsor. Funding is provided by the Natural Sciences and Engineering Research Council.

For more information on Dr. Gras or his research please visit <http://sites.google.com/site/ecosimgroup/home>