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Visualizing Complex Ecosystems

- **"Virtual Ecosystem" helps fulfill NASA mission to understand and protect our home planet**
- **Integrates data mining with virtual modeling to depict complex ecosystem dynamics**
- **Pilot use in Yellowstone National Park will support management policy decisions**

One of NASA's key missions is to understand and protect our home planet. To help NASA fulfill this mission, CICT's Intelligent Systems (IS) Project, through its Intelligent Data Understanding (IDU) subproject, is funding development of new technologies that help scientists integrate and analyze the vast amounts of data being gathered from NASA's satellite-based Earth Observing System (EOS) and other sources, including ground-based observation and research.

As part of this effort, Fred Watson, interim director of The Watershed Institute at California State University Monterey Bay, is developing the "Virtual Ecosystem" environmental modeling tool. The software provides an animated, 3-D depiction of the complex interactions occurring in an ecosystem. Watson's pilot project for this software is Yellowstone National Park.

Joseph Coughlan, manager of the IS Project's IDU subproject, says, "Watson's software effectively integrates the mining of satellite and ground-based climate, vegetation, and terrain databases and extensive wildlife tracking databases with virtual modeling technology."

Visualizing Yellowstone

The Greater Yellowstone Ecosystem is one of Earth's largest remaining intact temperate zone ecosystems. It is the home of large populations of wild bison and elk, extensive geothermal activity, seasonal snow cover, large tracts of forest and meadow, and recently re-introduced wolf packs.

To help meet the challenges of managing Yellowstone in the face of multiple, often competing, interests, Watson's "Virtual Ecosystem" software integrates dynamic data models of the park's fluctuating snow pack

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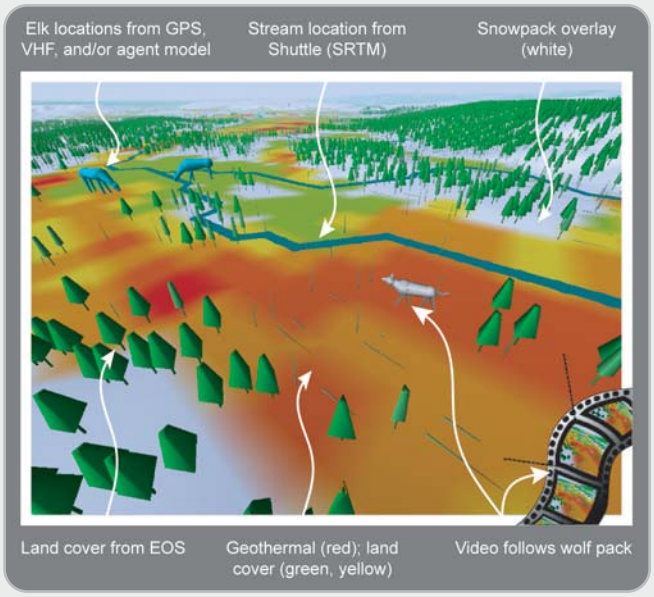

"Virtual Ecosystem" software shows the interaction of animals and geological and climatic phenomena in Yellowstone National Park. (Screenshot: Fred Watson)

Technology Spotlight

Technology

"Virtual Ecosystem" software, based on Tarsier—a Windows-based, object-oriented, environmental modeling tool

Function

Integrates the mining of extensive wildlife tracking databases with modeling of a variety of climate and landscape functions to provide an animated, virtual, 3-D depiction of the complex interactions occurring in Yellowstone's ecosystem

Relevant Missions

NASA Mission to explore the Earth, Moon, Mars, and beyond

Features

- Rapid development of simulation models from spatial and temporal data
- Data mining of wildlife data sets
- Geographical information systems (GIS) processing

Benefits

- Better scientific understanding of wildlife ecosystems
- Better-informed management integration tools for deciding policy
- Better public communication tools

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By tracking and depicting the movement of elk, bison, wolves, humans, and other mammals, based on field studies, "Virtual Ecosystem" will provide better support for wildlife management policies and better education for the public.

Photos: Fred Watson (elk, bison, snowmobiler) and Adam Messer (wolf)

and geo-thermal activity with dynamic exploration of tracking data and models of elk, bison, bear, and wolf population and migration. The interactive, PC-based tool can produce a video depiction of all these activities occurring simultaneously, even though the data are drawn from multiple databases.

Studying Yellowstone's ecosystem

Watson is part of a small, tightly knit science team that is studying Yellowstone's ecosystem. The team—led by Bob Garrott, professor of ecology at Montana State University Bozeman—has expertise in a wide range of disciplines, including mammalian ecology, population dynamics, spatial ecology, predator-prey dynamics, mathematics, statistics, hydrology, remote sensing, geographic information systems, computer science, and modeling. Additional expertise comes from the team's thirty-eight collaborating scientists and professionals across the nation.

So far, the team has developed extensive databases on the movement and population distribution of the large mammals in the central portion of the park, including elk, bison, grizzly bears, and the Nez Perce wolf pack. They have also accumulated annual population estimates, annual pregnancy rates, and estimates of survival and cause-specific mortality. As a complement to these data, the team has created databases of snow cores, snow pack temperatures and hardness, thermal gradients over varying terrain, and forest leaf area and stem diameter. Using advanced remote sensing technology, the team has also provided an unprecedented insight into geothermal activity in the park. All of this data feeds into the "Virtual Ecosystem" modeling tool that Watson has developed.

Once you have entered the object for study—say the annual migration of elk and wolves through the central portion of the park—"Virtual Ecosystem" provides you with a video showing icons or avatars of the elk and wolves moving dynamically through the area, with the elk moving closer to the thermal areas to escape the build-up of the snow pack and ranging further out as it recedes.

Tarsier—the software framework

"Virtual Ecosystem" is based on Tarsier, a modular, object-oriented, Windows NT/98/2000-based framework for rapidly modeling animal (agent) behavior interacting with a spatio-temporally dynamic environment. It can be used to create a variety of environmental computing tools such as simulation models, data storage and analysis tools, and visualization systems.

Tarsier was conceived by Watson, and developed with CICT funding in collaboration with the Cooperative Research Centre for Catchment Hydrology (CRCCH) in Australia. Developed within the Borland C++Builder IDE, Tarsier supports the organization of quantitative environmental information, such as grid maps, networks, time series, and simple lists of geographic locations. Upon these are built analytical tools for interpolation, statistics, sampling, and data transformation. At the top level are modules that implement a variety of simulation models, from cellular automata to stream pollutant routing models to large-scale spatial catchment hydrology models.

"Tarsier makes it easy for you to connect existing modules together to form your own custom analytical, visualization, and modeling systems that fit seamlessly into the existing framework," says Watson.

Yellowstone's hidden drama

"This ecosystem modeling tool will help us better understand Yellowstone's ecosystem," said Watson. "For the first time, we can see how the many components of the system—animals, humans, climate, snow pack, foliage, geothermal activity—interact through the seasons. This will help policy makers in deciding management strategies for the park's wildlife, and show the three million annual tourists how Yellowstone's ecosystem functions, and the role they play in it."

—Larry Laufenberg

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