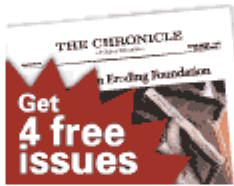

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Using Computer Models to Study the Complexities of Human Society

Some scholars say the trend is a breakthrough in the social sciences; others believe it's just a fad

By JEFFREY R. YOUNG

The Anasazi Indians mysteriously abandoned Arizona's Long House Valley many centuries ago, but researchers have now brought them back -- at least in a computer simulation.

In the computer model, hundreds of virtual people, called "agents," make decisions on whether to have children, to move to a new area of the valley, or to cultivate more land. The virtual people react to actual environmental conditions of the period from A.D. 400 to 1400, which have been programmed into the model.

The team of archaeologists, anthropologists, and computer scientists who created the simulation can replay the history over and over again, changing the rules that govern the people's behavior and observing how small changes in rainfall and other factors might have affected settlement patterns long ago.

The Anasazi model is just one example of how social scientists are using "agent-based" computer simulations to explore how societies function. The technique is not new -- it dates to the earliest computers -- but researchers say its use is expanding in fields like sociology, economics, and anthropology, thanks to the ready availability of faster computers.

In January, researchers started a new on-line journal about modeling, called *The Journal of Artificial Societies and Social Simulation* (http://www.soc.surrey.ac.uk/JASSS/).

"It's definitely growing," says Robert Axtell, a research fellow at the Brookings Institution who is one of the participants in the Anasazi-modeling project. "People are starting to take this seriously as a method."

Les Gasser, an official at the National Science Foundation, agrees. "To my mind, the really interesting new advances are in computer modeling in social sciences," says Mr. Gasser, who is director of the computation and social-systems program in the N.S.F.'s computing-sciences directorate. He adds that computer modeling is already

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well-established in the natural sciences, such as chemistry, physics, and meteorology.

The use of agent-based models in the social sciences varies widely. A psychologist has developed a computer model of the interactions of employees in a public-works department, to study how new technologies spread within workplaces. A team of sociologists has built a computer model of the U.S. population to test the effects of economic reforms on individuals.

"Basically, what we now have for the first time in history is the analogue of the physics laboratory for doing experiments with social phenomena," says John L. Casti, a professor at the Santa Fe Institute, a non-profit research center that focuses on computer modeling and what it calls "the science of complexity."

"For years, people have claimed that the social and behavioral areas could not be made scientific in the same way as the physical sciences because there was something about humans that put them beyond the bounds of scientific analysis," he says. "I think this is total nonsense. There's nothing any more special about humans than there is about electrons, other than that electrons always use the same rule of behavior and humans don't."

"It's my belief that the vagaries of human behavior can indeed be factored into computer models," he adds.

Skeptics, however, see modeling as a fad with limited potential. Human behavior is simply too complex to be simulated and predicted by computers, they say.

Others, including even some supporters of the research approach, warn that, if it became widespread, it might draw researchers away from field studies. "It's pretty easy to sit in a lab -- bright lights, fast computer, vending machine down the hall -- and fantasize what a real human situation is like rather than actually being in the field on the street," says Mr. Gasser, of the National Science Foundation.

Scott Page, an associate professor of economics at the University of Iowa, has developed an exercise to explain agent-based modeling for an undergraduate course he teaches. He asks his students to imagine an audience at a theater performance. At the end of the show, the audience may or may not give a standing ovation. Each person in the audience makes a decision to sit or stand while clapping, and people often follow the examples of those nearby.

Mr. Page helps his students design a computer simulation of an audience. In it, each of 100 virtual people -- the "agents" -- either stands or remains seated while clapping. The model takes into account where each virtual person is sitting: If agents in the front

row stand, agents in the back can see them, and are more likely to stand themselves. Mr. Page asks the students to try to find the most effective way to "seed" an ovation by planting 10 enthusiastic agents at strategic points in the auditorium.

He says the same technique could be used to study other social phenomena, such as out-of-wedlock birth rates, drug use, or high-school dropouts, in which people look to others for cues to appropriate behavior.

Mr. Page acknowledged that there are limits to how realistic such a model can be. "You can't just say, 'Here's the rule of thumb humans follow,'" he says. "That's what makes this modeling in the social sciences so much more delicate." But he says the simulations offer a way of of testing hypotheses quickly within complex systems.

An early example of a simulated society was set up with poker chips on a checkerboard back in the 1970s. Thomas C. Schelling, an economics professor at the University of Maryland at College Park, created the simple model to explore how communities become segregated.

He used blue and red poker chips to symbolize two ethnic groups, and assigned each group simple rules that its members used in deciding where to settle. He began by distributing the chips at random on the board, and then moved them around based on the rules he had set out. Reds, under one scenario, might prefer to live next to at least two other reds. Yet his virtual people also preferred that their neighborhood, over all, be diverse.

"The results I got surprised me," he says. "It turned out that you got quite striking segregation without much preference" -- without reds' having to specify that they wanted to live in an all-red neighborhood.

Mr. Schelling then helped program the rules into a computer to make the simulation easier to run. That was "back in the days when computers were huge, lumbering tele-typewriters," he remembers.

Other scholars have since taken the idea further.

At the University of Illinois at Urbana-Champaign, Noshir S. Contractor has built a computer model that simulates social networks within the public-works department at Fort Gordon, Ga. Mr. Contractor, a professor in the department of speech communication and psychology, has done plenty of field research to create the model. He has visited the Georgia office every two months for the last three years, asking employees about their work habits and social networks.

The office is now in the process of installing a new computer system.

Mr. Contractor says the three top managers there thought the best way to integrate the new system would be to start using it themselves and and then offer access to it to others who wanted to switch. But in Mr. Contractor's simulation, that would not have worked out very well. "There was only about 70-per-cent diffusion, and it took quite a long time -- about six months," he says.

So Mr. Contractor used the model to see what would happen if the technology were given to three people he identified as role models in the office. "Within three months, according to the computer model, almost everyone in the organization had adopted the technology," he says. "One of the few people who had not adopted the technology was one of the managers."

The managers have since agreed to try Mr. Contractor's approach, even though they have not been told exactly what the computer model predicted. Mr. Contractor will use their actual experience to gauge the accuracy of the model's forecast.

Computer models are also being used to study societies that have faded away.

One example is the Anasazi project, a collaboration of the Santa Fe Institute and the Center on Social and Economic Dynamics, which is jointly operated by the Brookings Institution and the Johns Hopkins University. Researchers say their simulation is shedding light on why the Anasazi abandoned Long House Valley, in about A.D. 1350.

Peyton Young, co-director of the center, says the subject seemed uniquely suited for simulation. "The historical record is quite amazingly preserved," he says, but even so, archaeologists have not been able to explain adequately why the Anasazi left the valley. "We said, Okay, let's build a simulation model with artificial agents with simple rules of adaptation, and see if we can generate a similar history."

When the model is running, the computer screen shows side-by-side maps of Long House Valley. One map plots the actual historical data about the settlement patterns of the Anasazi Indians. The other plots the settlement of hundreds of simulated people reacting to the same environmental conditions based on simple rules. Each year, the agents make interconnected decisions, such as whether to move to a different part of the valley or whether to have children.

When a researcher presses a button that looks like the "Play" button on a VCR, the model springs to life. On both maps, dots appear and disappear, and color shadings swell and recede, as history, both real and simulated, unfolds. The dots represent settlements, and the color shadings show environmental factors such as the depth of the water table and the condition of the soil. The model can be run quickly, so

that decades' worth of settlement patterns can be seen at a glance.

When blue shading darkens to indicate a rise in the water table, for instance, the dots of settlements bloom. The simulated settlements do not appear in the same locations and numbers as on the historical map, but the trends on both maps are similar.

George J. Gumerman, director of the Arizona State Museum at the University of Arizona and a participant in the project, says the model has helped the researchers "sharpen our questions" about what happened in Long House Valley more than 600 years ago. "It doesn't give us the answer," he says. "In no way are we trying to say this is the way society operates. It's much, much too simple."

What they've gained, he says, is a better sense of how important environmental factors were in bringing about the group's departure -- specifically, a prolonged dry period in the 1300s. "The model shows that, Yes, it was very important," he says. "We can show that three-fourths of the people had to move out" because the land could not support them. But that's a more-informed estimate than archaeologists have been able to make in the past, he says. "We're starting to be able to quantify the various kinds of elements that cause such things as population movement."

He suggests that social factors most likely led the remaining settlers to leave. "Maybe the most important clan moved out and the others followed," he says.

Mr. Gumerman says that, to his surprise, the computer is "actually giving us more of a humanizing view of the people," because it has forced researchers to imagine the decisions of each person. "Archaeologists deal with material culture, but we tend to have difficulty when dealing with social aspects," he says.

Meanwhile, researchers at Cornell University are using a computer simulation to forecast how policy changes could affect the U.S. economy.

Steven B. Caldwell, a professor at the university's Institute for Public Affairs, has spent the last 11 years developing an agent-based model of the U.S. economy using census data since 1860 and other government statistics.

Unlike most economics simulations, which tend to divide the population into a few large groups, the Cornell model simulates the individual decisions of everyone in a large population.

"You're simulating the actual life course of each person in the population of several hundred thousand persons, and you're simulating dozens of their behaviors -- marriage, work, earning,

saving," Mr. Caldwell says.

It takes about 14 to 16 hours for the computer to calculate an economic forecast for the next 40 years, but the model can be run for shorter or longer periods.

Mr. Caldwell says one of his graduate students just finished a project that used the model to simulate what would happen if various proposed reforms of the Social Security system were instituted.

Mr. Caldwell says he spends most of his time trying to make the model as realistic as possible. "We're obsessed with validation," he says. "We validate it against current census data. We look up and see our estimates and compare them to Social Security's actual records."

Despite such efforts, he says he would not trust the model to make policy recommendations. "We still don't think we're good enough," he notes. The model's results are "only very rough approximations still."

Even improved models will have to be used carefully, he says, because they will never be completely accurate. He hopes that many researchers will build models of the nation's economy, so that their results can be compared.

"My solid forecast," he says, is that "within 10 years we'll have a whole bunch of these policy models."

The University of Maryland's Mr. Schelling says he hardly imagined that his poker-chip model would start a trend. "I never thought that I was developing a new methodology or anything," he says. In fact, he has moved away from using such techniques in his own research. "I think you can learn a lot from [computer models], but you don't want to take them too far."

In fact, some people may think of agent-based modeling as little more than an elaborate game, like a popular series of video games produced by Maxis. In titles like SimCity, SimEarth, and SimSafari, players can build simulated environments and see how virtual people or animals react to them.

Mr. Axtell, of the Brookings Institution, says that the games are similar "in spirit" to the research models, but they don't actually compute the reactions of each individual. Instead, they use equations to average out how groups behave. Even so, he admits to being a fan of the games. "Back when I was in graduate school, I used to love to play SimCity all the time," he says.

As to whether work on simulations could diminish participation in field research, many scholars developing the simulations say that is

unlikely.

"I doubt very much that simulations will detract from field research, since the field research is a necessary preliminary step to the construction of these simulations," says Mr. Casti, of the Santa Fe Institute. In fact, other researchers point out, the trend could lead scholars to gather new types of data to improve the simulations.

Researchers say one of the difficulties of using social-science simulations is managing the collaboration that such projects require.

"In order to do this work, you need to bring together a very interdisciplinary team of researchers," says Mr. Contractor, of the University of Illinois. It's much easier for psychologists to work with expert programmers than to learn how to build simulations themselves. "Computers," he observes, "are really good at making a good research scientist into a lousy programmer."

But the payoffs are worth the effort, researchers who have tackled such projects say.

"Artificial society-type models may change the way we think about explanation in the social sciences," wrote Mr. Axtell in a 1996 book he co-wrote, *Growing Artificial Societies.* "Perhaps one day people will interpret the question 'Can you explain it?' as asking 'Can you grow it?'" -- in other words, Can you simulate it? The technique "holds out the promise of a new, generative kind of social science."

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