Artificial Societies*

by Peter Tyson

EES 4760/5760: Agent- and Individual-Based Computational Modeling
Reading for Monday Aug. 26

Notwithstanding the folk wisdom that history repeats itself, the rise and fall of civilizations is an experiment that runs only once, which makes the job of those who study society inherently challenging. Indeed, the inability to conduct repeatable, verifiable experiments on social phenomena has caused some in the physical sciences to denigrate the social sciences as "soft."

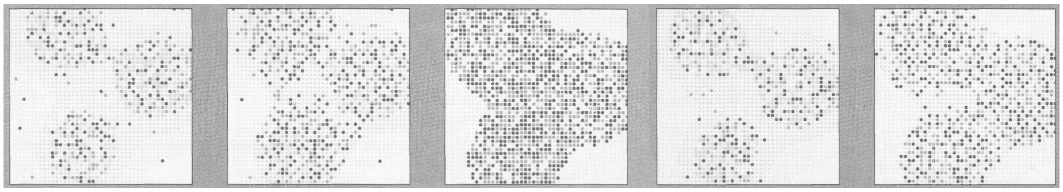
Well, the social sciences just got a little harder. Researchers at the Brookings Institution in Washington, D.C., have devised a sophisticated software program to study societies in silico, allowing economists, demographers, and other social scientists to rerun history, as it were, changing single variables and testing the results. Their so-called "artificial societies," the program's developers say, offer unique insights into issues ranging from racial segregation to mass migration, and may just revolutionize the way social scientists pursue their research.

The road to such artificial societies was laid down in 1953, when mathematician John von Neumann invented self-replicating automata. These cellular automata, as they are also known, consist of a lattice of cells with specific values that change according to fixed rules for computing a cell's new value based on its current value and the values of its immediate neighbors. Von Neumann found that, when left to their own devices, cellular automata naturally formed patterns, reproduced, even "died."

The first attempt to apply such techniques specifically to social science occurred in the 1970s, when economist Thomas Schelling created an artificial world using nothing more than pennies and dimes that he moved around a checkerboard according to simple rules. Schelling's study showed, among other findings, how even slight preferences for living and working with one's own kind can result in extreme segregation. Though primitive by today's standards, both efforts revealed how social patterns develop of their own accord out of the discrete interactions of individuals. Yet so-called artificial life did not take off until the 1980s with the giant leap in computing power and the advent of object-oriented programming, a technique that allows programmers to define objects, or entities, in terms of specific characteristics and actions.

Known to aficionados as Alife (see "What's It All About, Alife?", TR April 1996), these sophisticated artificial-life programs allow agents to interact directly with every other agent and the environment, rather than just with their immediate neighbors, say Brookings Alife developers, social scientist Joshua M. Epstein and computer modeler Robert Axtell. For example, in Sugarscape, as the researchers whimsically dub their most intensively studied artificial society, agents have some traits that are fixed and others that vary depending on their location and interactions. In a typical Sugarscape model, an agent's vision, sex, and metabolic rate are set for life, while its wealth, cultural identity, marital status, and health can change.

*This article originally appeared in MIT Technology Review Apr. 1 1997, https://www.technologyreview.com/s/400048/artifical-societies/



Artificial-life programs can be used to study real-world social phenomena, such as baby booms. In Sugarscape, red females and blue males proliferate when given plenty of space and yellow food. But overcrowding causes resources and populations to drop sharply, only to build up gradually and repeat the cycle. *Artificial-life programs can be used to study real-world social phenomena, such as baby booms. In Sugarscape, red females and blue males proliferate when given plenty of space and yellow food. But overcrowding causes resources and populations to drop sharply, only to build up gradually and repeat the cycle.*

The agents behave according to simple rules. In a typical run of Sugarscape, in which sugar represents food, agents follow the mandate, "Look around as far as you can, find the site richest in food, go there and eat it." Agents thrive if they secure enough food to meet their metabolic needs and "die" if they cannot.

A remarkable range of phenomena emerges from the interaction of these simple agents, according to Epstein and Axtell. For instance, the ecological principle of carrying capacity-that any given environment can support only a finite population-quickly becomes apparent, they say. When "seasons" are introduced, migration occurs. Tribal formation, cultural transmission, trade, hibernation, and combat have also been observed and studied.

All this would be just programmer's play if it didn't have real-world applications. But applied aspects are just what Epstein and Axtell are after. Their work is part of the 2050 Project, a joint venture of Brookings, the World Resources Institute, and the Santa Fe Institute, an independent research organization, to identify and achieve conditions for a sustainable global system in the next century. Epstein and Axtell are using Sugarscape and other artificial-society models for everything from evaluating economic theories to "growing" a silicon version of an actual human society.

In one experiment, the researchers tested theories about the distribution of wealth. Ever since Vilfredo Pareto, a nineteenth-century mathematical economist, first quantitatively described highly skewed distributions of income and wealth, economists have held that such stratifications are a given in human societies. Epstein and Axtell set out to test the theory in Sugarscape, where agents, like people in the real world, continually accumulate wealth (in the form of sugar). In run after run, under myriad variations of rules and environments, the law held up, Epstein says; indeed, it proved the first qualitative similarity between simulated and actual human societies.

The theory has challenged other commonly held theories. Classic laissez-faire economic theory, for example, holds that, if left to their own devices, markets allocate goods and services efficiently and reach a state of equilibrium-in which supply equals demand-without any help from the government. Classical mathematical models, which use so-called "orthodox" agents with infinite lives and fixed preferences, uphold that theory, as does Sugarscape when it uses such agents. But when Sugarscape's agents are made to look and act more like real people-that is, are given finite lives and evolving preferences-the computerized market never reaches equilibrium. "This challenges the efficiency of unregulated markets at a very deep level," Epstein argues.

The ability to turn particular behaviors "on" or "off" has made for other compelling discoveries. When the team added the social institution of inheritance to Sugarscape, by allowing agents to pass on whatever sugar they still owned at "death" to their offspring, they found that agents' visual abilities-to find the goods necessary for survival-on average actually went down over time. "That makes sense because inheriting sugar buffers you against natural selection," Epstein says. "You might not be endowed with tremendous genetics, but because you're born rich, you don't feel the selection pressure as much."

In another study, the Brookings researchers studied a genetically challenged population-one with both poor vision and high metabolism-that, in run after run, died out. They discovered that when a single variable was altered-the agents were allowed to trade-the society not only survived, but even rebounded, ultimately sustaining long-term oscillations in population. Axtell explains that much of this population, which needed both sugar and spice to survive, began dying out as before. But those who had only sugar began trading with those who had only spice. As a result, a few individuals prospered from the trading and began reproducing with abandon until the population grew too large and the cycle repeated itself.

Such experiments can be useful for testing theories about social conditions in the real world. Suppose you have a theory of international relations. "Deploy your little states on a space, give them the rules and regulations you think apply," says Epstein, "and see if you can generate the end of the Cold War, or the formation of NATO, or whatever you like."

Epstein and Axtell have been conducting one such study of how extraordinary social phenomena can form out of the interactions of individuals. Working with archeologists at the Santa Fe Institute, with which Epstein and Axtell are also affiliated, and the University of Arizona, the researchers are attempting to replicate the actual history of the Anasazi, a Native American people who lived in the Southwest from the first to the fourteenth centuries. "The idea is to take little cyber Anasazi, place them under the same environmental conditions that applied to the real Anasazi, and see if we can devise simple rules under which simulated evolution matches true evolution," Epstein says.

It's not a purely academic exercise. Archaeologists have long wondered why the Anasazi suddenly disappeared around 1350. Epstein and his colleagues first simulated the environmental factors that were relevant at the time, including climatic changes, but found that these alone could not account for the plunging population and the Anasazi's eventual departure. They are now introducing cultural elements such as clan formation and land-inheritance practices to determine their effect.

Epstein and Axtell chose the Anasazi because they wanted to model a society that was relatively simple, well-understood (from archeological studies), and more typical of societies in the developing world, where overuse of resources is occurring apace and where sustainable-development experts feel their efforts will bear the most fruit.

Agent-based computer simulations may just change fundamentally how social scientists go about their work. Many in the field have bemoaned the artificial decomposition of social science into separate disciplines, including economics, cultural anthropology, politics, and demography. Epstein and Axtell imagine artificial societies like Sugarscape as the first step toward a new "transdiscipline" that subsumes these various fields. Such an all-encompassing method would enable college professors, for example, to teach an interdisciplinary kind of social science. "An assignment might be to design the following artificial world and come in with a movie of its evolution," says Epstein. "Students might make connections they wouldn't otherwise think about-that, in fact, they're trained not to think about."