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Exploring Complex Social Phenomena with Computer Simulations

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In social studies classes, there is a longstanding interest in how societies evolve and change over time. Students are often engaged in the exploration of complex events that are usually told through the tales of historians. The lessons to be learned from history typically revolve around the premise that past events can teach us about patterns of behavior that are replicated over time. The adage, "if we don't learn from history, we are doomed to repeat it" plays a central role in these tasks.

However, as stories of the past unfold, it is often difficult to identify a direct link between causes and effects, so students are forced to accept at face value the interpretations of economists, political scientists, historians, geographers, and other social scientists. Researchers in these fields traditionally constructed models that were devoid of the complexities and historical intricacies of the time. Resulting patterns were attributed to simplistic causes, while seemingly random events were ignored or designated as inconsequential.

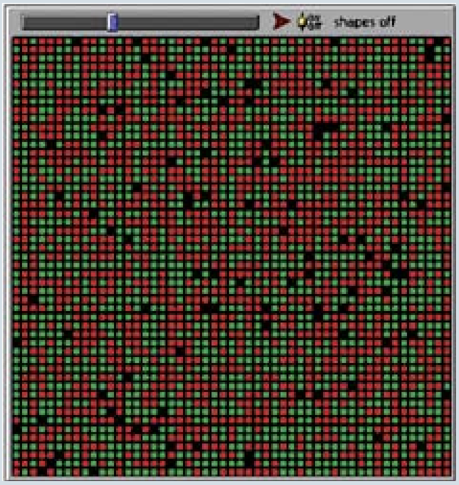
New technological tools are available that can help students explore how individual actions can collectively contribute to the emergence of social patterns—patterns that at times are predictable, but in many cases yield surprising results. Agent-based modeling and simulations are tools that have been adapted to acquire a deeper understanding of complex events in the social sciences.[1] Computers are used to imitate real life phenomenon by creating virtual interactions inside artificial societies that help explain how "social structures and group behaviors emerge from the interaction of individual agents operating on artificial environments." [2]

Who Are the People in My Neighborhood?

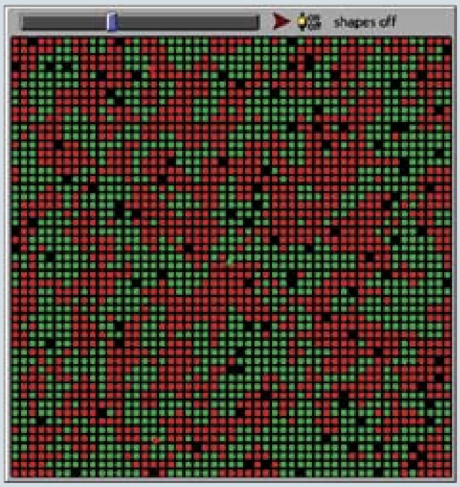
Thomas Schelling pioneered the creation of artificial neighborhoods to study human society.[3] Schelling used a checkerboard grid to model how neighborhoods become racially segregated even when individuals in the neighborhoods express a preference for integration. Schelling designed a simple model in which each individual, known as an "agent," was represented as either a copper or zinc penny. The agents adhered to a few basic rules. An agent would relocate if at least two of its eight neighbors were not of its same kind. Over time, the results showed that clusters developed in the artificial neighborhood that were geographically divided based on the kind of agent. Even though segregation was not the intended consequence of the agents, the collective outcome was a segregated society. Schelling concluded that knowledge of an individual's intent did not predict the social outcome. The end result was more than the summative effects of individual behaviors. Similarly, knowing the outcome of an event does not provide evidence of the intent of the individuals involved.

In the social studies classroom, teachers can explore this phenomenon with their students using the NetLogo Segregation model.[4] In the model, the agents are red and green turtles that live in a pond. Like Schelling's human agents, the turtles get along with one another, but they would like to reside near at least some like turtles. In fact, the turtles' personal preferences suggest that each one would be very happy living in an integrated pond. In order to satisfy their preference for living conditions, the turtles will jump to a new location in the pond. Although diversity is valued by the individual turtles, the results consistently show that the individual preferences rippling through this mythical pond lead to large-scale segregation.

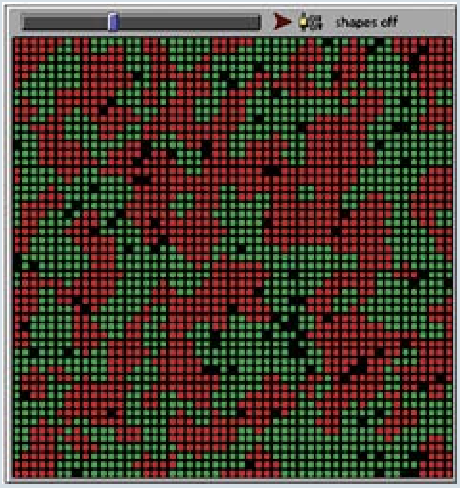
The figures on page 138 capture a series of screen shots from the NetLogo simulation of an artificial neighborhood containing red and green turtles.



First Frame



Second Frame



Final Frame

In the first frame, the turtles reside in a random pattern throughout the pond. However, not all of the turtles are happy with their living situation, and they move in the neighborhood to seek out a location where at least two of their neighboring turtles share their same color. In the second frame, the reds have begun to settle near other red turtles, and in the final frame, distinctly segregated areas have evolved.

In addition to exploring the dynamics of this phenomenon, students can also experiment with how changes in tolerance for diversity modify the results. On a more sophisticated level, students can consider scenarios in which one turtle group is more tolerant than the other.

The Anasazi

While some agent-based models explore social interactions (e.g., cooperation, segregation, and social stratifications), simulations of historical events can also enhance understanding of factors contributing to consequences. An example is the agent-based computational model of Long House Valley, the area near Monument Valley where the Anasazi people thrived in northern Arizona until a sudden decline in the population.[5] Whereas Schelling's model simulates human behavior and allows users to experiment with hypothetical situations to understand social phenomenon, the Long House Valley model was designed to explore hypotheses about a real world event. The simulation follows families who inhabited the region from C.E. 400 to 1400. Based on the detailed anthropological record that exists for the valley, data were used to create a model of the Anasazi society that was designed to test theories regarding the demise of the population. The agent-based model was intended to test two hypotheses:

> (1) the role of environment in explaining the population dynamics of settlement placement, the large population increase after [C.E.] 1000, and the complete abandonment of the region around [C.E.] 1300; and
>
> (2) the size of simulated and actual settlements that were selected and abandoned under various environmental, demographic, and social conditions in different years.[6]

The Anasazi were agriculturalists and the ancestors of the Pueblo people. Over time the Anasazi evolved into a socially complex society, as determined from present day archaeological records. Using ethnographies and historical documents, the Long House Valley settlement was accurately reconstructed to explore how changes in agricultural production affected the movement of people. This information also guided the make-up of the households, including family size, nutritional requirements, and amount of food available for storage. Based on data of the climate conditions that impacted crop output, simulated individuals were programmed with rules for their behavior.

The model defines specific criteria by which agents can move around the settlement in an attempt to adapt to marriage, environmental conditions, and crop yields. As a result, the simulation can depict the migration of households to more productive areas of the settlement. The model would be validated if the simulation actually mimicked the data researchers already had about the Anasazi people and the subsequent population crash that left the area unsettled. Would the model be able to simulate the Anasazi settlement that correlated with current data? As noted by George J. Gumerman et al., "Departures of real human behavior from expectations of a model identify potential causal variables not included in the model or specify new evidence to be sought in the archaeological record of human activities." [7]

Researchers have compared the relationship between the real Anasazi settlement map and the simulations run with the model. Data concerning the real Anasazi populations indicated

The simulated Anasazi population model was able to reproduce the same population patterns found in the real settlement. However, whereas the real Anasazi settlement was completely abandoned in 1300 C.E., the artificial society demonstrates that small numbers of families could have been sustained in the area, as the overall population dwindled.

that as the size of the settlement site grew and the population became denser, the organization of the community became more complex. Families clustered around a "central pueblo" site. The simulated Anasazi population model was able to reproduce the same population patterns found in the real settlement. However, whereas the real Anasazi settlement was completely abandoned in 1300 C.E., the artificial society demonstrates that small numbers of families could have been sustained in the area, as the overall population dwindled. The researchers concluded that social factors, as opposed to environmental factors, were the impetus for the total abandonment of the community. The community may have opted to migrate out of the area as one large, consolidated group rather than disband into smaller settlements. Using an agent-based model, the researchers established an alternative hypothesis regarding the abandonment of the settlement that had not been previously considered.

Agent-Based Modeling in the Classroom

Computer simulation is becoming an important method of building and evaluating theories in the social sciences. As more accessible versions of models are made available for the classroom, teachers can engage students in an in-depth study of social processes to assist in understanding causal mechanisms.

StarLogo offers a user-friendly site for students in K-12 to explore social systems with agent-based modeling.[8] Social studies classes can work with the programmable models to see traffic patterns and the distribution of resources in a community. NetLogo also offers a programmable modeling environment with many examples of social science simulations that can be used in the classroom.[9]

The models provide a context for students to visibly see how complex patterns arise from simple and seemingly benign individual behaviors.

> The social sciences seek to understand not only how individuals behave, but also how the interaction of many individuals leads to large-scale outcomes. Understanding a political or economic system requires more than an understanding of the individuals that comprise the system. It also requires understanding how the individuals interact with each other, and how the results can be more than the sum of the parts.[10]

Conclusion

The use of agent-based models to simulate the relationship between individual behavior and social phenomenon is being used with greater frequency in the social sciences. It offers a visual method for imitating and examining global patterns. The models are not intended to provide an exact replica of the real world, such as would be found in simulations for flight training, but they can introduce students to methods that may transform how we reflect on the past and foresee the potential of the future.[11]

Notes

1. Robert Axelrod, "Advancing the Art of Simulation in the Social Sciences," in Jean-Philippe Rennard, ed., *Handbook of Research on Nature Inspired Computing for Economics and Management* (Hershey, Penn.: Idea Group, 2005); Axelrod and Leigh Tesfatsion, *On-Line Guide for Newcomers to Agent-Based Modeling in the Social Sciences*, www.econ.iastate.edu/tesfatsi; Michael Agar, "An Anthropological Problem, a Complex Solution," *Society of Applied Anthropology* 63(2004): 411-418; Jonathan Rauch, "Seeing around Corners," *The Atlantic Monthly* (April 2002): 35-48; Jean-Philippe Rennard, "Artificiality in Social Sciences," *MPRA Paper No. 1458*, posted 13 January 2007, mpra.ub.uni-muenchen.de/1458.
2. Joshua M. Epstein and Robert L. Axtell, *Growing Artificial Societies: Social Science from the Bottom Up* (Cambridge, Mass.: MIT Press, 1996), 6.
3. The Schelling Segregation Model (SSM) was first developed by Thomas C. Schelling (Micromotives and Macrobehavior, W. W. Norton and Co., 1978, pp. 147-155). It represents one of the first constructive models of a system capable of self-organization. Also see Rauch, "Seeing around Corners, " *The Atlantic Monthly* (April 2002): 35-48.
4. Uri Wilensky, NetLogo Segregation Model. (Evanston, Ill.: Center for Connected Learning and Computer-Based Modeling, Northwestern University) ccl.northwestern.edu/netlogo/models/Segregation.
5. George J. Gumerman, Allan C. Swedlund, Jeffrey S. Dean, and Joshua M. Epstein, "The Evolution of Social Behavior in the Prehistoric American Southwest," *Artificial Life* 9 (2003): 432-444.
6. Ibid, 437.
7. Ibid, 439.
8. StarLogo, education.mit.edu/starlogo.
9. See Wilensky, NetLogo [Computer software] (Version 3.1) (Evanston, Ill.: Center for Connected Learning and Computer-Based Modeling, 1999), ccl.northwestern.edu/netlogo; Wilensky, NetLogo Rumor Mill Model (1998), ccl.northwestern.edu/netlogo/models/RumorMill; Wilensky, NetLogo Ethnocentrism Model (2003), ccl.northwestern.edu/netlogo/models/ethnocentrism.
10. Axelrod and Tesfatsion, *On-Line Guide for Newcomers to Agent-Based Modeling in the Social Sciences*, www.econ.iastate.edu/tesfatsi.
11. Agar, "An Anthropological Problem, a Complex Solution."

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