Timothy Barrett and Eli Weinberger

Professor Strigul

EN250 Quantitative Biology

10 October 2019

Agent-based Modeling

**History**

The ancestry of agent-based modeling began in the 1940’s with John von Neumann’s Von Neumann machine, capable of reproducing itself indefinitely but only in theory without the aid of computation. Later on with the help of his friend Stanislaw Ulam, the idea of cellular automata was proposed: each cell in a grid of cells had a given state for any value, most commonly referring to the states of the cells directly or indirectly around them. John Conway’s Game of Life in 1970 utilized this model to create the first example of a ‘living’ cellular automata with less complex rules than that of Neumann’s original theory. Running the Game of Life simulation produced ‘natural’ results, but was also just as easily manipulated to create machines within the program rather than using printing techniques similar to von Neumann’s.

Concepts for agent-based modeling as we know it today were accelerated in the early 1990’s, most notably Robert Axelrod’s and Craig Reynolds’ contributions for human and non-human biological behavioral patterns. Axelrod, using the culmination of data from human competitors facing each other in the Prisoner’s Dilemma, created agent-based models for the scenario and many others where value is indeterminate. Reynolds applied the theory in an attempt to understand occurrences in nature, such as the determination of flight patterns in birds.

The technological advancements at the end of the 20th century allowed for more complex simulations and models than ever before, such as Joshua Epstein and Robert Axtell’s independently developed ‘Sugarscape’ agent-based model for diseases and reproduction. At this time, most interest remained in computation of human social interaction as it is better suited for simulative results, and not easily explained through mathematical form.

Currently, there are now three main international organizations that focus on agent based modeling in the field of social simulation: the North American Association for Computational Social and Organizational Sciences (NAACSOS), the European Social Simulation Association (ESSA), and the Pacific Asian Association for Agent-Based Approach in Social Systems Science (PAAA).

**Application**

Agent-based models have a huge variety of use cases. They can be used to model any group of autonomous “agents” in an environment interacting with one another and producing a result. There are many different things that an agent can represent. Agents can be individual humans, a body of government, they can even represent individual bacteria and viruses. However, there are some things that agent-based modeling should not be used for. Agent-based modeling assumes that each agent acts in a relatively similar manner. This means that it would be difficult to predict behavior using agent-based modeling if one of the agents acts in an erratic manner. A few of the areas where agent-based modeling can be applied are biology, economics and business, and social interactions.

*Biology*

Agent-based modeling is used extensively in the field of biology. Just a few of the many examples include: The spread of epidemics, invasive species, and bacteria growth and spread. In the case of epidemics, agent-based modeling can be employed by representing people and how they move around in an urban environment. This involves who they talk to, what shops or other places they visit, and how much time they spend doing these things. That model can then be combined with a generic disease spread model to help predict how and when a disease will spread.

When modeling invasive species, one way to do it is to have three different types of agents: the species itself, importers, and border patrol agents. The species can tell when it is in a preferable environment and then spread. The importers and border patrol agents can make their own decisions based on their motives and goals. The importer’s goal being to bring the species to a new place and the border patrol’s goal is to prevent this species from entering the new territory. Both the importer and the border patrol agent will have incentives and decentives as well.

*Business and Economics*

When modeling business and economics, agent-based modeling can be used to simulate people making choices and interactions based on monetary and informational incentives with the results being how the business or economy was affected. An example of this is modeling stock prices. The agent can be a human that trades on the stock market. They can make choices to buy or sell a stock using market forecasting tools. The agent will prefer to use forecasting models that have previously proven successful and will dismiss forecasting strategies that did not net a positive result. Traders then choosing to buy or sell will affect the price of the stock.

*Social Interactions*

A third area in which agent-based modeling can be applied is in modeling social interactions among people or groups of people. In this scenario, agents are placed into an artificial society, with rules as to what their preferences are. The environment is then simulated for a period of time and then the results show how the agents acted when put into certain situations. These results can then be extrapolated onto a non-artificial society to help predict the behavior of the people or the group of people that live there.

One very interesting example of the above is social segregation. The above methods can be used to simulate how two or more groups of people will separate from the other group or groups and settle near people that are like them. The agents here are given preferred and undesirable types of social interactions. When an agent has an undesirable interaction, they will move away from the agent that they interacted with. When they have a preferable interaction, they will stay near the agent that they interacted with.