Multi-Agent Modeling of Societal Development and Cultural Evolution

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Abstract

In the study of social sciences within human history, the model should reflect the historical process of development. Many agent based modeling applications currently exist, but approach the simulation from the aspect of the result. This project will instead implement the "bottom-up" approach by implementing the background world and individualized agents with specific attributes, using the Multi-Agent Simulator of Neighborhoods (MASON) library, to parallelize default societal and human characteristics. The importation of simple rules to regulate agent behavior establish the agent-based simulations with correlating results to historically recorded migration developments. The simulation records the complex behavior results through economic aspects of wealth distribution and trade, and social aspects of reproduction, death, health, and cultural exchange. The study results include graphical representations for the change in wealth distribution and patterns of agent migration as the program steps.

Background

The concept of life as information spurred on research in the area of artificial life, most notably John Conway's game of Life. Later teams programmed the game into a computer in the first known case of artificial life from computers. Among the many questions that Life raised was whether a finite initial configuration can generate an infinite population. The implications of the simple rules were complex, leading programmers to wonder whether the such simple rules can apply to the real world to explain complex results.

From the implications of Life, bottom-up models of real world situations followed in the form of Craig Reynolds's ``boids" and later Robert Axtell and Jushua M. Epstein's Sugarscape. Boids stood for ``birdoids", which investigated Reynold's theory for bird flocking through a computational model of decentralized activity. Rather than following a form of centralized control, each individual boid followed simple logical rules for its own good. The results showed a behavior that copied the movement of flocking as it occurred in nature. The results of the boids study further implicated that seemingly centralized activity in the real world are simply patterns created through the summation of the decentralized activity of individual agents or cells.

The boids study then brings agent-based modeling to the world of Sugarscape, initially created by Brookings researchers Joshua Epstein and Robert Axtell to study the aggregate effects of resulting interactions from simple rules on Sugarscape's agents. Sugarscape has been used to model a variety of complex situations, such as proto-history, cultural evolution, population pressures, and warfare, in the bottom-up approach with simple causes for individual Agents.

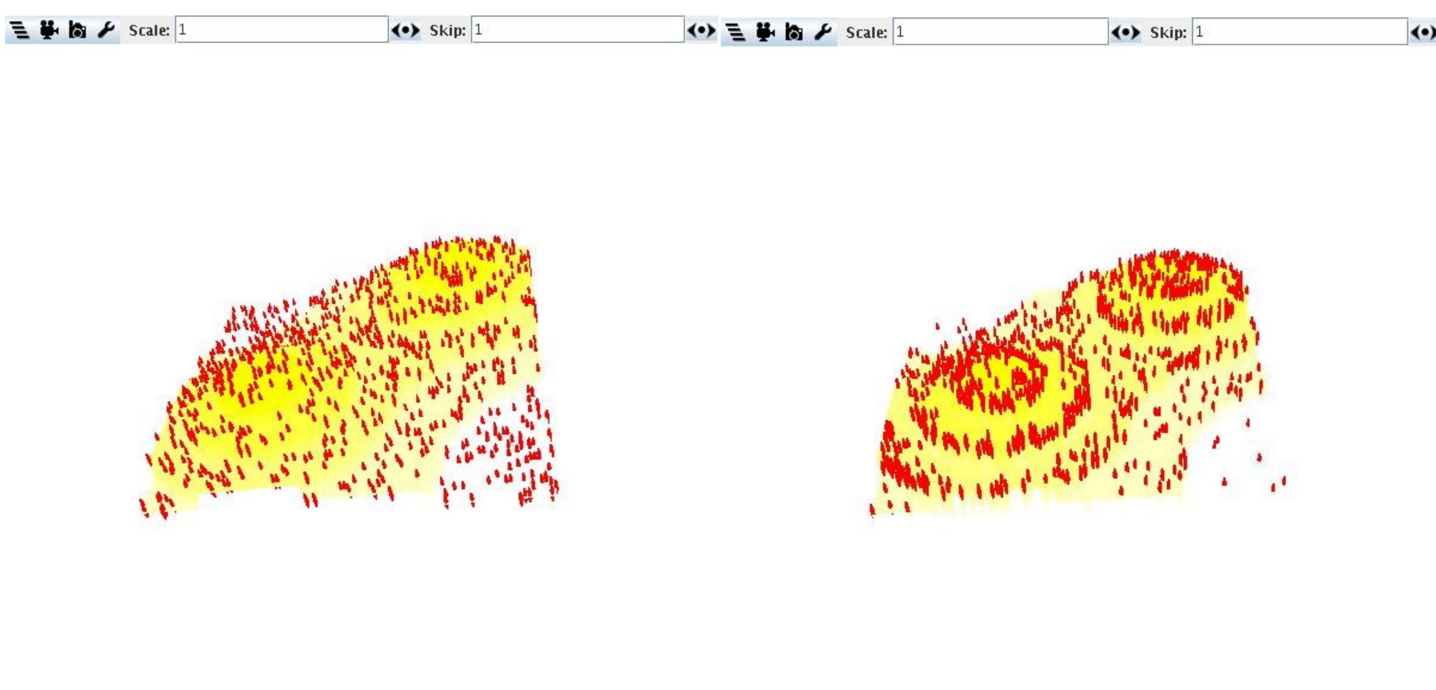
Agents exist in a world of limited natural resources, sugar, which grows back at a specified rate after an agent harvest the sugar within a certain coordinate. All agents are "born" with random attributes of metabolism and vision, and will seek the coordinates with the best conditions with regards to resource and its abilities. An agent that cannot obtain more sugar than it consumes will die and disappear from the model.

Testing

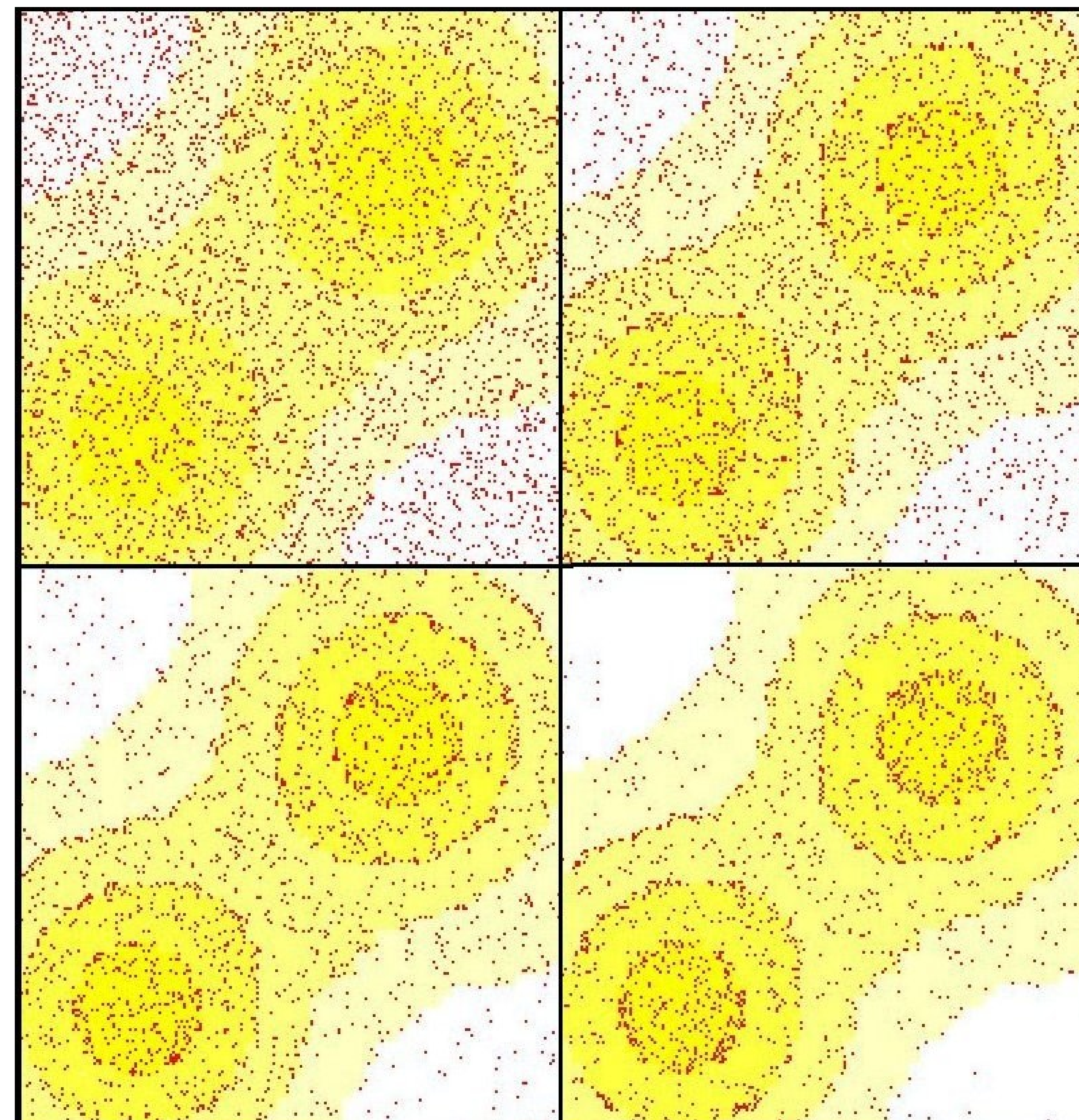
The functionality testing consists of testing with the variables that the user can change during the program. While the initial values of the variables are set by the program, the user can change the values for MaxVision, gridHeight, gridWidth and scale, agentCount and randomMovementProbability. The testing is done by changing the various parameters during runtime and refreshing the program to start() again.

The engineering testing consists of both tests on the correct implementation of the steppable functions, and tests of whether the expected output is the same as the theoretical output. The new rule implemented is Distribution3D1 meant to gather the data for the wealth distribution of the agents. The rule has been incorporated into the schedule of Sugarscape after the growth rule (RuleG), to test whether or not it collects data in the correct manner (it had trouble with obtaining an agent's information from the Sparcegrid3D agent grid, and is not collecting data correctly). The output pattern of the agents do correspond with the expected patterns around the latices of the different sugar levels.

The addition of the distribution rule also tests for the adaptability of the program to encompass new rules in its runtime schedule. Further rules, such as reproduction and cultural exchange should also be viable, given the problem with the accessibility of the agents' private fields.



3D representation



Rule {G1, M} Implemented

Methodology

The project will build on the algorithm of another agent-based modeling program (ie. Sugarscape in NetLogo or RePast) and begin with a prototype in MASON to duplicate the fundamental rules of Sugarscape, G for reproduction of essential resources and M for agent movement. After establishing the initial parameters of the agent world, the parameters of the agents will encompass gender, age, multiple resources, culture, etc to establish reproduction, trade, cultural exchange, etc. Data recording will be implemented along with the development of the agent-world rules, to display statistical information of the artificial society.

Results

In the instance when each agent begins the first step of the program with random positions, the agents demonstrate a tendency to gather at lattices under the finite growth rule (RuleG1). Initially the agent migration patterns showed some error, such as a tendency to move back and forth in the horizontal direction, or a tendency to bypass closer cells with equal amounts of sugar. The pattern of moving to lattices was also only visible when the world was scaled to the size of 200 X 200 and up to 4000 agents. However, with the implementation of a distance check in the agent's step() method, which determines the cell of the best value that is closest to the agent, the agent migration correlated with expected patterns. The agents start with randomly assigned positions on the grid in the form of (x,y). With each step the agent will pick the optimal position and continue to advance until the pattern in Figure 3 occurs. This is the case when the growth rule is infinite. When the sugar growthRate is a limited number, the agents move to the poles, where the greatest amount of sugar is available.

The initial positions of the agents have been changed to a square within the grid of the Sugarscape world. The size of the square's side length is roughly 40 percent that of the grid, starting in one of the corners. The migration pattern should show waves of agents moving from one pole towards the other pole. The sugar amount will lower with each step of the agent, causing the agents to move forward (towards the other pole), because the amount of sugar in front of them will be greater than the amount behind. The agents show the pattern of movement, but since the toroidal grid is implemented, some agents wraps around to the other pole through the corner rather than forward. The next step is to make the grid non-toroidal.

Conclusion

The basic statistics of agent movement, wealth distribution based on the accumulation of resource were recorded and displayed through the use of screen shots and graphs. The array of events and changes in the agent world were displayed through a Java applet, updating itself with each iteration.

The patterns of migration in the agents show interesting insight into progression of a population when a limited resource is in question. When each member of a society acts for its own benefits, an aggregate pattern of either gathering at lattices or wave movement is distinct. Through decentralized rules, the society creates seemingly centralized activity.