Population Dynamics Using Multi Agent Modeling

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1 Abstract

Most populations are modeled with a series of equations based on gathered data. In a stable, unchanging environment, populations usually experience periodic populations growth over time. This model seeks to model the same situation, but using multi agent modeling as opposed to equation based modeling. Multi agent modeling creates a simulation of the environment, with a "grass" unit that grows, "bunny" agents that eat the grass, and "fox" agents that eat the bunny. Each agent is programmed with a certain set of functions similar to the animals they are based on. They can move around, hunt, eat, and reproduce. There is a maximum number of agents that can fit in a given unit of the model. The characteristics of the agents (total population, reproduction rate, metabolism, vision, etc.) were tracked throughout each trial as a basis for comparison to the traditional models. If implemented correctly, the multi-agent model should report very similar characteristics at a given point as predicted by the traditional models.

2 Procedure

This project was written in Java based Repast. Repast came with several models, one of which was used as a shell for this program. The program was then adapted to add different types of Agents, one of which could eat the other. Spaces were modified to contain multiple Agents at one time, to allow more agents, and therefore more types of agents. Each version was tested repeatedly, to determine if the model would allow a continuous survival of each species. A 'surviving' species is one that does not become extinct within a few thousand steps of the trial.

3 Implementation and Results

The initial model contained only two species, the grass and the herbivore, dubbed 'bunnies'. As expected, the herbivore agents quickly shot up in population. As their food source became limited, competition limited the number of species and caused a drift in the characteristics of the species. Reproduction in this model required a single parent whose age was greater then or equal to its own personal maturity value, and whose food was somewhat higher then that necessary for survival. The offspring produced has attributes of values that are slightly randomly varied from its parent, going no higher or lower then the initial caps placed on the values.

In this model, the population followed a sinusoidal curve, as is predicted for population models. The birth rate of the bunnies shot up, as was also predicted, as those bunnies with higher birth rates would produce more offspring and be present in larger numbers. The metabolism minimized itself, and vision maximized itself. Both of these patterns followed the hypothesis. However, the maturity rate of the bunny agents increased as well. This was surprising. There were several theories as to why this may have occurred. Perhaps the placement of spawn near the parents caused an increased competition among those bunnies. However, if this were the case, the birth rate would also have decreased. This was not observed. None the less, the model was tried with a random placement of offspring, and no change in the results occurred. Next, we tested the theory that a longer period of immaturity allowed the parent to stockpile food so that when it began using food to reproduce, it did not reproduce itself into its own premature death. To monitor this, another chart was added, showing both the average stockpile of all bunnies and the average stockpile of newly matured bunnies and the average stockpiles of all mature bunnies. While the values varied among the different demographics, there was no change over time of the values, even as the other attributes of the agents changed to maximize the agents successfulness. At this time, the question remains unresolved.

The second model added a third carnivorous species, foxes. This caused several problems, because the bunnies who died were not removed until all other agents had also moved, so at times the foxes ate bunnies that harmed the foxes with negative health. A minimum life count was added (or, rather, changed from zero) so that instead of an agent dying when it reached a stockpile of zero, it died when it reached a minimum life count of some number. The rest of the changes to the program at this point consisted of adapting it for multiple species, adding an Agent class which all agents now extend, and modifying all the graphs so that they graphed things from multiple species of agents. This model, once fine tuned, behaved largely as expected. When the fox population was depleted, the bunny population would sky rocket, then level off due to a lack of food. Soon, however, the fox population would recover with the help of abundant food, and would decrease the bunny population. Their own food supplies depleted, the foxes would die off, and the process would repeat. Heritable traits did not move towards one end of the spectrum in this model, because during periods of non-pressure, the values would, essentially, reset themselves. Another interesting result was that the metabolism and vision seemed to be directly related instead of inversely so, which differs from the initial model that did not include the foxes. I have no hypothesis as to why that occurred at this time, except that the decrease in competition at certain periods skewed results away from the hypothetical max. Also, foxes searched out the agent with the largest stockpile of food, so having a large stockpile lost its advantage. When this feature was removed, the results behaved more as predicted, however the pattern persisted.

The next change was the reproductive mechanisms of agents. It required two agents, one male, one female, to reproduce, and traits were modeled by two genes, one received from each parent. Mutation was removed from the model. Because of this, agents need to search each other out in order to breed. Because of the size of the model, foxes are having trouble being plentiful enough to breed. This feature was soon found to be unsuccessful. Upon further research, it was decided that biologically detailed reproduction mechanism do not be modeled so closely. The model should show that the new offspring are based off of the old ones; how this is done is irrelevant.

Two more types of Agents were added, BirdAgents and WormAgents. For the WormAgents, another characteristic was added to each space, called waste. Waste accumulates every time an Agent dies, and also at random. The Worm survives on waste similar to the way the Bunny survives on Grass. The Bird survives off of Worms, and Foxes additionally may eat Birds. This model proved to be considerably less succesful then previous models, as no agents survived for more then a generation or two, whereas in previous models would survive for as many as ten generations before collapsing.

This model was not succesful. Because no model had been substantially succesful (i.e. continued indefinitly) since the implementation of multiple species per space, a new model was created without the new species, in order to study the bug. This bug was fixed, and the model, with two species, stabalized for many generations, though still not indefinitly as the FoxAgents are eventually outeating their food source.

4 Conclusion

Currently, the model fails to prove the hypothesis that a multi-agent model would mirror the traditional model for multiple species. For a single species, the multi-agent model and the traditional match very similarly in shape, though mathematical comparisons have yet to be preformed. An interesting finding is the degree to which predation increases the range of the population of the prey. An increase of some amount is expected, because the predation allows times for stocks of food to build up while the population of predators is high and the population of prey is low. Because the model is still not accurate with multiple species, it is difficult to draw a conclusion from this data, as it is unreliable. If the data should produce a similar pattern in a succesful model, further research could include an investigation into this result.

5 Bibliography

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