Agent Based Segregation Model

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Contents

1 Abstract:

Agent Based Modelling is a powerful simulation modelling technique that has seen a number of applications in the last few years. We develop and simulate an artifical society based off of a Sugarscape model developed in the 1990's to explain the tendency towards the unequal distribution of wealth in society. This was done by manipulating initial conditions on the original Sugarscape model to analyze and predict future changes. The subsequent part of the article deals with methodology and objectives of this paper. At the end, a brief look into future challenges is given.

2 Introduction:

The histroy of agent based modelling or ABM can be traced back to the "Von Neumann Machine", a theoretical machine capable of reproduction. The machine would go on to follow precisely detailed instructions to produce a copy of itself. This concept was then built upon on paper as a collection of cells on a grid. This idea then intrigued Neumann to create the first of the devices later termed "cellular automata". Another advance was introduced by the mathematician "John Conway" who construced the well known "Game Of Life".

The Sugarscape model was introduced in 1996 by Joshua Epstein and Robert Axtell. It is an agent based model of an "artifical society" intended to support experiments related to economics and other social sciences. In layman's terms this model is used to explore and explain the distribution of wealth i.e. the tendency towards inequality.

The model in general is of a simple economy where agents move around on a 2-D grid harvesting and accumalting "sugar" which represents economic wealth. Some parts of the grid produce more sugar than the others and some agents are better are finding it than others. Each cell has a capacity i.e. the maximum amount of sugar it can hold. In the original model, there are 2 high sugar regions with capactiy = 4 surrounded by cocentric rings with capacities in decreasing order.

3 The Problem in Question:

In the first version of Sugarscape agents are not replaced if they are unable to survive resulting in a decline in population over time which does not recover. In the second version of Sugarscape agents are replaced if they are unable to survive resulting in a constant population. In our version of Sugarscape, agents are replaced after every time step i.e. agents are exposed to “Population Pressure”. For analysis purposes all the models above use the same initial conditions which are:

- Vision uniformly distributed from 1 to 6.
- Metabolism uniformly distributed from 1 to 4.
- Sugar uniformly distributed from 5 to 25.
- Initial agent population: 1000.

4 Objectives:

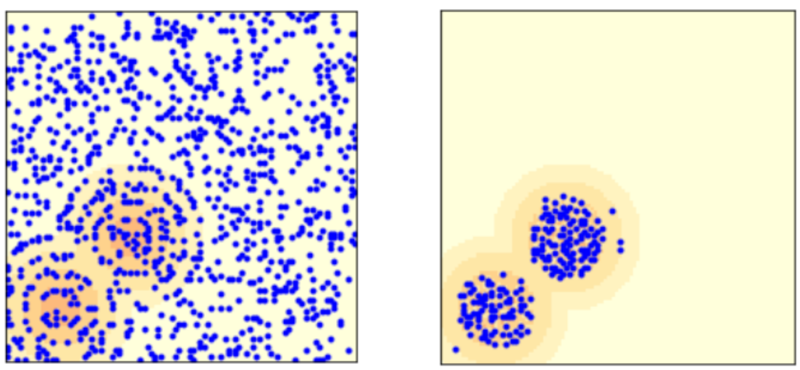
The objective of this paper is to compare the changes in population, vision and metabolism with the original Sugarscape model when population pressure is introduced into the system. Population pressure in this context is adding an agent after every time step. This gives rise to another paradigm of questions mainly relating to “Overpopulation” and “Survival of the Fittest” which are then compared to simple predator - prey models in general to get an existing idea of how the system is intending to behave for a long period of time.

5 Methodology:

We built our model based off of the original Sugarscape model which started off with the idea of 0 population pressure i.e once the population fails it does not recover. The limitations with this model was that for whatever reason if the population died there was no way for the population to rebound back up. This was adjusted using a more refined Sugarscape model i.e. adding population pressure. We then compared several time step graphs of different attributes of agents with different initial conditions to come up with a conclusion.

6 Analysis & Results

We start off our analysis with the original Sugarscape model i.e. once the population dies off it does not recover. The initial conditions are set to n = 1000 (No. of agents), distribution of vision is distributed uniformly (1 - 6), distribution of metabolism is distributed uniformly (1 - 6), distribution of sugar is distributed uniformly (5 - 25) and the simulation is being ran on a 100 x 100 grid. Based on these conditions, the agents reach their equilibrium point or carrying capacity at approximately ≥ 185 agents.



(a) Initial Simulation

(b) Final Simulation

Figure 1: 1st Version Sugarscape Simulation

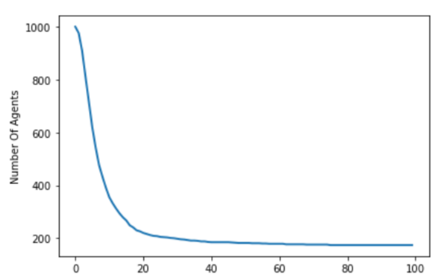
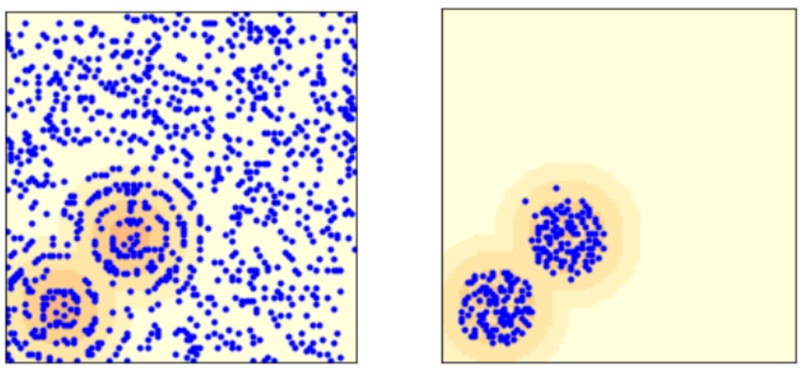


Figure 2: Plot of Agent Size Vs Time

For the following initial conditions, all simulations were ran with n = 1000 and on a 100 x 100 grid.

6.0.1 Increasing distribution of Vision from (1-6) to (1-10):

For an agent the vision is the amount of cells it can scan for sugar. Increasing this parameter led to the agents being able to scan for more cells which led them to have more chances of survival as more cells are available to move to which in turn led to an increase in its carrying capacity i.e. approximately ≥ 210.



(a) Initial Simulation (b) Final Simulation

Figure 3: 1st Version Sugarscape Simulation with increased distribution of Vision

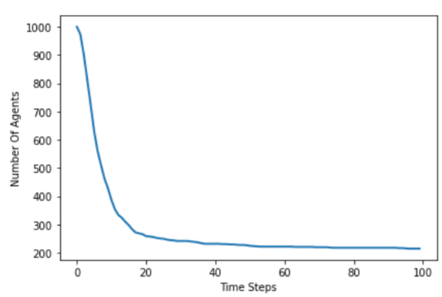
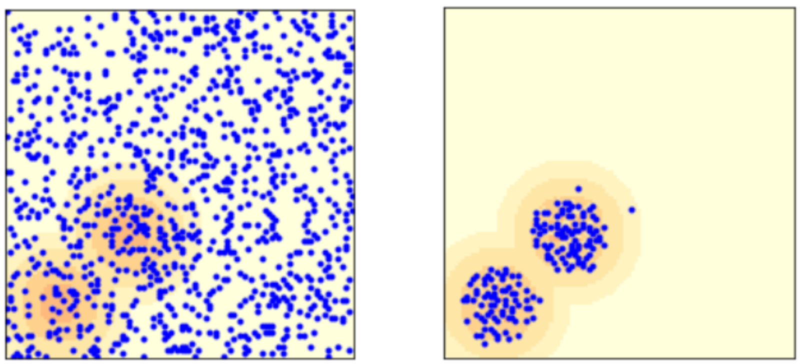


Figure 4: Plot of Agent Size Vs Time

6.0.2 Decreasing distribution of Vision from (1-6) to (1-3):

The carrying capacity decreases as vision decreases which is expected as the agents are not able to see cells that may be unoccupied because of their low vision score. The carrying capacity is approximately ≥ 150.



(a) Initial Simulation (b) Final Simulation

Figure 5: 1st Version Sugarscape Simulation with decreased distribution of Vision

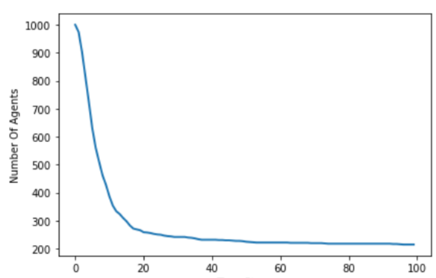
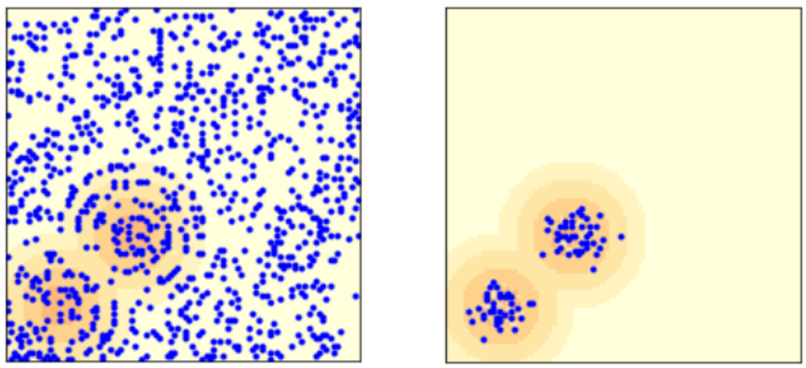


Figure 6: Plot of Agent Size Vs Time

6.0.3 Increasing distribution of Metabolism from (1-4) to (1-10):

For an agent metabolism refers to the amount of sugar it must consume if it wants to survive when approaching an unoccupied cell with x amount of sugar after each time step. Increasing metabolism lowered the carrying capacity as agents are consuming more sugar than they can afford i.e. approximately ≥ 35.



(a) Initial Simulation

(b) Final Simulation

Figure 7: 1st Version Sugarscape Simulation with increased distribution of Metabolism

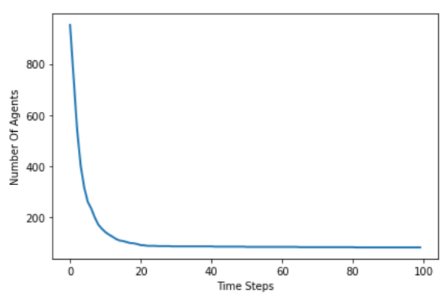
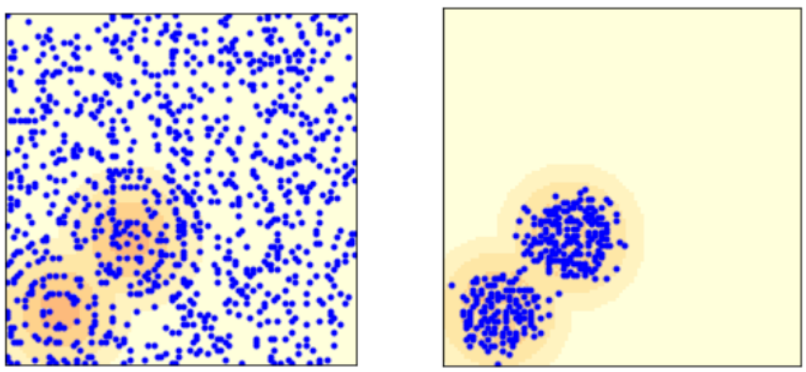


Figure 8: Plot of Agent Size Vs Time

6.0.4 Decreasing distribution of Metabolism from (1-4) to (1-2):

Decreasing metabolism means the agents will need to spend only little amounts to occupy an unoccupied cell i.e. the total amount of sugar for each agent will always be positive. Hence the carrying capacity will increase approximately $\geq$ 280.



(a) Initial Simulation (b) Final Simulation

Figure 9: 1st Version Sugarscape Simulation with decreased distribution of Metabolism

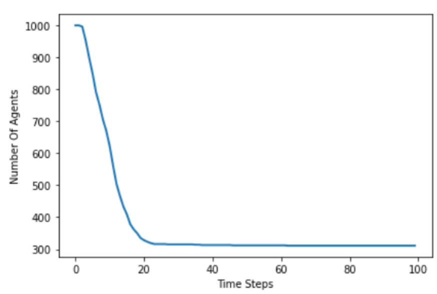
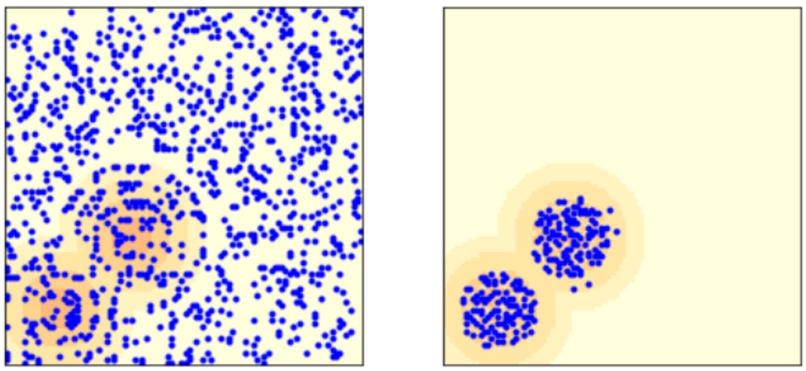


Figure 10: Plot of Agent Size Vs Time

6.0.5 Increasing distribution of Sugar from (5-25) to (5-50):

For an agent, sugar refers to the amount of wealth an agent has to survive. Increasing the distribution of sugar increased the carrying capacity as the agents have a wider range of income approximately $\geq$ 190.



(a) Initial Simulation (b) Final Simulation

Figure 11: 1st Version Sugarscape Simulation with increased distribution of Sugar

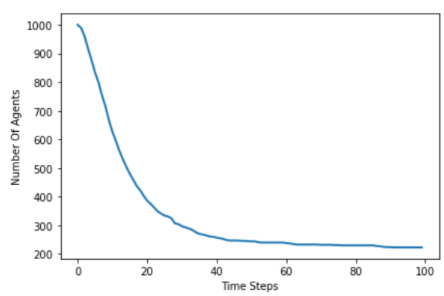
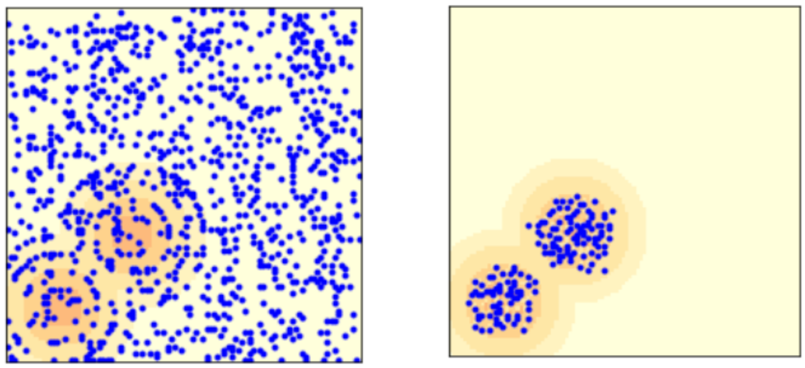


Figure 12: Plot of Agent Size Vs Time

6.0.6 Decreasing distribution of Sugar from (5-25) to (5-10):

Less range of income or sugar lowerd the carrying capacity approximately $\geq$ 115.



(a) Initial Simulation

(b) Final Simulation

Figure 13: 1st Version Sugarscape Simulation with decreased distribution of Sugar

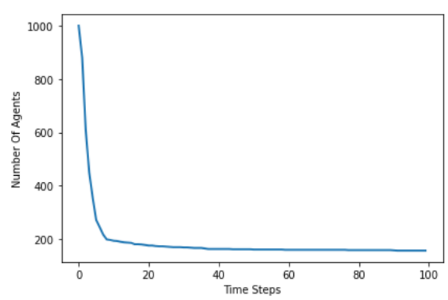
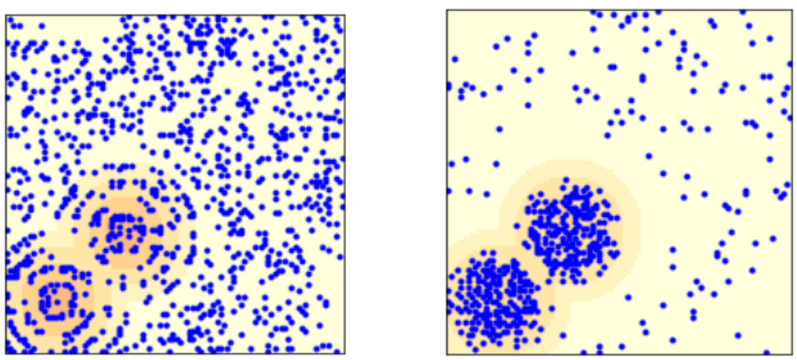


Figure 14: Plot of Agent Size Vs Time

6.0.7 Best case Scenario:

In a perfect world, the best case scenario for the agents would be increased vision, decreased metabolism and higher sugar. This makes sense as for an agent

if it earns a lot of sugar and metabolism is low, it can occupy almost any unoccupied cell without having to sacrifice a lot of sugar. Since it has an increased vision, it can view a lot more cells and make a decision based off of that i.e its survival probabiltiy after each time step also increases.
The following simulation was ran using Vision (0-10), Metabolism (1-2) and Sugar (5-200).



(a) Initial Simulation (b) Final Simulation

Figure 15: 1st Version Sugarscape Simulation with best case scenario

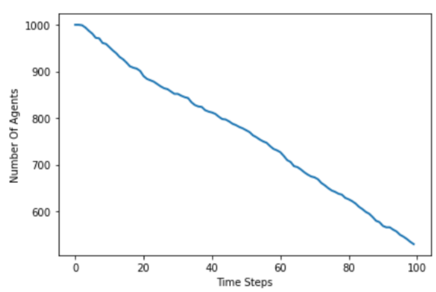
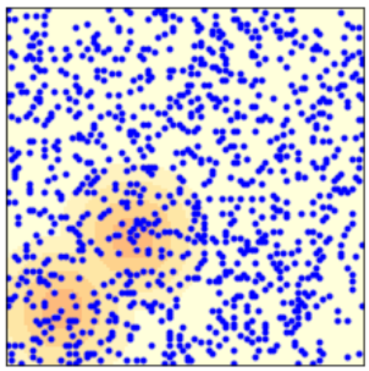


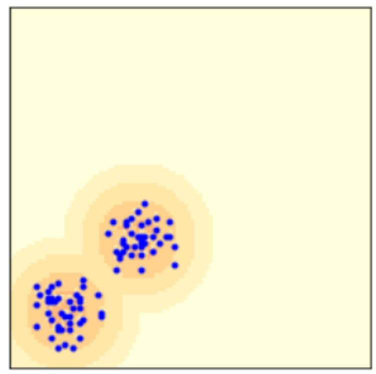
Figure 16: Plot of Agent Size Vs Time

6.0.8 Worst Case Scenario:

Worst case scenario for agents would be the exact opposite of the above i.e. decreased vision, increased metabolism and decreased sugar. The following simulation was ran using Vision (0-2), Metabolism (1-10) and Sugar (5-100).



(a) Initial Simulation



(b) Final Simulation

Figure 17: 1st Version Sugarscape Simulation with worst case scenario

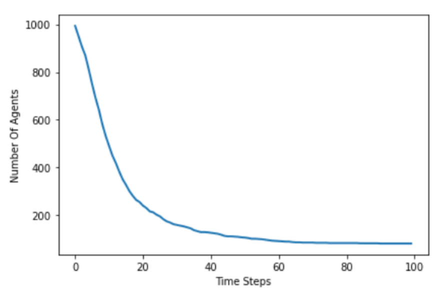
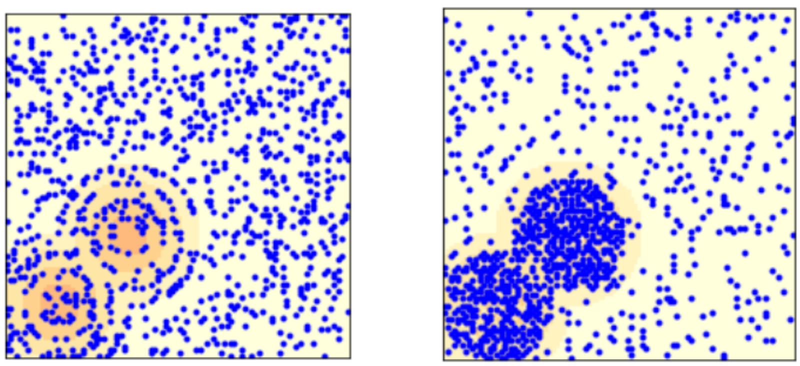


Figure 18: Plot of Agent Size Vs Time

6.1 Sugarscape Version 2:

We move on to analyze the 2nd version of sugarscape i.e. we replace an agent after it dies. Therefore we expect the population to remain constant. We are using the same original parametes as we used in the 1st version of Sugarscape for the following simulations.



(a) Initial Simulation

(b) Final Simulation

Figure 19: 2nd Version of Sugarscape Simulation

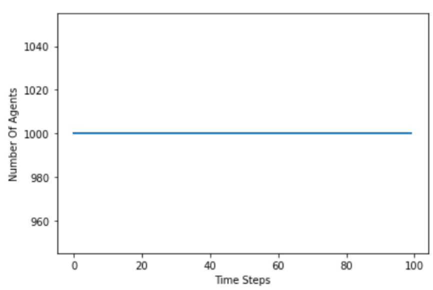
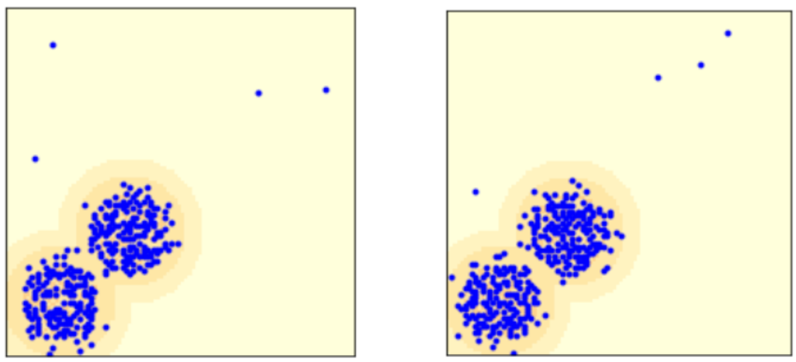


Figure 20: Plot of Agent Size Vs Time

6.2 Sugarscape Version 3:

We move on to analyze the 3rd version of sugarscape i.e we add an agent after the end of every step. We are using the same original parametes as we used in the 1st version of Sugarscape for the following simulations.



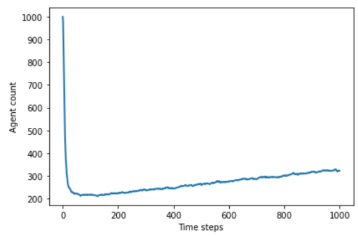
(a) Initial Simulation

(b) Final Simulation

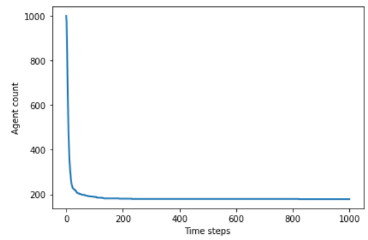
Figure 21: 3rd Version of Sugarscape Simulation

We move on to compare the graphs of the average vision, average metabolism and average sugar of Sugarscape version 1 with Sugarscape version 3 to draw some reasonable conclusions.

6.2.1 Average Population Comparison:



(a) Avg. Pop. Sugarscape 3

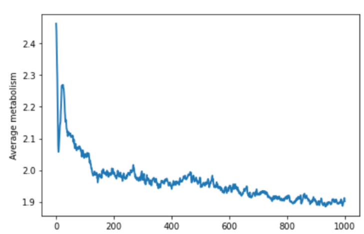


(b) Avg. Pop. Sugarscape 1

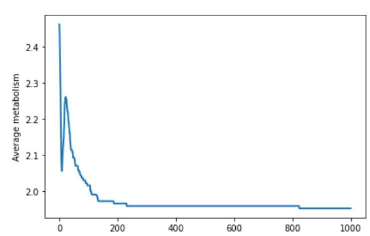
Figure 22: Avg. Pop. comparison

As we can see from the above graphs, for the graph that corresponds to the 3rd Version of Sugarscape (left), we can see the initial population dies down but rebounds and starts increasing. It is also possible that the inital die off overshoots the carrying capacity. For the graph that corresponds to the 1st Version of Sugarscape (right), we can see that the initial population dies down quickly and the population does not recover.

6.2.2 Average Metabolism Comparison:



(a) Avg. Meta. Sugarscape 3

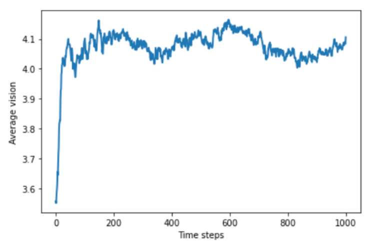


(b) Avg. Meta. Sugarscape 1

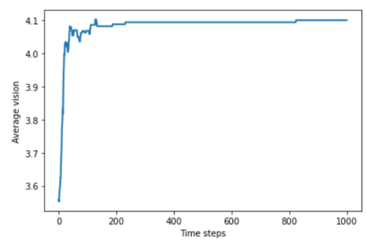
Figure 23: Avg. Meta. comparison

As we can see from the above graphs, for the graph that corresponds to the 3rd version of Sugarscape (left), we can see the metabolism drops off quickly initially but it continues to fall as new agents are born and now is totally dependent on the survival of the fittest. For the graph that corresponds to the 1st Version of Sugarscape (right), we can see that the agents with a high metabolism die off quickly so the average drops as well.

6.2.3 Average Vision Comparison:



(a) Avg. Vis. Sugarscape 3



(b) Avg. Vis. Sugarscape 1

Figure 24: Avg. Vis. comparison

As we can see from the above graphs, for the graph that corresponds to the 3rd version of Sugarscape (left), we can see the average vision increases but this is mainly dependent upon the number of agents currently present in the simulation at each time step. For the graph that corresponds to the 1st Version of Sugarscape (right), we can see that the agents with poor vision die off and agents with higher vision can see further and survive.

7 Conclusion:

Adding an agent after each time step forces the agents to dominate for their survival. The population dies down almost instanteneously but seems to rebound back up based on the initial die off that creates pressure that kills agents that would have initially survived if it were a steady state. The average vision does fluctuate based on a number of runs however when the population is rebounding the average vision tends to decrease. This also leads to a decrease in average metabolism which makes it easier for the agents to survive after the intial die off phase. In general, it is not the strongest or the most intelligent who will survive but those who can best manage change. Evolution is not optimal. There might be features that are impressive to one certain individual that shadows a lot of other things which might be a reason for their death.

8 References:

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