University of Melbourne

SWEN90004

Modelling Complex Software Systems

Wealth Distribution System

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1 Background

In this project, we aim to simulate a simplified wealth distribution system comparing to real world. There are multiple reasons and motivations for us to analyze this topic. Firstly, it relates to our daily life. The more we know about the wealth, the better we could manipulate it such as daily usage or investment. In our model, people are divided into three classes, the poor, the middle and the rich.

We aim to accomplish two parts. The first part concentrates on replicating the original model provided by NetLogo. The basic attributes we applied to contribute to wealth distribution list blow.

- grain growth interval
- max vision
- max of metabolism
- number of grain grow
- percentage of best land

The second part focuses on extensions. We add multiple variables and try to make some differences of the wealth distribution. In this project, we focus on three aspects, **Heritage inheritance**, **Season**, **Reclamation**.

2 Design

2.1 Original Model

The first task to rebuild original model is the whole world initialization, which contains grain and people initialization based on specific configuration. We assume that the whole world is a 2-dimension matrix. There are several properties for every single person, which are the same as model in NetLogo.

- ID: identification of person.
- Age: the age of person.
- Vision: determines how far a person could see.
- Metabolism: person cost in every global clock.
- Life expectancy: how long a person stay alive
- Position: current position of person.

There are two behaviors for a person in every clock. Firstly, everyone tries to find a best land within vision and cost some money. When someone's age is larger than expected life expectancy, he will die and reborn with random values of properties.

2.2 Extensions

Based on original model, we are going to improve its complexity by adding multiple extensions. Here we list the extensions we added in this project.

1. Heritage inheritance

   In original model, people will discard all the money when they are dead. In our extension, we introduce inheritance function for collecting their money when they reborn. Based on our assumption, it should be a way to speed up model development.

2. Season

   The richness of land is fixed when the world is initialized in original model. In our extended model, the richness of land varies based on different clock. We assume there are two seasons, land generates the same amount of grain as before in summer. In winter, land only generates half grain. We will find out the relationship between seasons and wealth distribution.

3. Reclamation

   There should be lots of factors to impact a small part of land's richness. In order to simulate this situation, we introduce the reclamation function, which aims to improve or reduce a small part of land's richness suddenly in a time interval. We want to figure out if sudden incident will impact final wealth distribution.

3 Results & Discussion

3.1 Pre-analyzing

Before we run the detaild experiment of our model, we try to choose a set of hyperparameters to make the gini index change linearly. We create two index to explain the transformation of variables.

$$Resource = \frac{\text{num grain grown}}{\text{grain grow interval}} * \text{percent best land}$$

The value of *Resource* represent the richness of resource. The bigger the *Resource*, the easier for people to get grains.

$$Talent = \frac{\text{max vision}}{\text{metabolism max}}$$

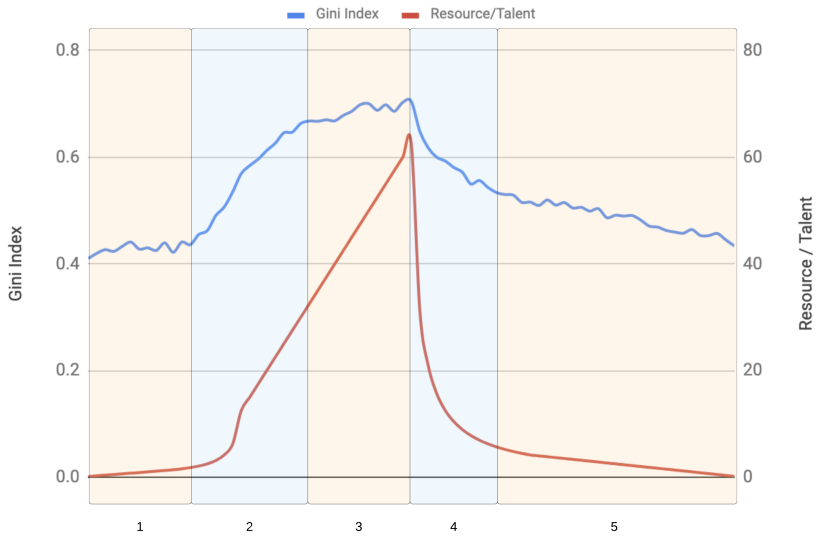
The value of $Talent$ represent the ability of a people, The bigger the value, the stronger the individual.

3.2 Results of Original Model

According to the analysis above, we adjust the variables to increase the *Resource* at first and then the $Talent$. Then we got 77 groups of parameters.

Id	#Grain Grow	Grain Grow Interval	Best Land Percentage	Max vision	Metabolism Max
1	1	10	5%	1	25
	⋮				
10	10	10	5%	1	25
		⋮			
19	10	1	5%	1	25
			⋮		
39	10	1	25%	1	25
				⋮	
53	10	1	25%	15	25
					⋮
77	10	1	25%	15	1

Each group of parameters will run 10 times and each time will calculate the average of last 200 tickets' Gini index. Then we will calculate the average result of 10 times as the gini index of this group of parameters.



We use a line chart to show the result of our model. It can easily to find that the transformation of gini index is similar to the value of $Resource/Talent$.

The curve of Gini index can be depart to five phases.

- 1st phases: 1-13

  During this phase, The total resource in the world is very limited, The mainly source of grains is from rebirth. Thus, the Gini index keeps in a low degree and increases slowly.

- 2nd phases: 14-26

  The Gini index has a remarkable growth in this phase with the total resource increase.

- 3rd phases: 27-39

  When the resource grow to a high level, the Gini index will not continue increasing, it will remain at a relatively stable level. This might be the most darkness time of the virtual world. There are sufficient resource but an extreme gap between the poor and the rich.

- 4th phases: 40-46

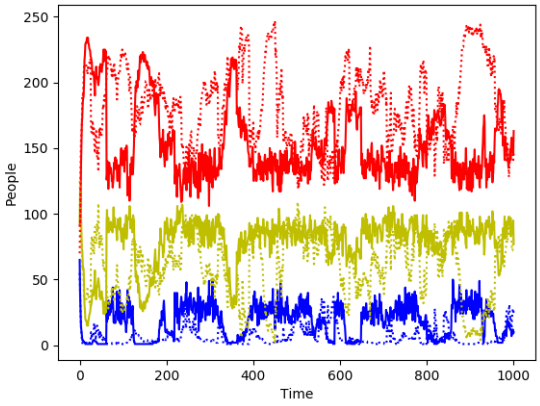
  This is an exciting result. It shows that even a little improvment of people's ability will obviously eliminate the wealthy gap.

- 5th phases: 47-77

When the *Talent* increase to a threshold, we notice that the Gini index will slowly reduce. Eventually, The Gini index will back to the same level as the very beginning.

3.3 Results of Extended Model

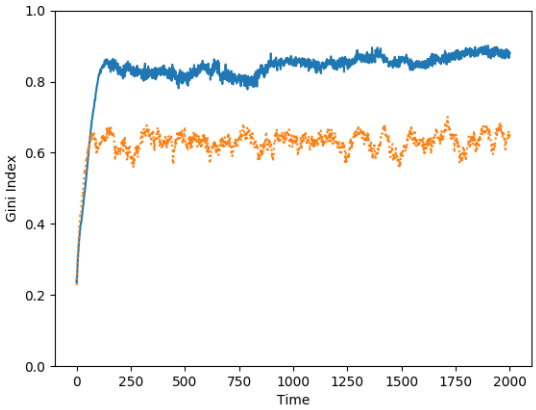
All three extensions are tested in rich, normal, poor circumstances. In poor circumstance, people die and reborn every clock so the performance of system is quite similar as original model no matter what extension added in system. Without inheritance, all simulate results in poor circumstance are same as below:

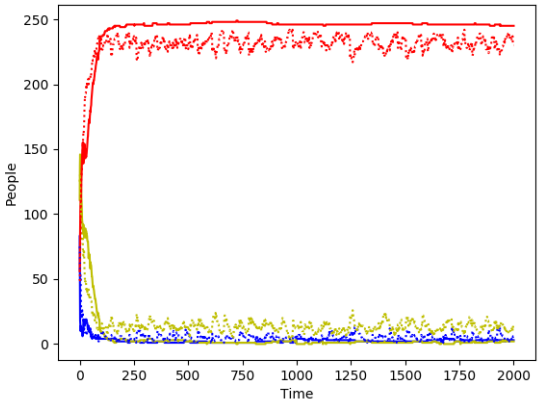


We find that our three extensions don't impact the final wealth distribution under most situations. However, there is a huge difference during the evolution such as evolution speed and fluctuation. Here we will discuss the results from extensions to answer the questions addressed above.

3.3.1 Heritage Inheritance

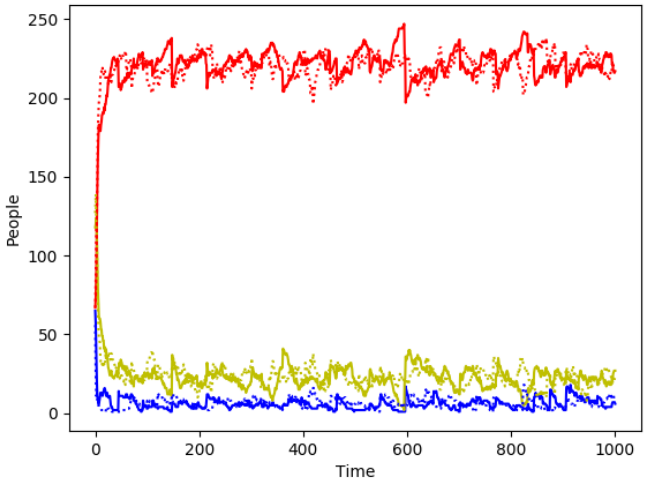
The result of extension prove our assumption that the heritage inheritance will speed up evolution of wealth distribution. The experiment result also shows that the movement between class of people become less (almost 0) after we add inheritance mechanism. Finally, the Gini-index arrive 0.8 which means there are a huge gap between rich and poor in this world.





3.3.2 Season

We define the 100 clocks as 1 year and divide it into 2 parts, summer and winter.

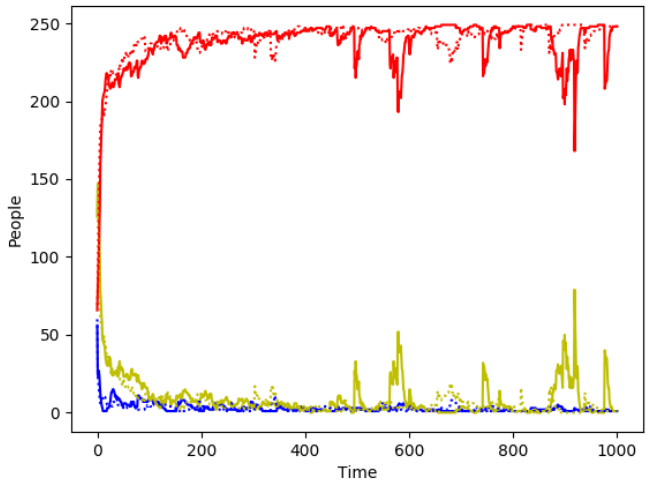


It could be found that there are more fluctuations in new model. We find that season is a complex factor to impact the wealth distribution. In rich or middle circumstance, there is no significant difference. In poor circumstance, large number of poor people could not survive from winter.

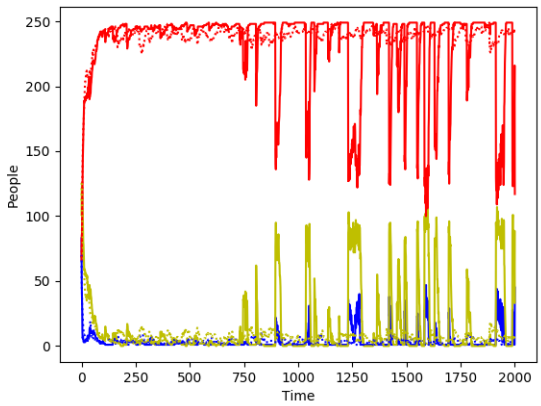
Finally, we get the conclusion of relationship between season and wealth distribution, which is that season may put pressure on everyone's life. However, the rich can get over it with bench of savings while the poor may not be able to survive if the situation is too severe.

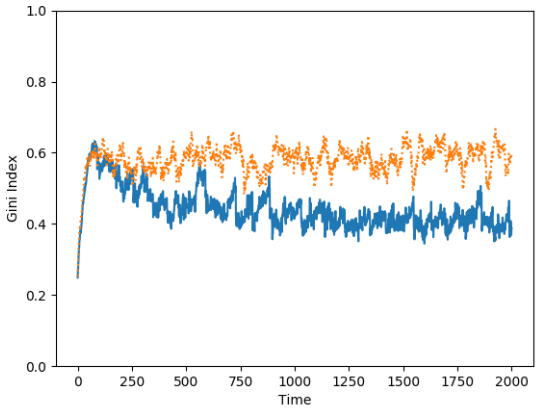
3.3.3 Reclamation

We implement reclamation function by replacing grains of two random lands. Based on result we get from simulator, we find that there is redistribution process every time reclamation happens. It relatively slows down the evolution speed.



If we reduce the vision of people and increase the frequency of reclamation, the result would be more obvious. The more interesting thing is that the movement of people between poor and middle become more frequent after a while. In this situation the Gini-Index value also reduced.





Appendix

In our group, Rui Zhao focuses on implementing the replicated model based on the original NetLogo model. Weikai Zeng implements the extensions with the base of replicated model. Yang Zhang concentrates on writing the reports.

During implementing the whole wealth distribution system, we met two challenges and wish to overcome it in the future.

- Firstly, we actually didn't find out a possible way to prevent or mitigate the wealth distribution gap between the poor and the rich.
- Secondly, we would have wanted to implement the loan system as extension. However, we find that it's also a very complex system as we can't track every single person in our system.