SYDE 332 Earth Systems
Winter 2012

Caring for My Neighbor: An Agent-Based Poverty Simulation

Paul Mou
20292157

Table of Content

Table of Figures

1. Introduction

This project is a broad survey of the issues surrounding wealth distribution and poverty. The motivation for this project stems from the personal observation that the world is broadly divided into two: the rich, comprising primarily of North America and Europe, and the relatively poor, made up of essentially the rest of the world. A standard practice in the rich world in attempting to eradicate poverty is through charitable donations. However, despite the goodwill and the tremendous resources already poured into helping the poor, around 22% of world population still lives in poverty as of 2008 (World Bank, 2012).

Instead of operating charities at a large scale, this project will look at if grass-root approach works better: can poverty eradication and egalitarian wealth distribution be achieved if neighbors care for each other's well-being? That is, in a large scale simulation with thousands of participants where each cares only about his immediate neighbor and himself, will poverty and slum develop? If so, what rules can be implemented such that poverty is minimal? The ultimate purpose of this project is to explore policies to find out how to improve welfare.

Inspired by the modeling ease and the ability to monitor global behavior of the mock society, agent-based simulation has been chosen as the preferred way to conduct the study in this project. In addition, the academic world is rich with interesting and elegant social simulation that this study can reference.
Schelling's neighborhood study, a simulation that demonstrates racial segregation is a natural consequence of people's desire for at least one neighbor similar in ethnicity, as well as Epstein's genocide simulation, a study demonstrating how mob psychology results from individual actions, are two prominent examples of social simulation with simple rules that reaches surprising conclusions that this project draws inspirations from (RAUCH, 2002).

2. Model Description

To conduct the study, the agent-based simulation is implemented in MATLAB. In this section, a detailed overview of the modeling structure as well as the rules that govern agent interaction are outlined.

The model is a time-based simulation in a 45x45 grid, where each cell represents one household and each household has a maximum of four neighbours: up, down, left, and right. Each cell has a wealth status represented by household savings. When the savings falls below the poor limit, the household is tagged as poor. At each time step, each household savings goes up by a randomized earning power set at the beginning of the simulation. Each agent then interacts with one another based on the following three rules.

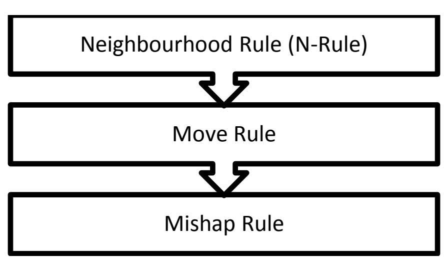

Figure 2.1 – Rule Application Precedence

The neighbourhood rule (N-Rule) requires the wealthy neighbours to help its poor neighbours; the most effective form of assistance is what this project seeks to answer. In addition to the neighbourhood rule, each household has a predetermined probability of being inflicted financial mishaps at each time step. This is intended to simulate people slipping into poverty and is named the mishap rule. Mishap rule reduces savings of the household. The mishap probability is proportional to the number of poor neighbours each household has. The agent also has a tendency to move to an area where at least of one its neighbour is not poor. That is, each agent will seek to move to a new location if all four of its neighbours become poor. This is named the move rule. Only an agent above poverty limit can move and the party which the agent switches with will be compensated financially. This rule is implemented to partially model people’s tendency to shun away from poor neighbourhood.

3. Simulation Setup

In order to conduct the study, this project simulates a particular scenario to observe the evolution of the simulated society. The setups for each of the scenario tested are tabulated in table 1 below.

Scenario Setup	Rules in Use	Rationale
1. Equal and Uniform Start: no poor households	Mishap Rule	To verify that poverty spreads and minimal segregation occurs
2. Equal and Uniform Start: no poor households	Mishap Rule N-Rule Move Rule	To study how “donate & forget” N-rule helps in minimizing the effect of mishap rule and find out whether move rule contributes to segregation or not
3. Equal and Uniform Start: no poor households	Mishap Rule N-Rule Move Rule	To study how N-rule that improve the earning power of neighbours helps in minimizing the effect of mishap rule and find out whether move rule contributes to segregation or not

Table 3.1 – Scenario Setup

Each scenario is simulated multiple times with parameters such as poor threshold and implementation of N rule varied to identify the optimal setup that minimizes poverty. Detailed discussions with the selected simulation results are discussed in the next section.

3.1 Simulation Results and Interpretations

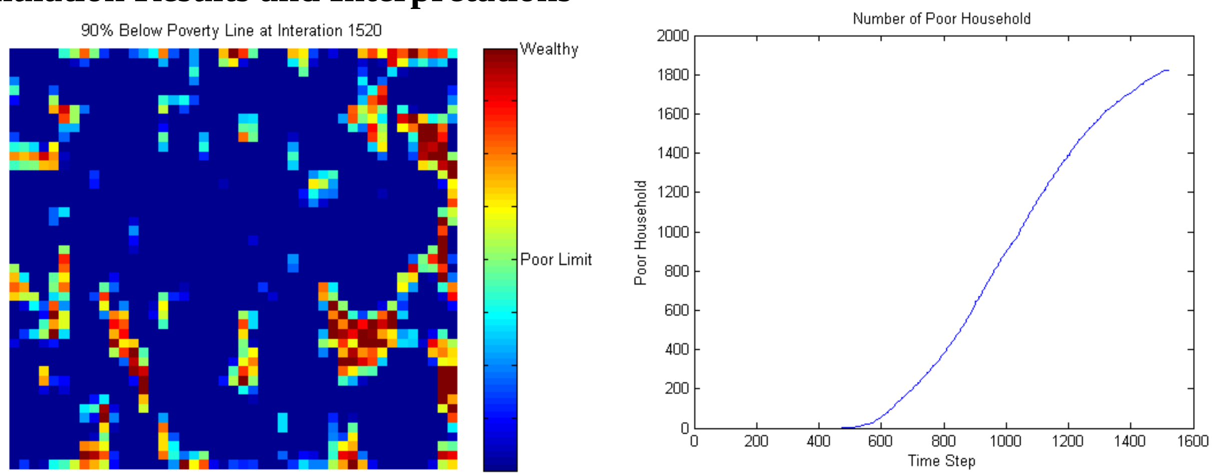

Figure 3.1 – Scenario 1: Equal and Uniform Start: no poor households

Scenario 1’s main purpose is to validate the model is implemented correctly; that is, poverty spreads as the simulation progresses since both N-Rule and Move Rule are disabled.

As can be observed in figure 3.1, the simulated society experiences mass poverty quickly. As soon as some members of society fall below poverty line, the society quickly develops into a slum due to the positive feedback nature of the implemented mishap rule: the more poor neighbours one has, the higher the chance one will be hit by the mishap rule.

The quick transition from simulation is demonstrated in figure 3.2 below. The society gradually loses its wealth as the simulation progresses, but the pace hastens when a few households fall below the poverty line.

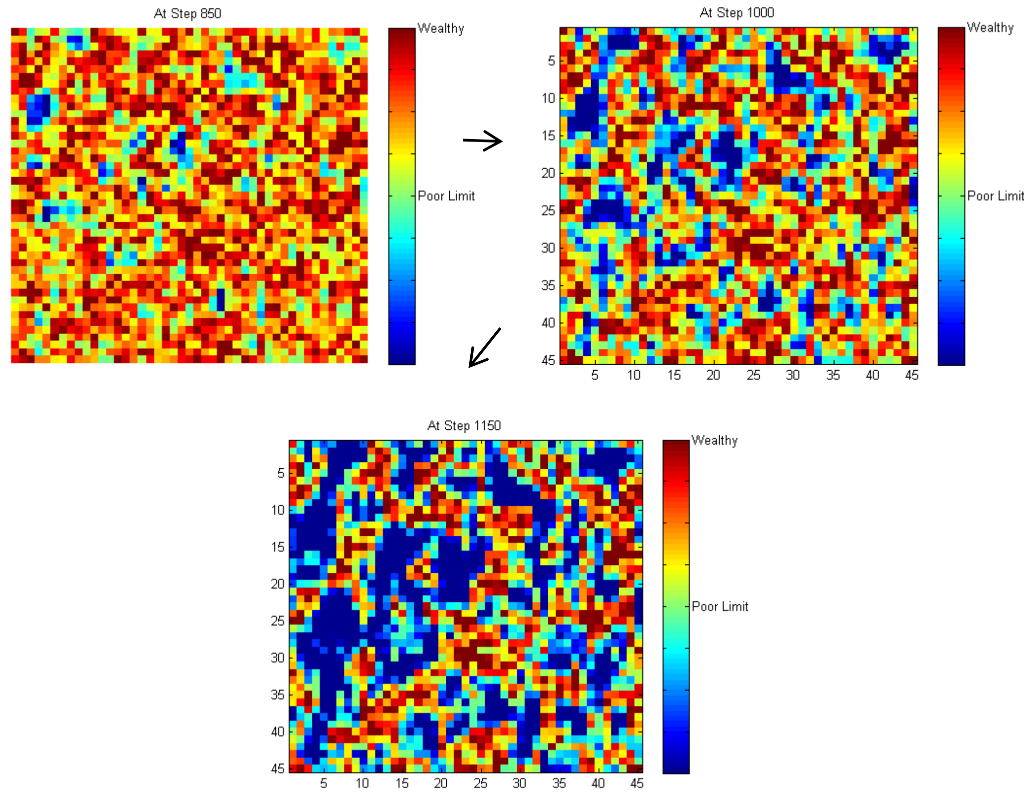

Figure 3.2 – Quick Spread of Poverty in Scenario 1

An interesting phenomenon to note here is that poor neighbourhood is almost always surrounded by rich neighbourhoods. While this is expected given an understanding of the mishap rule, if one only looks at the simulation results, one might reasonably conclude that having rich neighbours somehow increases one's fortune. This effect is observed irrespective of whether move rule is applied or not. The reason why this is an interesting observation is because this is usually how the world perceives the current society: the rich get richer while the poor gets poorer. This understanding points out how difficult it is to infer the underlying mechanism of society dynamics given only observations.

For scenario 2, setup is identical to scenario 1 except N rule and move rule are enabled. For the implementation of N rule in this case, it is assumed the neighbours help its poor neighbours by donating some percentage of its earning at each time step. In other words, the neighbours adopt a "donate and forget" approach, hoping that donating will pull its neighbour of poverty. The simulated result is shown in figure 3.2. Through trial and error, the minimum amount of donation to make N-Rule's effect noticeable while keeping the simulation time reasonable is 75%.

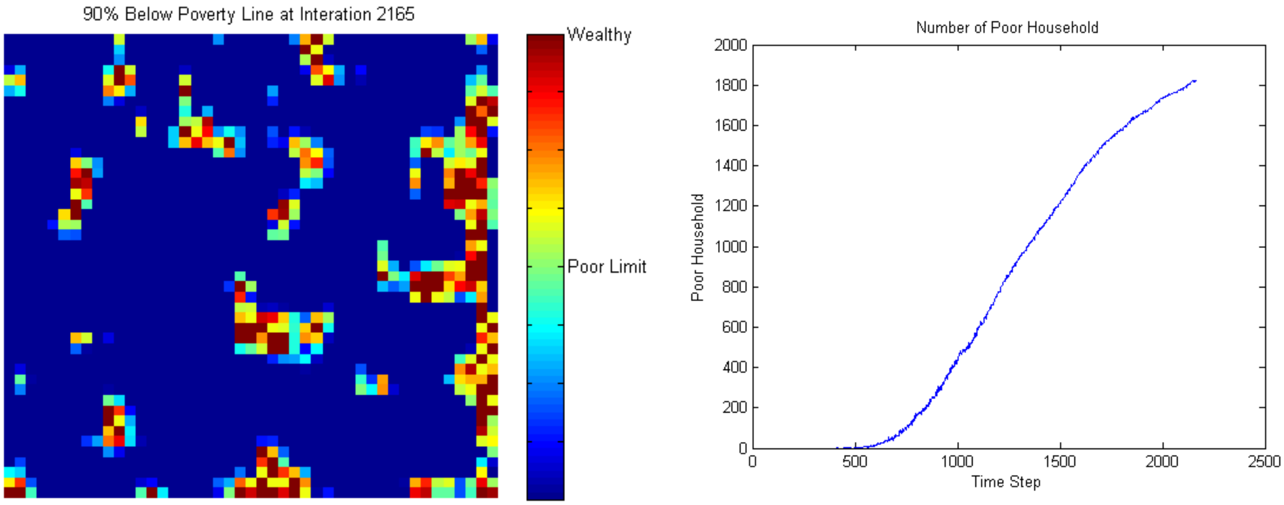

Figure 3.3 Scenario 2 Equal and Uniform Start: no poor households with N-Rule and Move Rule

Comparison between the number of poor households with respect to time of scenario 1 and scenario 2 reveals that the general trend of simulation is identical; eventually, the simulated society slip into mass poverty.

Focusing on a limited time range shows that the N-Rule is only effective for a short duration. The number of poor household does decreases from time to time as neighbours help one another. But the effect is short-lived and limited as the mock society still marches toward poverty. Therefore, the conclusion is that “donates and forget” N-Rule is not effective at eradicating poverty, only in slowing its spread.

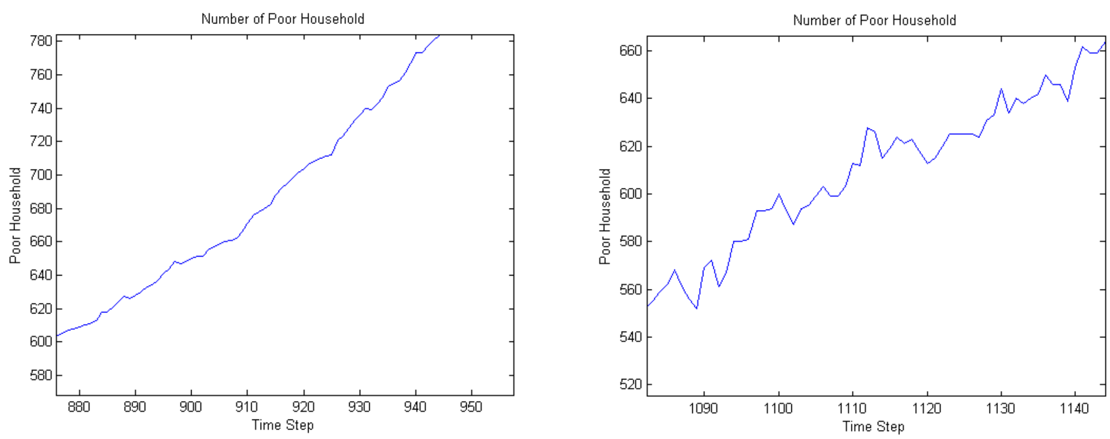

Figure 3.4 Comparison of Number of Poor Household Trend in Scenario 1 (left) and 2 (right)

Even with this limited model, the problem with this donation model is obvious. Short term assistance that does not improve the underlying conditions of poor households is only effective on a short time scale; eventually, the household will slip into poverty again. Given that human tends to focus on short-term performance goals, this is a potentially serious problem because charitable organization will falsely believe that they are improving the situation when in reality, the effect is inconsequential.

Scenario 3’s N-Rule implementation attempts to improve the “donate and forget” approach of scenario 2 by making the neighbours help in the form of both donating directly as well as increasing the poor household’s earning power. In real life, the latter could take the form of helping the neighbour find a better job. The simulated result is shown in figure 3.5 below.

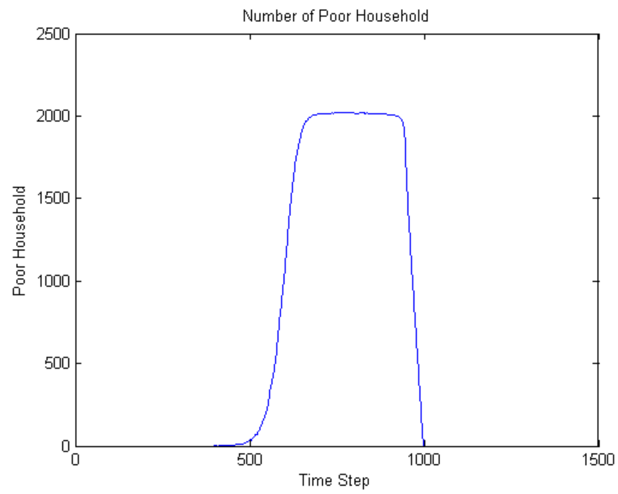

Figure 3.5 – Scenario 3 Number of Poor Household

The simulation result is quite startling: the society undergoes a drastic transition from normal to extreme poverty and then back to rich again. Closer inspection reveals that even though the society as a whole suffers from poverty, a few households "survives" and eventually helps its neighbour out of poverty. The virtuous cycle then repeats, eventually lifts the entire society of out of poverty. This is shown in figure 3.6 below. However, this result is indeterministic. Not every trial runs result in a wealthy society. Some trials experienced the same mass poverty as in scenario 1 and 2 that never returned to normal. Some had a few rich neighbourhood remaining but the society as a whole did not experience the sharp transition within the given simulation time.

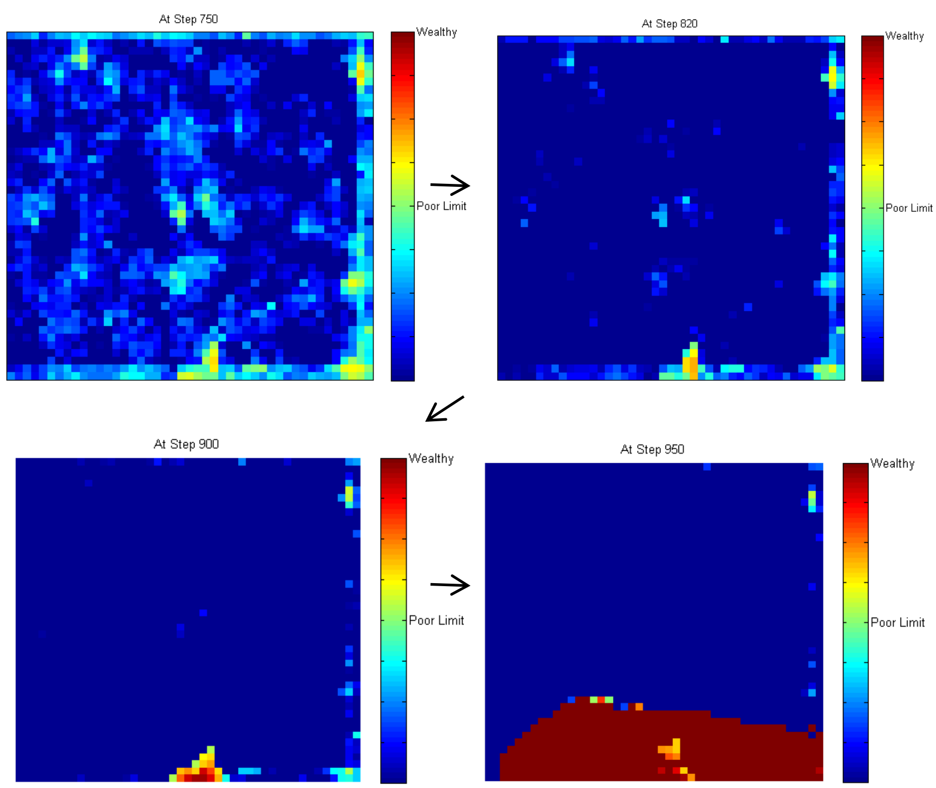

Figure 3.6 – Simulation Progression (from top left to bottom right)

While the sharp transition in this scenario is unrealistic, the result in scenario 3 suggests helping in the form of increasing a household's earning power is much more effective in the long run. In real life, this can take the form of helping a person find a better job, getting a better education, etc. It is realized that this is a difficult proposition and only dedicated agencies such as government have the ability to conduct welfare assistance to this extent. Nevertheless, scenario 3 serves as a validation that fighting poverty requires more than just donation alone. Ending poverty requires us to the resolve the underlying issues that causes poverty; in this case, the poverty developed because some households were experiencing mishap at a rate that decreases savings more than the earning power the household is able of offset.

4 Future Improvements

While the simplified model was useful to study poverty spread and eradication, the model in this project lacked many real-life phenomena that are important in translating insights from this project to real-life.

First, the model does not take human emotion into account. Humans are irrational agents that do not always act in a predictable manner. Specifically, the agents in this simulation always donated when its neighbours were in trouble. This is not a realistic assumption as people will most likely stop helping if they do not see progress. The model also needs to account for human social interactions to better study whether a policy such as the neighbourhood rule will be followed by the general population. Finally, there needs to be an explicit incentive mechanism for people to aid the poor in the model.

Second, the model needs to incorporate a more sophisticated economic model. Currently, each agent is assumed to be a working household that has a predefined earning power. But real world is much more complex and households' finances are affected by government incentives, unemployment rate, taxes, inflation, welfare policy, etc. These are complex but important variables that directly affect the welfare of society at large. If any model is to be credible in convincing policy makes, these factors must be modeled in the simulation. The credibility of the agent-based simulation will also be greatly improved if real world economic data were used to initiate the model.

Lastly, the simple model should be extended to account for region differences. Currently, the model treats every single location in the modeled grid space equally. Everywhere a household is subjected to same probability of financial mishap and every household obey the same rule when it comes to helping its neighbours. However, in the real world, location matters. People living on Wall Street would, statistically speaking, be richer and possibly more generous when helping its less fortunate peers. Incorporating this effect is important to study why some areas are more prone to poverty.

5 Conclusion

Despite the relative simplicity of the model in this project, important insights were obtained. First, helping one's neighbour by only donating does not, in the long run, halts the spread of poverty. In the short term, this policy may appear to be effective in stopping poverty but it is only good at slowing the spread of poverty. Second, helping one's neighbour by increasing his or her earning power is a much more effective form of poverty prevention mechanism, as evidenced by the dramatic turn of fortune in scenario 3 simulation. However, the timing of the recession of poverty induced by scenario 3's N-rule cannot be deterministically calculated. This fact, coupled with the difficulty in improving the earning power of one's neighbour in the real world, makes convincing decision makers to implement this welfare system to combat the spread of poverty an unlikely prospect.

Finally, while this exercise has proven useful in studying the wealth distribution evolution, the results from a simple simulation such as this one cannot be taken as reality. More detailed study and more sophisticated economic rules would have to be devised, as discussed in the previous section, in order to validate the model for implementation as a real world policy. The real power of social simulations lies in giving the academic the ability to observing how simple rules on an individual level turn into a large scale phenomenon.

6 References

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