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Homework Two: Extending Schelling's Model of Segregation

Thomas Schelling's seminal paper, *Dynamic Models of Segregation*, inspired the base NetLogo model "Segregation" (Schelling, 1971; Wilensky, 1997). Schelling's model explores segregation through the manipulation of two parameters, population density and individual preferences. Specifically, the model defines the density of an agent population and the percentage of similar neighbors each agent must have in order to be "happy" (happy is a binary classification used to indicate an agent's satisfaction with their current location - i.e., the neighborhood is equal to or greater than their desired proportion of similar neighbors). If an agent is not happy, they will move to another location. Schelling's paper examines two distinct models: the spatial model in which an agent makes a decision to move based on their local neighborhood (radius = 1), and the compartmental model in which an agent makes a decision to move based on commonly-defined regions. However, the NetLogo Segregation model only examines the spatial model. In an effort to extend both Schelling's work and the NetLogo model, we report the results of two model extensions. The first extension, a variant of the locally-defined neighborhood model, explores the effect of changing agent preferences based on their location. The second extension, a region-based model, explores the emergence of segregation as a result of wealth distribution in an agent population.

First, we describe our variant of the spatial model, which was derived directly from the base NetLogo model "Segregation". With this model, we sought to answer the following question: how do highly desirable zones influence individual choices to produce different patterns of segregation? Based on this question, we hypothesized that the proportion of low-income agents in a desirable zone would mediate the gentrification of the zone; that is, the zone would be more likely to remain mixed or low-income dominant as the initial proportion of low-income agents increases. To explore this question, we defined a highly desirable zones and endowed high-income agents located within the highly desirable zone to see all agents in the zone in addition to the agents in their local neighborhood. We further hypothesized that gentrification, defined as the expulsion of low-income agents from a neighborhood as high-income agents move in (Torrens & Nara, 2006), would only emerge when the initial proportion of low-income agents in the highly desirable zone was set below a certain value. This threshold, we thought, would be met at around a proportion of 0.5. We made this prediction based on the assumption that high-income agents in the highly desirable zone would not be able to supplement a low percentage of similar agents in their local neighborhood with the percentage of similar agents in the entire zone if the initial proportion of high-income agents in the zone was greater than 0.5.

We tested this hypothesis through several modifications of the NetLogo model. The color of the agents was used to partition the population into two exhaustive categories, high-income and low-income. High-income agents were defined by a gold color value of 43, and low-income agents were defined by a purple color value of 115. High-income agents were able to make decisions based on the composition of both their immediate neighborhood and the desirable zone. A high-income agent in the desirable zone would become happy if the sum of their local neighborhood and the desirable zone exceeded the preset happy threshold.

There are many factors that can be analyzed in this model that could cause the simulation to converge on a certain result. Given our above stated hypothesis, we decided to analyze three parameters and the results produced by different combinations of these parameters. Specifically, we analyzed the results of the following parameters and parameter values:

- Percentage of Similar Neighbors Wanted: 0.3, 0.5, 0.7
- Desirable Zone Size 3x3, 6x6, 12x12
- Initial Proportion of Low-Income Agents in Desirable Zone: 0.3, 0.5, 0.7

Before describing our findings, it should be noted that the above parameters and all tested combinations of the parameters produced large patterns of segregation. After numerous runs, it was apparent that the *Desirable Zone Size* parameter produced the least amount of change in levels of gentrification. In particular, *Desirable Zone Size* seemed to affect the rate at which gentrification emerged. The *Percentage of Similar Neighbors Wanted* parameter had a relatively positive linear effect on gentrification in the desirable zone, in that, as the percentage desired increased, gentrification increased. Conversely, the *Initial Proportion of Low-Income Agents* parameter showed an inverse linear relationship with the emergence of gentrification. Thus, as initial proportion of low-income agents in the desirable zone increased, gentrification of the desirable zone decreased. However, as noted above, the diminished emergence of gentrification should not be misconstrued with a lack of segregation in the highly desirable zone.

Next, we describe our region-based model, aimed at exploring the emergence of segregation as a result of wealth distribution in the United States. For this extension, we put forth the following question: how do patterns of segregation emerge as a result of an uneven distribution of wealth? This simulation was loosely based on the “Segregation” NetLogo model and statistics on trends in wealth distribution (Wolff, 2010). We adapted this model by first distributing a variable amount of money (our tests were with ~$1,000,000) to the population as follows:

1. Top 1% (35% of total money, represented by a box shape)
2. Next 4% (27% of total money, represented by an airplane shape)
3. Next 5% (11% of total money, represented by a house shape)
4. Next 10% (12% of total money, represented by a truck shape)
5. Upper Middle 20% (11% of total money, represented by a square shape)
6. Middle 20% (4% of total money, represented by a square-x shape)
7. Bottom 40% (1% of total money, represented by a hollow square shape)

Next, the grid was broken up into *n* regions. The colors red and blue are distributed based on a variable slider. The distribution of empty spaces to spaces with an agent on them is also based on a variable slider. Each region is assigned a price based off of the average wealth of all the agents currently living inside of it. All agents want to move to the wealthiest, or most expensive, region that they can afford, has available (i.e., empty) space, and meets their desired similar color percentage. If they are in a region that does not meet their desired similar color percentage, they will then be willing to move to the most expensive region that meets their color percentage and also has available space. After every 'tick' of the simulation, the price of each region is calculated. Additionally, the color percentages of each region is updated dynamically. The simulation ends when agents are no longer able to move, either 1) due to the lack of regions available that will meet agents' desired color percentage, or 2) because all agents are satisfied with their region's color percentage and they reside within the most expensive region they can 'afford'. We hypothesized that segregation will emerge based on both color and wealth assigned to the agent population. Furthermore, we hypothesized that as the number of regions increased, the level of segregation would also increase. As long as there are enough regions for agents to move into, richest and poorest agents become grouped together by color. We believe this will happen because as soon as a region meets one group's desired color percentage, then all of the other groups will move out of that region, as long as there is available space in a region they can afford (a somewhat similar effect as gentrification). Also, every agent wants to move to the most expensive neighborhood they can, and only the richest agents can move to certain regions, which means they will form groups. As a result, many regions will be occupied with mid- to low-level wealth agents. This hypothesis was tested on metrics such as: rate of movement, percentage unhappy, final proportion of red-to-blue in a region, and average amount of wealth in each region.

The results of our simulation confirm our hypothesis, that is, that segregation would emerge as a result of both the color and wealth of agents. Our results appear to show that as the number of regions increases, the more homogeneous each region becomes as there are more regions than the possible combinations of color and wealth brackets. A result that we found surprising was that as the slider for red-to-blue distribution leaned more towards one color, moving from approximately 25% to 75%, we observed more integration of wealth brackets and color in all the regions. This happens because the minority has a small chance of any regions meeting their desired color percentage, and if the region does meet this percentage, it fills up quickly with both mid- and high-level wealth agents.

Thus, we conclude from these simulations that there are a number of factors that can tend a population towards segregated communities. In the both simulations, we show that a desire to live in a location for some intrinsic value of that location can produce patterns of segregation and even gentrification. The first simulation shows this where the intrinsic value of the desirable zone is the amount of similar agents residing in it. This information asymmetry between the two types of agents (as only the high-income agents could determine the amount of similar agents in the entire region), allowed for the high-income agents to force the low-income agents out which created a gentrified community within the desirable zone. The second simulation shows this where the intrinsic value of the region is the cost of living inside of that region. When each agent constantly is wanting to live in the highest cost of living region that they can afford they tend to end up residing in a region that is the highest they can afford, but, they also settle into a homogeneous region, as this makes them happy. However, there are many more parameters that could be analyzed in these models, as there are many different reasons that might influence agent to prefer a particular region. As such, there is a need for research that further explores how these intrinsic values facilitate segregation within a population.

References

Schelling, T. (1971). Dynamic models of segregation. *The Journal of Mathematical Sociology, 1*(2), 143-186.

Torrens, P. M., & Nara, A. (2006). Modeling gentrification dynamics: A hybrid approach. Computers, Environments, Urban Systems, 31, 337-361.

Wilensky, U. (1997). NetLogo Segregation model. http://ccl.northwestern.edu/netlogo/models/Segregation. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Wolff, E. N. (2010). Recent trends in household wealth in the United States: Rising debt and the middle-class squeeze-an update to 2007. *Levy Economics Institute Working Paper Series*.