Project 1: Schelling's Model of Segregation and Norms

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1 Introduction

The Schelling Model of Segregation provides a powerful framework for understanding how individual preferences can lead to unintentional "de facto" segregation. Schelling showed that even mild bias could lead to a highly segregated society.

In this assignment, we used norms to guide our agents' behavior. Norms are informal rules considered acceptable in society. Research has shown that cooperation between both members of the same species and different species has been important for their survival and evolution. In real life, norms can be anything from saying "bless you" to a person who sneezed to expectations around governing reciprocity and apprenticeship that shape the way the United States Congress works.

In our simulation, we use norms to give our agents preferences that dictate how they move across society, or in our case, a matrix. In our simulated society, we have two type of agents — Red and Blue. In every type, there are three subtypes with different tolerance levels for the other type. "Tolerance" is how comfortable agents are with being surrounded by agents of different types in the simulation. Light agents have the highest tolerance, followed by Pale agents and finally Dark agents are the least tolerant. Tolerance is determined by the threshold at which agents relocate. Light agents move when move than 75% of their neighbors are a different type, Pale agents move when more than 50% of their neighbors are a different type and Dark agents move when more than 25% of their neighbors are a different type. Note that tolerance relate only to an agent's comfort with their neighbor's type, either Red or Blue, not their subtype, which is their shade.

We use the Moore neighborhood method in our simulation, which includes the eight surrounding cells for agents in the middle of the matrix. Corner and edge agents consider up to three and up to five neighbors, respectively. Agents will relocate when the diversity of their neighbors is greater than their tolerance level.

$$\text{Diversity} = \frac{\text{Total number of different types of agents in Moore neighborhood of the agent}}{\text{Total number of agents in Moore neighborhood of the agent}}$$

2 Simulation

We consider a 50 x 50 matrix in our simulation, with only one agent per cell. At the start of the simulation, the matrix is randomly populated with agents of each type and subtype. The simulation stops either when equilibrium is reach our each agent has be relocated 1000 times.

We use three different society types with different levels of tolerance: Tolerant, Neutral and Intolerant. In the Tolerant Society, 50% of the agents are Light, 25% are Pale and 25% are Dark. In the Neutral society, 50% of agents are Pale, 25% are Light and 25% are Dark. In the Intolerant Society, 50% of agents are Dark, 25% are Light and 25% are Pale. For each of these societies, we run our simulation for three different population sizes — Dense: 80%, Moderate: 50% and Sparse: 20%. For each society and population, we run three different relocation strategies:

- Move Randomly: Move to a random available location on the matrix.

- Move to a Random Cell with Higher Satisfaction: Randomly move to a location with a higher satisfaction than its current location.
- Move to the Nearest Cell with Higher Satisfaction: Relocate to the closest available cell with satisfaction higher than its current location. Note that in this simulation, distance is calculated using Manhattan Distance.

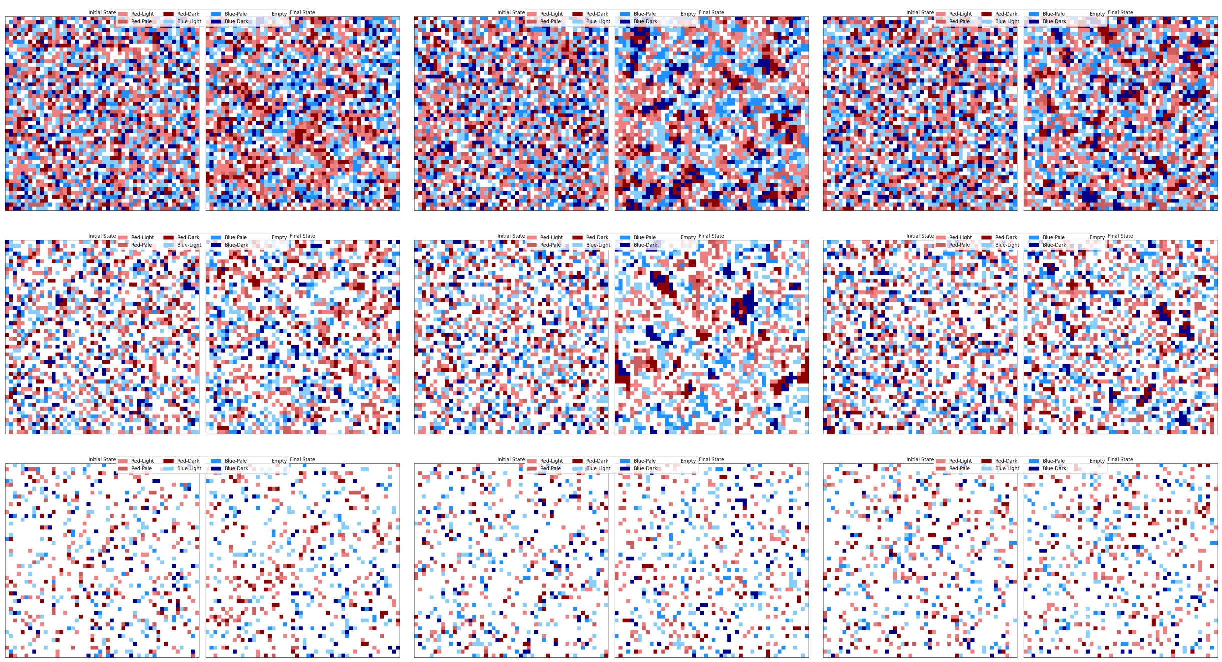
3 Simulation Results

We ran 27 different experiments for each Society, Density and Relocation type. Simulations were constructed as multi-agent systems using the Mesa package in Python. Results are ordered by population, starting with Dense in the first row, followed by Moderate and then Sparse.

3.1 Society 1: Tolerant Society

In this society, 50% of agents are Light, 25% are Pale and 25% are Dark.

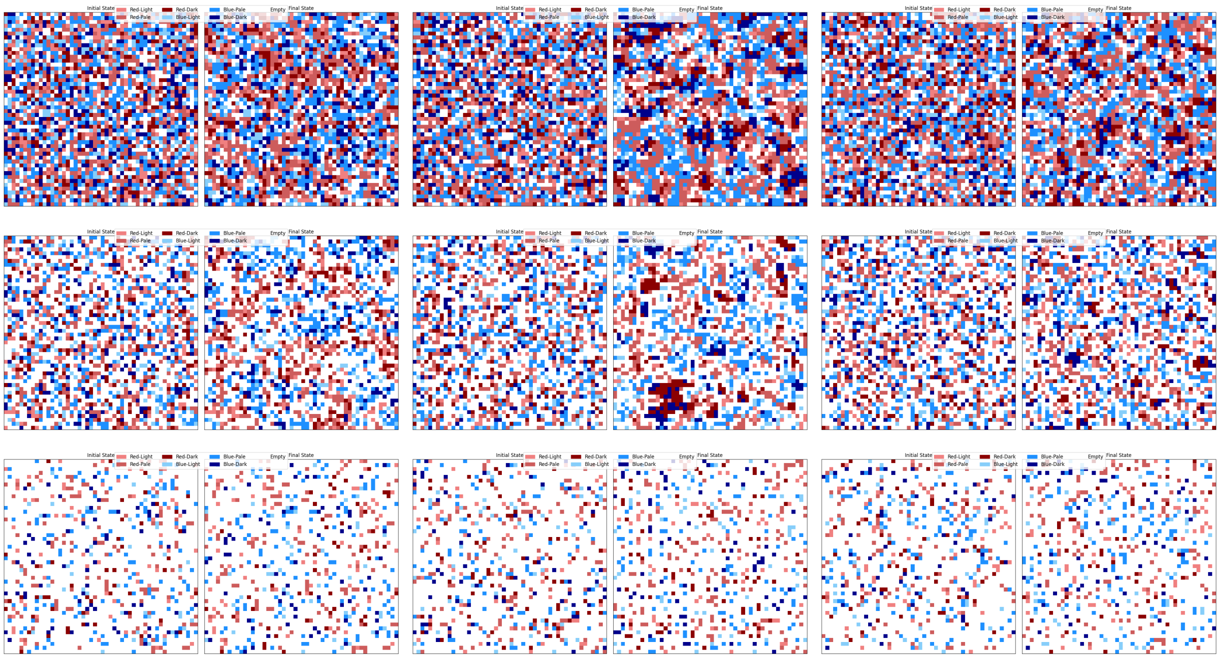
Random | **Random Higher Satisfaction** | **Nearest Higher Satisfaction**



3.2 Society 2: Neutral Society

In this society, 50% of agents are Pale, 25% are Light and 25% are Dark.

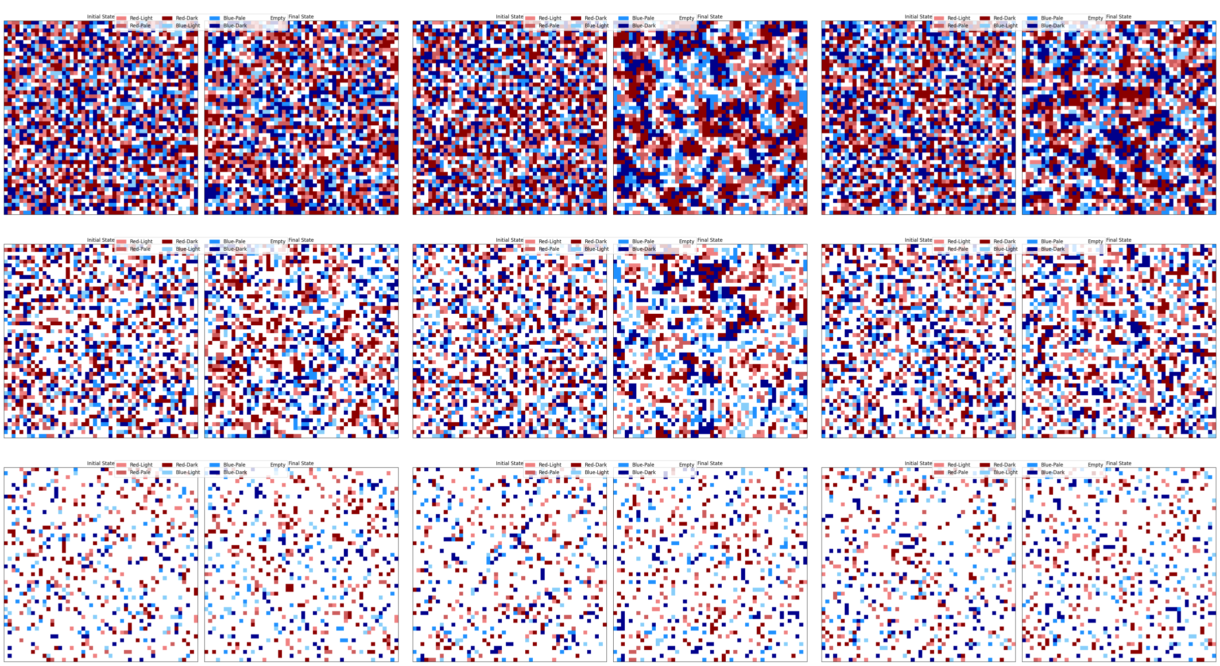
Random	Random Higher Satisfaction	Nearest Higher Satisfaction



3.3 Society 3: Intolerant Society

In this society, 50% of agents are Dark, 25% are Light and 25% are Pale.

Random	Random Higher Satisfaction	Nearest Higher Satisfaction



4 Analysis

4.1 Satisfaction

In our experiment, Satisfaction is measured how happy an agent is in their current position.

$$\text{Satisfaction} = \frac{\text{Total number of similar subtypes of agents in the Moore neighborhood of an agent}}{\text{Total number of agents in Moore neighborhood of the agent}}$$

We calculated average satisfaction across societies, as well as initial and final satisfaction. We got the following results:

Society	Initial Satisfaction	Final Satisfaction	Average Satisfaction
Intolerant	0.41	0.57	0.53
Neutral	0.42	0.55	0.52
Tolerant	0.40	0.53	0.50

Table 1: Satisfaction Results for Different Societies

Across all society types, agents were more satisfied at the end of the simulation than they were at the beginning. In our experiments, the Tolerant society was the least Satisfied of the societies, followed by Neutral and Intolerant was the most satisfied. However, we should note that the differences in Satisfaction did not have a wide variance. All final Satisfactions were within 0.04 points of each other. Average Satisfaction only varied 0.03 points of each other.

Movement Method	Initial Satisfaction	Final Satisfaction	Average Satisfaction
Random Higher Satisfaction	0.41	0.66	0.60
Nearest Higher Satisfaction	0.41	0.56	0.52
Random	0.41	0.43	0.43

Table 2: Satisfaction Results for Different Movement Methods

Across different movement methods, there was more of a difference in Satisfaction. Agents that moved to a random cell with a higher Satisfaction had the highest Final Satisfaction, followed by those who moved to the nearest cell with higher satisfaction. Both those movement methods yielded Satisfactions more than 0.1 higher than their initial Satisfaction. Agents that moved to a random cell barely increased their Satisfaction.

Density	Initial Satisfaction	Final Satisfaction	Average Satisfaction
Sparse (0.2)	0.47	0.64	0.62
Moderate(0.5)	0.38	0.53	0.49
Dense (0.8)	0.37	0.47	0.43

Table 3: Satisfaction Results for Different Densities

Across different population densities, Sparsely populated societies tended to have a higher Final Satisfaction, followed by Moderate populated societies, then Dense societies. Moderate and Dense populations had similar Final Satisfaction and Average Satisfaction, both within 0.06 of each other.

From our analysis across society type, movement methods and population density in our simulation, it appears that the variable with the most impact on our agents' Satisfaction is Movement Method. Specifically, the movement methods in which agents were able to move to a cell with higher Satisfaction saw greater improvements in Satisfaction than the random movement method. It makes sense that agents would be more Satisfied after moving to a cell with higher Satisfaction. Population density also had some impact on Satisfaction. Agents in the Sparse society had the highest final Satisfaction, followed by Moderate then Dense societies. Sparse populations might have higher Final Satisfaction due to the fact that since they have fewer neighbors, these agents are less likely to be around agents that they feel uncomfortable with.

4.2 Homophily

In our experiment, Homophily is the tendency of agents to be surrounded by others of the same type or subtype, where a higher Homophily score indicates a more homogenous neighborhood and lower diversity. In this project, however, Homophily is calculated as the same as Diversity. We consider Homophily for both Type and Subtype.

4.2.1 Type Homophily

Type Homophily was calculated as:

$$\text{Type Homophily} = \frac{\text{Sum of the diversity of each agent}}{\text{Total number of agents in the matrix of a specific type}}$$

Society	**Initial Homophily**	**Final Homophily**	**Average Homophily**
Intolerant	0.47	0.25	0.31
Neutral	0.47	0.22	0.28
Tolerant	0.47	0.24	0.30

Table 4: Type Homophily Results for Different Societies

Across societies, Type Homophily decreased from the beginning to the end of the simulation. There was no dramatic different between Average or Final Type Homophily across the different society types.

Movement Method	**Initial Homophily**	**Final Homophily**	**Average Homophily**
Random Higher Satisfaction	0.47	0.21	0.28
Nearest Higher Satisfaction	0.47	0.29	0.32
Random	0.47	0.21	0.29

Table 5: Type Homophily Results for Different Movement Methods

Across movement methods, Type Homophily decreased from the beginning to the end of the simulation, there again was not a big difference between different movement methods.

Density	Initial Homophily	Final Homophily	Average Homophily
Sparse (0.2)	0.42	0.05	0.11
Moderate (0.5)	0.50	0.28	0.35
Dense (0.8)	0.50	0.38	0.43

Table 6: Type Homophily Results for Different Densities

Across population densities, Type Homophily decreased from the beginning to the end of the simulation. In this case, there was a difference in Final Homophily and Average Homophily across the population times. Sparse populations had the lowest Type Homophily, followed by Moderate populations, and Dense populations had the highest final Type Homophily.

While we did not see a big difference in Type Homophily across societies and movement methods, we saw a difference in Type Homophily across population densities. This might be due to the fact that when you have smaller sample sizes with fewer agents, the results tend towards less and less diversity.

4.2.2 Subtype Homophily

Subtype Homophily was calculated as:

$$\text{Subtype Homophily} = \frac{\text{Sum of the diversity of each agent}}{\text{Total number of agents in the matrix of a specific subtype}}$$

Society	Initial Homophily	Final Homophily	Average Homophily
Intolerant	0.63	0.47	0.52
Neutral	0.62	0.48	0.51
Tolerant	0.63	0.50	0.53

Table 7: Subtype Homophily Results for Different Societies

Across all society types, Last and Average Homophily decreased. There was no marked difference between the Final and Average Subtype Homophily across different societies.

Movement Method	Initial Homophily	Final Homophily	Average Homophily
Random Higher Satisfaction	0.63	0.37	0.43
Nearest Higher Satisfaction	0.63	0.48	0.52
Random	0.63	0.61	0.61

Table 8: Subtype Homophily Results for Different Movement Methods

Across the different movement methods, Subtype Homophily decreased for agents that randomly moved to cells with higher satisfaction and agents that moved to the nearest cell with higher satisfaction. However, agents that moved to random cells did not experience the same decrease in Subtype Homophily.

Density	Initial Homophily	Final Homophily	Average Homophily
Sparse (0.2)	0.56	0.39	0.40
Moderate (0.5)	0.66	0.50	0.55
Dense (0.8)	0.67	0.56	0.61

Table 9: Subtype Homophily Results for Different Densities

Across different population densities, there was a decrease in Subtype Homophily. There was not a marked difference in the difference between the Initial and Final Subtype Homophily across population types, but since the Sparsely populated societies started with lower Subtype Homophily in general, their Average Homophily was lower than the other population densities.

Subtype Homophily differed across movement types the most. This might be because when agents move to cells with higher Satisfaction, they are choosing less diverse neighbors by Type, not Subtype. Agents that relocate randomly don't have that same bias, so they have a higher Homophily. Average Subtype Homophily differed across population densities, and Sparse populations had the least Subtype Homophily. This might be because they have fewer neighbors and thus fewer opportunities to be surrounded by another agent of the same Subtype.

4.3 Corner and Edge Agents

Corner and Edge agents are defined at the agents in the four corners of the matrix and agents along the border lines of the matrix, respectively. These agents have fewer neighbors, which may impact how they move and experience this experiment.

Position Type	Satisfaction	Type Homophily	Subtype Homophily
Corner	0.61	0.33	0.52
Edge	0.55	0.24	0.47
Middle	0.56	0.24	0.47

Table 10: Position Type

We found that across our experiments, Corner agents tended to experience higher Satisfaction than Edge and Middle agents. They also experienced slightly higher Type Homophily and Subtype Homophily. This might be due to the fact that since they have the fewest neighbors, they have less opportunities to be uncomfortable with their neighbors.

5 Discussion and Conclusion

In this experiment, we explored different society types, densities and relocation strategies to understand how segregation and integration might be impacted by different norms. In Schelling's original model of segregation, he showed that even having mild in-group preferences could lead to a segregated society.

From our experiments, we learned that, despite the society's tolerance level, it will become more segregated when agents are allowed to relocate to find a spot where they might be more comfortable —surrounded by agents more like themselves. The movement method had a significant effect on satisfaction and segregation patterns. Agents who moved to a random cell with higher satisfaction showed the highest final satisfaction scores, suggesting that seeking satisfaction over proximity can lead to a more homogeneous environment, potentially increasing segregation. Sparse populations consistently had higher satisfaction levels, likely due to agents having fewer neighbors, reducing the likelihood of being surrounded by 'uncomfortable' neighbors. This might reflect real-world urban planning challenges, where lower-density areas could experience less social friction but could also lead to higher segregation if movement preferences are not constrained.

5.1 Limitations

While the Schelling model is powerful in demonstrating the emergence of segregation from individual preferences, it is a simplification of real-world interactions. In reality, factors such as economic disparities, policy, and infrastructure play significant roles in shaping neighborhood demographics. Nonetheless, this model provides crucial insights into how even mild preferences can lead to unintended societal outcomes, such as segregation.