Simulation of Segregation Model using Agent Based Modeling

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Schelling's Segregation Model shows how, if individual people have certain preferences for their neighbourhood, a segregated pattern is formed in an area consisting of population with two traits even if the individuals prefer an integrated neighbourhood. Here, we try to understand and analyze different behaviors obtained in movement of unhappy as well as happy agents by changing different parameters which affect the forming of the clusters in an area.

I. Introduction

Schelling's Segregation Model as proposed in [1] is a very popular Socio-Economic Model which has been studied to understand the housing patterns in an area having two very different kinds of population which could be a majority or a minority. The agents in the model who have occupied a cell needs to have a certain fraction of neighbours of his/her own kind in order to be happy/satisfied and the agent decides to leave the cell if the preferences are not met. Many variants to the Schelling's Model have been proposed by factoring in the nature of individual preferences, where some more preferences are considered[3] and sometimes even the agents try to change their preferences according to their neighbours [2]. Thus, these variants change the utility function of the agents which signifies the movement of the agents in the model. Hatna and Benenson in [4] have adapted the Schelling's model where the agents try to find the next best empty cell which provides them more happiness.
Here, we present the observations and results as obtained by modeling two variants of the utility functions, the functions being adapted from [1],[4].

II. Model

The basic agent based Schelling's Model as described in the [1] for the 2-D area distribution has empty spaces in the area which allows the movement of the agents for relocation. Thus relocation of an unhappy agent can be done in two ways which are described below. Unless stated otherwise the terms used mean the following: $h_{threshold}$ denotes the percentage of the similar agents a agent needs in his/her neighbourhood to be happy; $empty_p$ denotes the percentage of the empty cells in the entire area (here a grid); r_{prob} is the probability by which a satisfied agent relocates to an empty cell. A particular Population-1:Population-2 ratio is taken for the remaining occupied cells of the grid. Happiness value of a cell denotes the ratio of the similar agents to the total agents in the neighbourhood. Integrated is the pattern in which both the populations are dispersed in the area and not many well noticeable segregated clusters of the two populations are formed. The segregation and integration for these models has been observed by varying parameters affecting the happiness, population ratios and relocation.

Schelling's model

In the Schelling's model, an unhappy agent relocates to an empty cell which has happiness value equal or greater than the $h_{threshold}$ otherwise it remains in the same cell. That is unhappy agent always tries to find the satisfactory site. The agent tries to find the nearest empty site. If the unhappy agent moves to any random cell providing at least $h_{threshold}$ level, this approach converges to same result as that of the above one. The final configurations obtained in the approach were verified with the results provided by Schelling.

Modified Schelling's model

The modified model as adapted from [4], is different from the Schelling's model in the following ways. When relocation takes place, an unhappy agent is relocated to an empty cell where it can find maximum happiness value among all the empty cells, which may be less than the $h_{threshold}$ but greater than his/her current happiness. In this model, even a happy agent is given a choice to relocate itself if it wants to. The shifting probability of a happy agent is r, which is a random number generated each time, if r is less than r_{prob} the happy cell can also relocate itself to a location where it can find happiness value more than its current value of happiness.
The above given two utility functions have been compared by varying the $h_{threshold}$ and because of more realistic nature of the modified Schelling's Model, it has been used for the rest of the results.

Rules and Assumptions:

- Segregation has been observed in the grid of 50x50 cell. A cell has Moore neighbourhood of 3x3 cells.

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- A cell is either vacant or occupied as population-1(red) or as population-2(blue).
- There is always an empty cell available for relocation but the agent needs to think whether it is suitable to relocate by comparing the happiness value of the agent with that of the empty cell.
- An agent is happy if he/she has at least $h_{threshold}$ fraction of neighbours of the population same as himself/herself.
- Both the population have same $h_{threshold}$ that is their tolerance level is same.
- Empty cells are not counted while calculating the happiness of the agents.
- Agent knows the color ratios of each cell while opting for the relocation. So, if agent is unhappy he/she will move to the best empty cell available. Thus, the distance between cells has no effect on relocation.
- Simulation runs until all agents become happy or at least one agent can find empty cell with more happiness.
- There is no birth or death involved. Thus the number of agents and empty cells do not change.
- The area is initialized randomly, the agents are dispersed uniformly across the area.
- The boundaries are considered to be fixed. That is we used absorbing boundary condition by assigning the extended boundary cell a constant value of 3.

The rules stated above are used unless stated otherwise. In order to observe the patterns of how the local preferences of the cells affect the global pattern, the simulation for various $empty_p$, various $h_{threshold}$, r_{prob} and various population ratios were run. This enabled the understanding of the noticeable pattern which can be found in the segregation patterns of different areas of the world.

III. Results

Analysis when empty cell proportion is varied and all other parameters are kept constant

The ratio of empty cells are taken to be 5%, 7%, 10% and 15% respectively. $h_{threshold}$ is kept to 0.67 which is a high value, so the agent needs more neighbours of same kind to be happy. r_{prob} is kept 0 and ratio of population-1 and population-2 is kept to be 50:50.

We can observe from Fig.:1 that as we increase the empty cells, segregation boundaries become more well defined. For less number of empty cells, agent has tendency to relocate to the cell with more number of neighbours having same population as himself/herself while if more empty cells are available to relocate, agent can have more cells to relocate which has neighbourhood of both empty spaces and population same as itself. So, for more empty cells, we may not get large groups of same population as compared to that of less empty cells. So, from hereon, we consider strict bound of relocation with 5% empty spaces for further analysis.

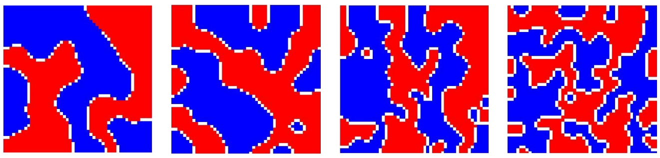

FIG. 1: Final positions when no. of empty cells are 5%, 7%, 10% and 15% from left to right.

Analysis for varying $h_{threshold}$ and comparing the two models by looking at the final states of the simulation for $r_{prob} = 0$

Here the equal population of red and blue are considered. As the $h_{threshold}$ is increased, the initial happiness of the population gets lower as the demand of the agents for the neighbourhood to have similar kind of population increases. By looking at the Fig:3, one can notice that in the Schelling's model, the final state of maximum happiness is not reached that is maximum population remains unhappy. For smaller values of $h_{threshold}$, all the agents become happy at end. This is because the agents tend to have more integrated pattern. In the Schelling's model, it was observed that as the value of $h_{threshold}$ was increased beyond 0.67, the pattern started to get integrated as an unhappy agent was unable to find an empty cell with atleast happiness value of $h_{threshold}$. Thus, in the final configurations the population remained mainly unhappy. In the case of the modified model, where the unhappy agent tries to relocate at the next best possible empty cell providing him/her more happiness, we observe from the Fig:3, mostly the entire population remains happy at the final state. That is by relocating to empty cells providing more happiness, the final configuration shows that the population gets segregated (Fig:2) and the majority of the agents are happy.

The final patterns of integration and segregation can be compared in the Fig:4 for $h_{threshold} = 0.875$ for both models, where we can see that the modified model shows realistic conditions. In the modified model, the proportion of people unhappy for larger values of $h_{threshold}$ shift to other empty positions thus creating empty positions for other population to fill in and increasing the happiness value of the neighbourhood where they have moved. Fig:2 shows how for both the models, the patterns of integration to segregation occur for varying $h_{threshold}$. $h_{threshold} = 0.25$ shows an integrated pattern. $h_{threshold} = 0.33$ shows the mixed pattern from where we see that the clusters of the two populations start to form. This show that 0.33 is the critical $h_{threshold}$ value, from

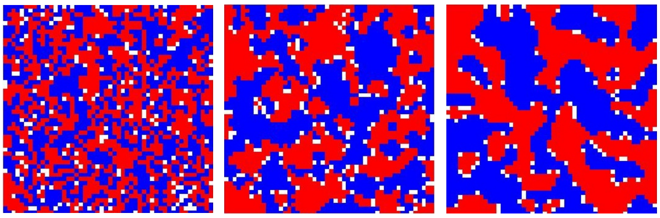

FIG. 2: Final patterns when all the parameters are same but $h_{threshold}$ are 0.25, 0.33 and 0.42 from left to right.

where we start to observe the segregated patterns. Thus for $h_{threshold}$ around 0.5, we get clear segregation patterns and in the Schelling's Model after $h_{threshold} = 0.7$, we get the integrated pattern.

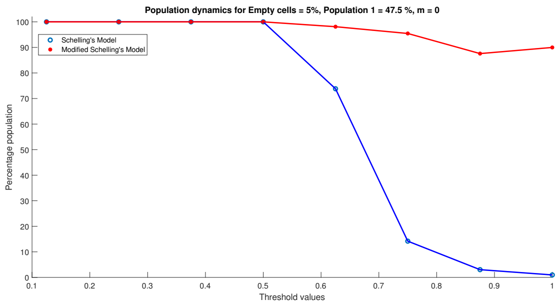

FIG. 3: Comparison between the Schelling's Model and the modified segregation model with respect to final proportions of happy agents where the red and blue populations are in equal ratios and the $empty_p = 5\%$

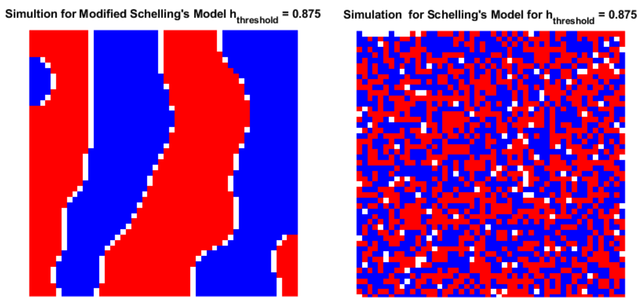

FIG. 4: Simulation for Schelling's Model and the modified segregation model where the red and blue populations are in equal ratios and the $empty_p = 5\%$

Analysis when population ratios are varied and all other parameters are kept constant

The ratio of red to blue population are taken to be 15:85, 33:67 and 50:50 respectively for comparison. $h_{threshold} = 0.67$, $r_{prob} = 0$ and $empty_p = 5\%$ are taken. It can be seen from Fig:5, that initially, the agent that belongs to the majority group(in terms of population size) has lesser unhappy percentage as compared to the minority group. This is because being a part of majority group implies higher probability of the neighbours being from same population. Since the threshold is also higher, i.e. 0.67 here, more neighbours of same population are needed for the agent to be happy. This can also be observed for the final state. 15% population of red has the highest unhappy population percentage and 85% population of the blue has the least unhappy population percentage.

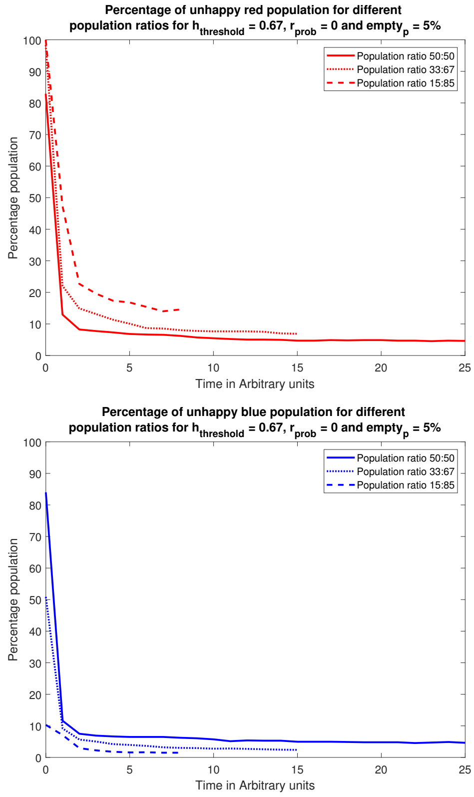

FIG. 5: Percentage of unhappy red and blue population when $h_{threshold} = 0.67$, $r_{prob} = 0$ and $empty_p = 5\%$

Initially, the movements of the agents are more. As the time passes, the movements of both the agents decreases as they mostly approach their happy or satisfactory place. Also it is observed that if the agents belong to the majority group, then number of moves needed to reach the location where the agents gets satisfied or happy is less. The red population in red:blue ratio of 15:85 has lesser chance of finding neighbours of red population to meet the threshold value whereas the blue population has higher chance to find neighbours of its population.

Also, it can be observed that as the magnitude of the difference of the red population and blue population decreases, i.e. as the ratio increases from 15:85 to 33:67 to 50:50, the number of clusters formed decrease and the size of each cluster increase. More and more small clusters congregate to form bigger clusters with time.

Analysis of final state by varying r_{prob} and keeping other parameters constant

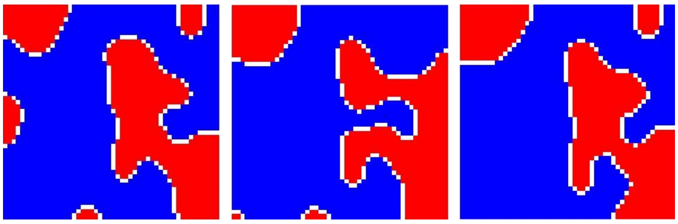

FIG. 6: Comparison of final states when $r_{prob} = 0$, $r_{prob} = 0.2$ and $r_{prob} = 0.5$ from left to right.

In this case we took a fixed initial grid, which was generated randomly, along with fixed values of other parameters. Except r_{prob}, value of fixed parameters are as follows: $h_{threshold} = 0.67$, $empty_p = 5\%$ and population ratio= 33% of the occupied grid.
It is observed that as r_{prob} increases more number of agents get happy. Small clusters start vanishing. As r_{prob} signifies the choice given to the happy agents to relocate, if it's value increases, more number of happy agents can shift and they tend to go towards more happier places. This can be seen from the final states in all the three cases in Fig:6. Since the happy agents are free to move to more happy spaces they tend to move to regions where majority of the happy agents of same traits are present. Hence smaller clusters vanishes and almost patches of each traits are observed. Following table shows the number of happy agents as r_{prob} changes.

r_{prob}	# Happy Agents
0	2314
0.2	2320
0.5	2336

It was also observed that the average value of happiness of the agents was greater than 0.67 in this case for larger r_{prob}. When other factors are kept constant, and if the movement is not restricted by increasing the number of empty cells, the simulation shows that all the agents become happy in the end.

IV. Conclusions

Here, first we looked into Schelling's Segregation model. We verified the integration and segregation patterns for different values of $h_{threshold}$ and got a range of values for which segregation takes place. Next, the rules of the existing model were modified for relocation of the unhappy agent by assuming that an agent always opts for next best option if the happiness level of $h_{threshold}$ is not available. By introducing r_{prob}, an already happy agent can re-locate to some random cell that has happiness level more than $h_{threshold}$. The different parameters of the Segregation Model gave very different patterns that show how the dissatisfaction within a locality could make bigger clusters to attain happiness. Thus, r_{prob} and the modified relocation rule suggested that the model could closely relate to real world scenarios given that there are no economic constraints.

As the $empty_p$ is increased, more and more satisfaction is achieved finally for even the larger $h_{threshold}$. This behaviour was due to allowance of more movement. Well defined boundaries were made around the clusters of the two types of agents by empty cells as $empty_p$ is increased.

If $h_{threshold}$ is less, the agent needs less number of same neighbours to be happy, hence the population is more integrated. But when r_{prob} is increased for smaller $h_{threshold}$, we see that the agents even if they prefer integrated neighbourhood moved to show a segregated global behaviour. As the value of $h_{threshold}$ increases it requires more number of neighbours of same kind to be happy so the population overall becomes more segregated rather than integrated. As the value of r_{prob} increases, small clusters congregate to form bigger clusters.

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