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Project 1-B

1. Segregation Measurement with Parameter Variation

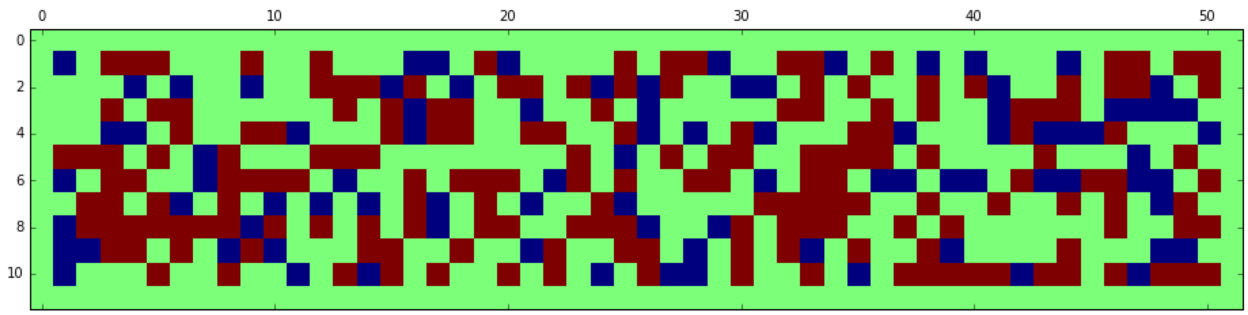
I slightly altered my proposed measurement from the first assignment, in order to make my results more comparable across trials with varying parameters. The measurement still takes the centroid for each tribe. It then computes (for each individual) the difference of the distance to the opposite tribe's centroid and its' own tribe's centroid. These values are averaged across all individuals (not weighted by tribe). Finally, the averaged value is normalized by dividing it by the maximum possible segregation for a grid, which I assumed to be the length of the longest diagonal. The final value is a number between 0 and 1.

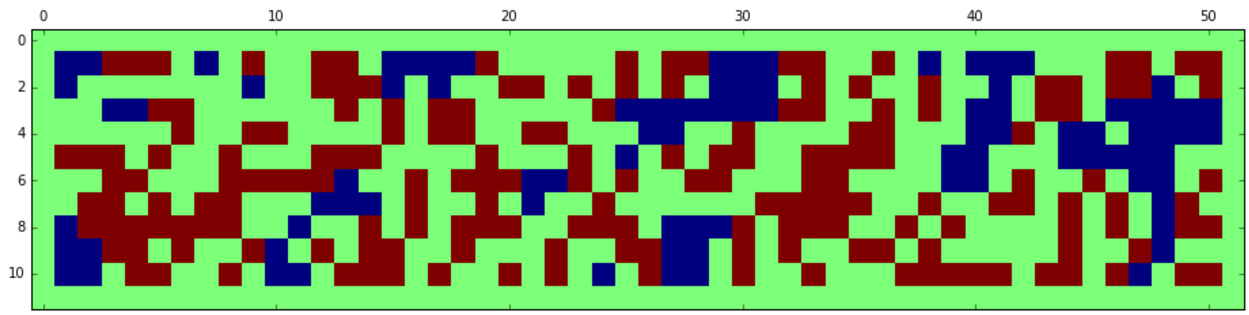
The default values are:
$M, N = 10, 10$
$PROB\_OCCUPIED = .5$
$COND\_PROB\_A = 2/3$

Varying $\boldsymbol{M}, \boldsymbol{N}$

- $M, N = 10, 10$
  Initial Segregation = 0.00848, Final Segregation = 0.02192, Steps to Equilibrium = 3,
  Start to Finish Segregation Increase = 258%
- $M, N = 10, 50$
  Initial Segregation = 0.00016, Final Segregation = 0.00393, Steps to Equilibrium = 5
  Start to Finish Segregation Increase = 2456%
- $M, N = 50, 50$
  Initial Segregation = 0.00140, Final Segregation = 0.00765, Steps to Equilibrium = 6
  Start to Finish Segregation Increase = 546%
- $M, N = 50, 250$
  Initial Segregation = 0.000031, Final Segregation = 0.00177, Steps to Equilibrium = 6
  Start to Finish Segregation Increase = 5709%

Based on just a few experiments, it appears that the grid becomes more segregated (according to my measurement) after the simulation as the grid gets bigger or as the grid gets "skinnier". The same changes also correlate to an increase in the number of steps before the segregation stops. It's unclear if this effect is due to bias in my measurement for differently sized grids, but it could also be that the increased grid size offers each individual more moving options, thus increasing segregation over time. The starting and finishing states of the 10x50 simulation are shown below to illustrate some of these ideas.

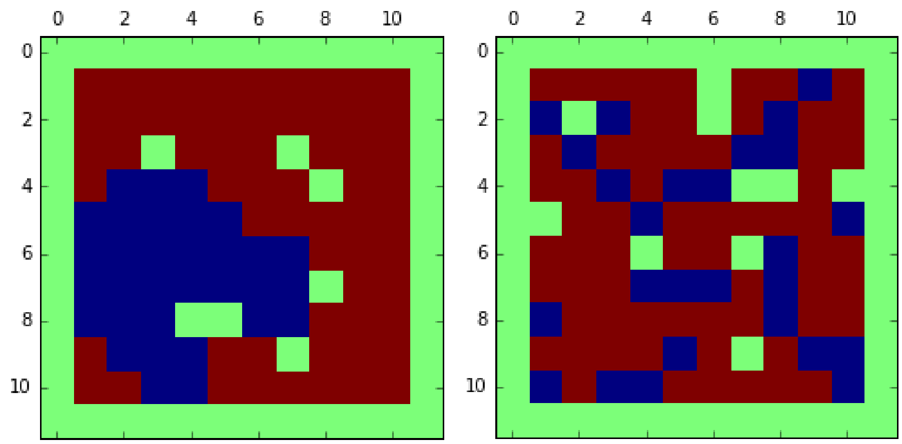




Varying $PROB\_OCCUPIED$

- $PROB\_OCCUPIED = .25$
  Initial Segregation = 0.00799, Final Segregation = 0.03481, Steps to Equilibrium = 3
  Start to Finish Segregation Increase = 435%
- $PROB\_OCCUPIED = .5$
  Initial Segregation = 0.00848, Final Segregation = 0.02192, Steps to Equilibrium = 3,
  Start to Finish Segregation Increase = 258%
- $PROB\_OCCUPIED = .75$
  Initial Segregation = 0.00879, Final Segregation = 0.06589, Steps to Equilibrium = 4
  Start to Finish Segregation Increase = 749%
- $PROB\_OCCUPIED = .825$
  Initial Segregation = 0.00775, Final Segregation = 0.07062, Steps to Equilibrium = 5
  Start to Finish Segregation Increase = 911%
- $PROB\_OCCUPIED = .9$
  Initial Segregation = 0.01662, Final Segregation = 0.11676, Steps to Equilibrium = 5
  Start to Finish Segregation Increase = 702%

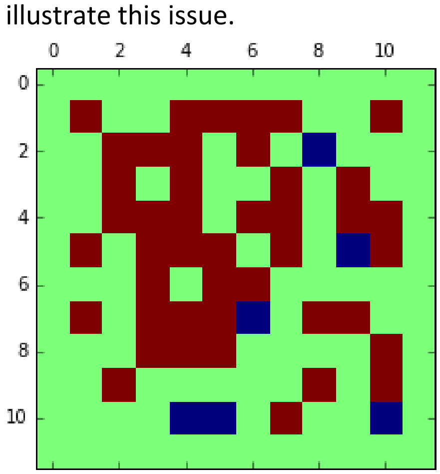
It's unclear how increasing the occupied probability (essentially population density) affects the percentage increase in segregation from start to finish (although it appears that higher values generally become more segregated than lower values). The data above is from only one trial, but running a few trials with higher density reveals a large variance in results, because the grid either separates very well or gets "stuck" early in the simulation due to its high density. To illustrate this variance, a very well segregated grid and very poorly segregated grid are shown below (they are from separate trials). Both are from when $PROB\_OCCUPIED = .9$.



Varying $COND\_PROB\_A$

- $COND\_PROB\_A = .5$
  Initial Segregation = 0.01163, Final Segregation = 0.04557, Steps to Equilibrium = 3
  Start to Finish Segregation Increase = 391%
- $COND\_PROB\_A = .7$
  Initial Segregation = 0.00274, Final Segregation = 0.02413, Steps to Equilibrium = 3
  Start to Finish Segregation Increase = 880%
- $COND\_PROB\_A = .8$
  Initial Segregation = 0.03902, Final Segregation = 0.16473, Steps to Equilibrium = 5
  Start to Finish Segregation Increase = 422%
- $COND\_PROB\_A = .9$
  Initial Segregation = 0.05961, Final Segregation = 0.07090, Steps to Equilibrium = 3
  Start to Finish Segregation Increase = 118%

As the conditional probability of A increased, the model wasn't able to become as segregated. This is because, with such a high density of tribe A, there were very few spots that appealed to members of tribe B, so they just remained spread out. An example from the last trial is included below to illustrate this issue.



Conclusion

I think that my segregation measure performed in the way that I wanted it to. That is, it prefers when the tribes are with each other and far from the other tribe. The measurements are very low across the board for every trial (they are consistently below .1 on a 0-1 scale), but I think that this is because of the nature of the model. The model is set up in a way that encourages it to stay in undesirable states (in terms of my metric) for many reasons: If individuals are happy they will not consider spots where they will be happier, individuals consider themselves to be in their neighborhoods, and if there are no available swaps, then nothing happens, even if the segregation is not optimal. Granted, this is a more realistic representation of the world, but if the model were more flexible it would allow my segregation metric to rise to greater values, rather than getting stuck in a local optimum early in the simulation. If I were to modify my metric, I would attempt to take into account the smaller groups that naturally occur across the grid.

2. Model Extensions

Extension 1 - Moves to More Desirable Locations

One of things that bothered me in part one of the assignment was that individuals wouldn't move to a new location even if there was an available spot that would make them happier. This caused the simulation to stall out very quickly. So for my first extension, I changed that.

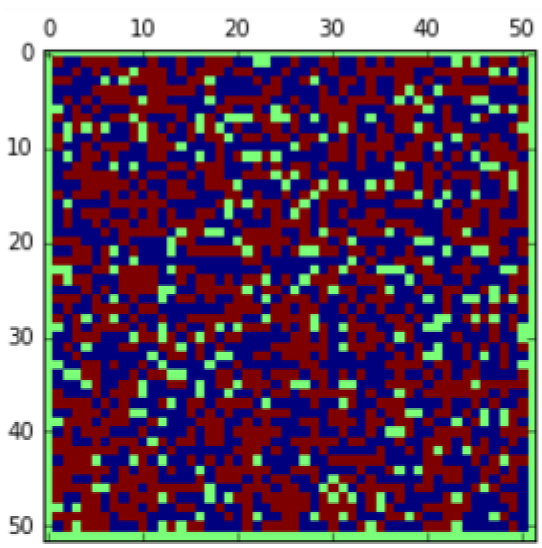
I extended the model this way by creating a new function to execute swaps in the grid. The function considered campers 1 by 1 in a random order (alternating between A and B) and then for each camper that it considered, it would look at the available locations in a random order. It would execute a swap at the first location it found that increased a camper's happiness.

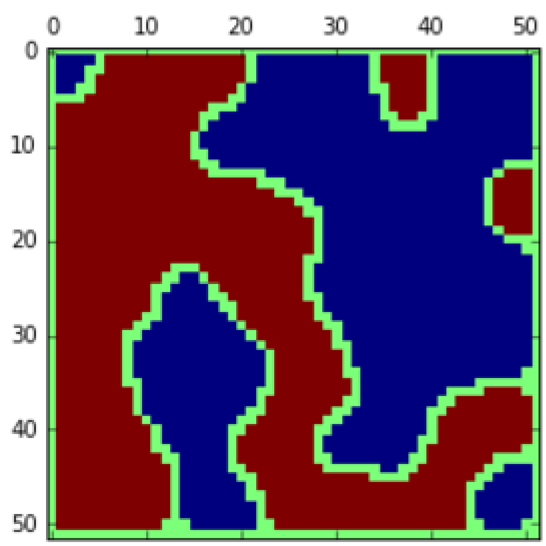
The results were exactly as I'd hoped. The members of each tribe tended to avoid each other and stick with their own on a much larger scale. As an example, here are the results of a trial that I ran which I found interesting.

Parameters:
$M, N = 50, 50$
$PROB\_OCCUPIED = .9$
$COND\_PROB\_A = .5$

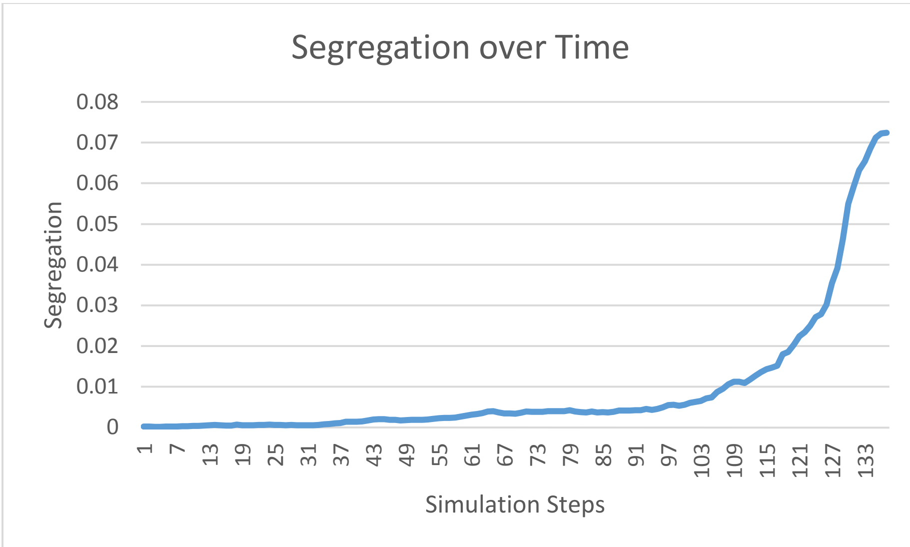
Numerical Results:
Initial Segregation = 0.000223, Final Segregation = 0.072444, Steps to Equilibrium = 137
Start to Finish Segregation Increase = 32486%

Initial/Final Grid:

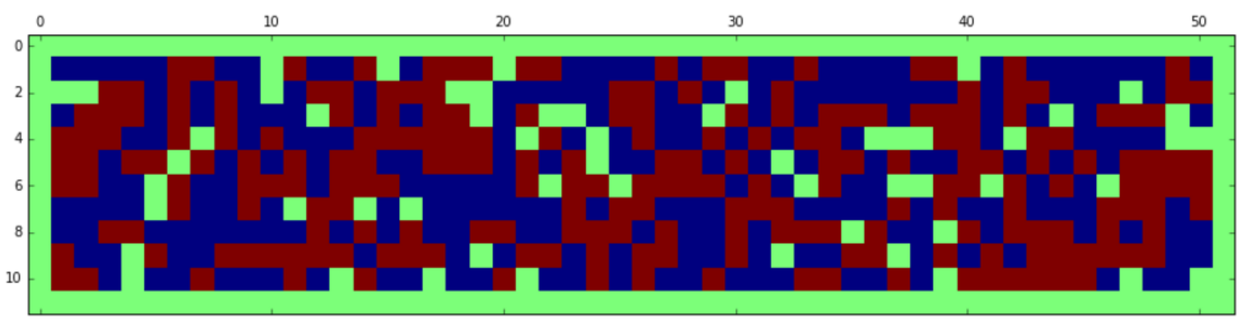


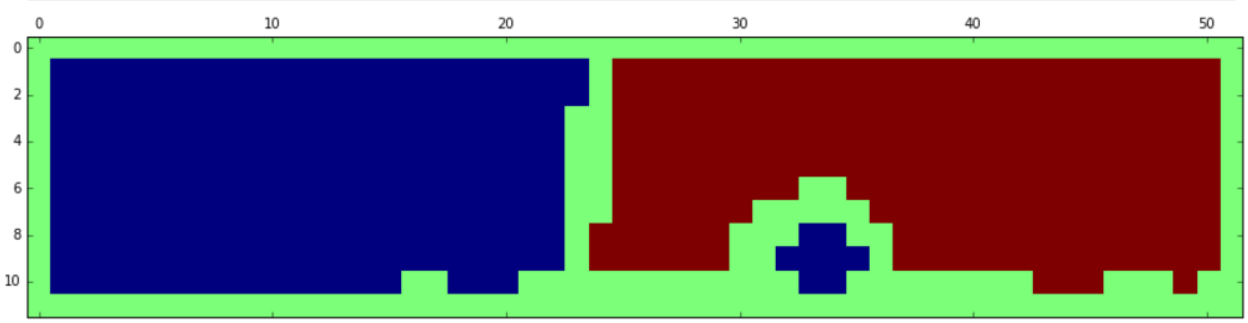


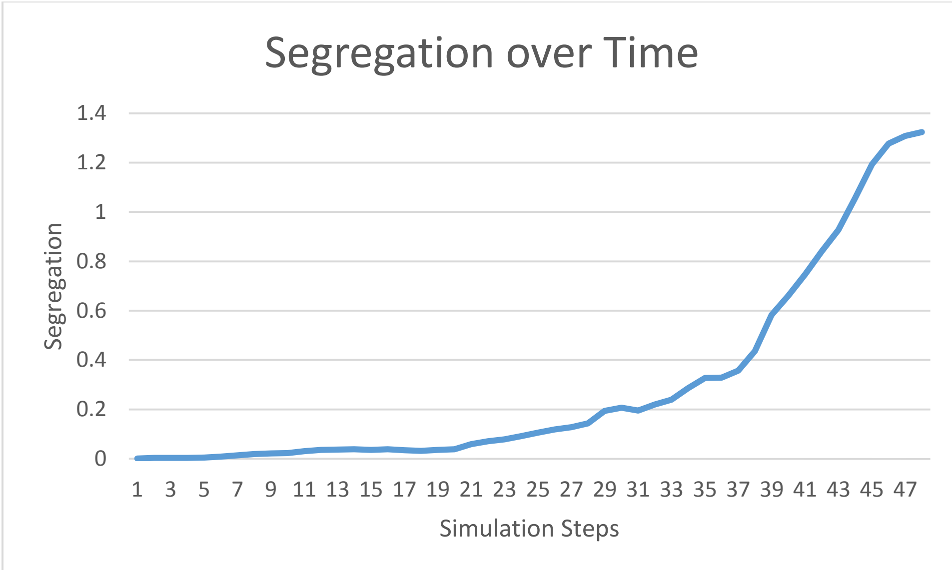
Segregation Measurement over Simulation Steps:



Lastly, here is another start/finish example that I thought looked interesting. Note: the segregation measure here increased to over 1, so I discovered here that there is some error in my scaling operation. The measure still works well for comparisons, however.







Both of the graphs of segregation over time looked like they might be exhibiting logistic growth, which I found to be quite interesting.

Extension 2 – Limit Mobility

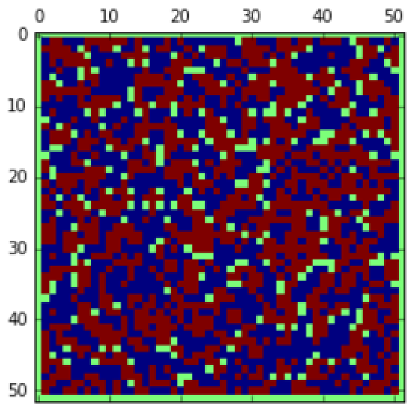
Since my first extension greatly increased the speed and effectiveness of the segregation process, I decided to inhibit the segregation. I did this by adding a constraint that limits how far on the grid an individual can move at each step. The process was otherwise the same as in the first extension.

To do this I added another variable MAX_MOVE which I set to a few different values to see how it affected behavior.

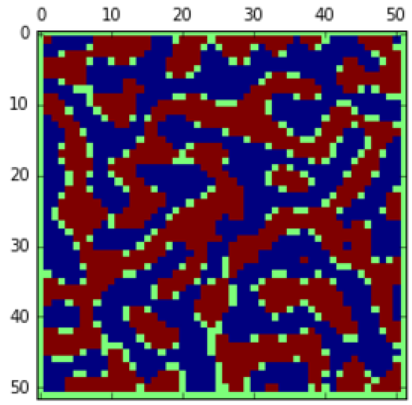
Parameters
$M, N = 50, 50$
$PROB\_OCCUPIED\ = .9$
$COND\_PROB\_A\ = .5$

The final states are shown below for several variations of the new parameter.

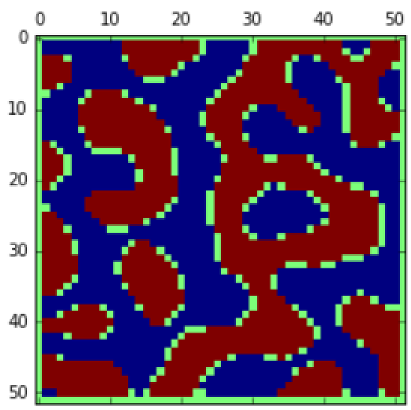
$MAX\_MOVE = 1$



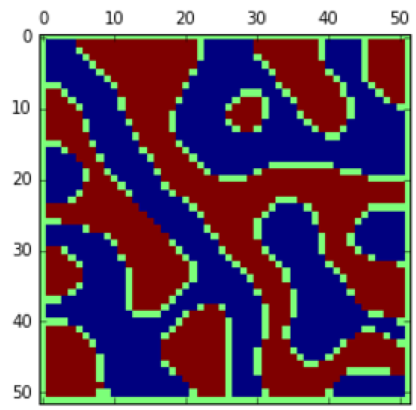
$MAX\_MOVE = 2.5$



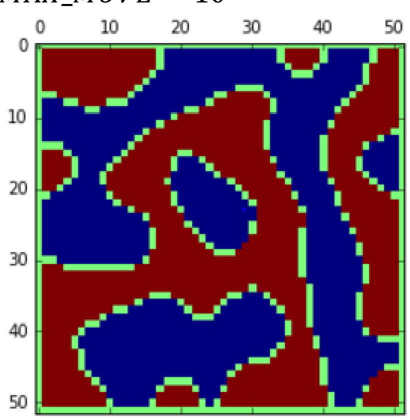
$MAX\_MOVE = 5$



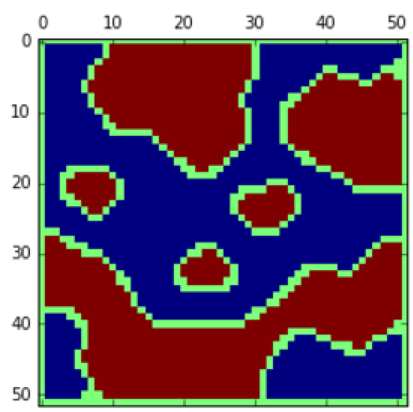
$MAX\_MOVE = 7.5$



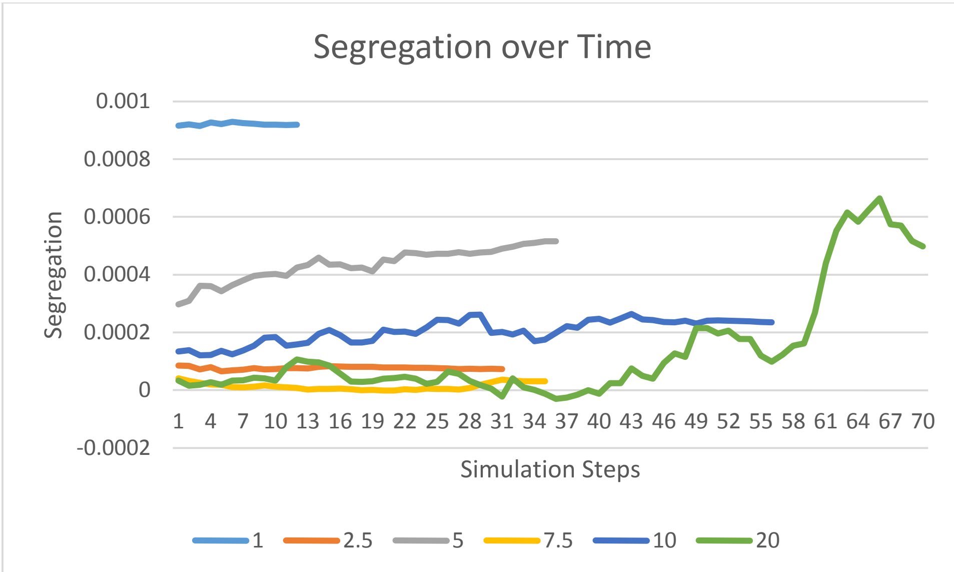
$MAX\_MOVE = 10$



$MAX\_MOVE = 20$



Below is the chart of segregation over simulation steps. The different lines are by the maximum distance parameter.



The addition of a maximum move parameter clearly limited the segregation capabilities of the system. With lower mobility, the tribes tended to group together on a smaller scale, and segregation measure didn't move much at all. The number of steps until an equilibrium state was reached was also lower. The segregation measure wasn't allowed to improve by much until the maximum move was relaxed to 20.