Capstone Abstract

The spatial distribution of the urban poor has long been the focus of urban sociologists, geographers, and economists. Understanding where these low-income populations reside in cities allows policymakers to identify areas that have high social risks and allocate public resources accordingly. However, the residential locations of people living in poverty are difficult to track and characterize as they tend to rent places in unregulated markets and move frequently. In my Capstone Project, I want to use agent-based models to predict the spatial distribution of low-income population residences in cities and validate the models against available empirical data. The first part of the project/validation will focus on examining economic factors and exploring how different distribution (e.g. concentric, random, and network) of these factors will alter low-income population's preferences for residential locations. The second part of the project/validation will calibrate the model according to urban characteristics of a particular city and assess the model's accuracy.

Model Description

My model attempts to model the spatial distribution of different income groups in the city in ABM under economic dynamics. The ultimate goals are to evolve the mechanisms until the spatial distribution is close to Burgess's concentric model and thus in the process, understand the implications of different handlers (e.g. land price, density etc.). These are the assumptions of the model adopted from Burgess's Concentric Model:

- The housing price drops from the center to the peripheral, which follows the bid rent curve.
- Job opportunities distribute from high to low from the city center to its peripheral, which corresponds to the assumption that industries located close to CBD.
- Rich people have higher sensitivity to population density and can afford to live further away with cars (Noted that Chicago public transportation was not very advanced when Burgess published his work)

The following table presents the agent and patch attributes and model parameters

Agent and Patch	**Attributes**	**Parameters**
PeopleAgent: - People PatchAgent:	PeopleAgent - category ("poor", "middle", "rich") - income (1, 2, 3) - density-sensitivity (5, 3, 1)	Frames per Second (Number of frames to change per second)

- Land Patch	- happy (True, False) PatchAgent - density (#number of people on patch#) - land_price (1, 2, 3) - housing_price (land_price /density) There are also other attributes for each agent that are instrumental or generic (e.g. model and position)	Number of Agents (from 90 to 900 and changes 9 for each step)

When the model is initialized, the number of poor, middle, and rich people are created in a ratio of 5:3:1 (the ratio is arbitrary) given the total agents selected by the user. At first, agents are randomly placed on the patches. At every time step of the model, each agent will evaluate their happiness according to the constraints. If they are unhappy, move to a neighbor that satisfy the constraints within the radius of five. If there is no such neighbor, the agents will be removed after a period of time as if they leave the city. The most advanced model so far (model 4) has three constraints, which are affordability (agent's income is greater than the land price or housing price), satisfactory density (agent's density sensitivity is greater than the patch density), and job probability (agents will roll a dice biased by their target patch's job probability to see if they get a job). The following model interpretation moves from the simplest model (model 1) with only two handlers (one constraint) to the most complicated one (model 4).

Model Visualization

To run the ipyb or py file and play with the actual model, you need to first install Python mesa library. An interactive web browser should be opened automatically to show a model that you can play with.

The default model visualization by Mesa Python Libary is organized as Figure 1, which is one canvas and one chart at maximum on the screen in vertical order. To display the model dynamics under different layouts (land price, job probability, and density), I inserted Javascript, HTML, and CSS codes to the original library to reorganize the browser visuals locally. Figure 2 shows three layouts simultaneously running the same model and aligned horizontally with labels below.

The red dots represent poor people, yellow dots represent middle people, and green dots represent rich people. If they overlap in the same patch, then you can see rings around the dots as they are in different sizes. The chart below the canvas shows the temporal changes of the percentage of unhappy poor, middle and rich people within their own population.

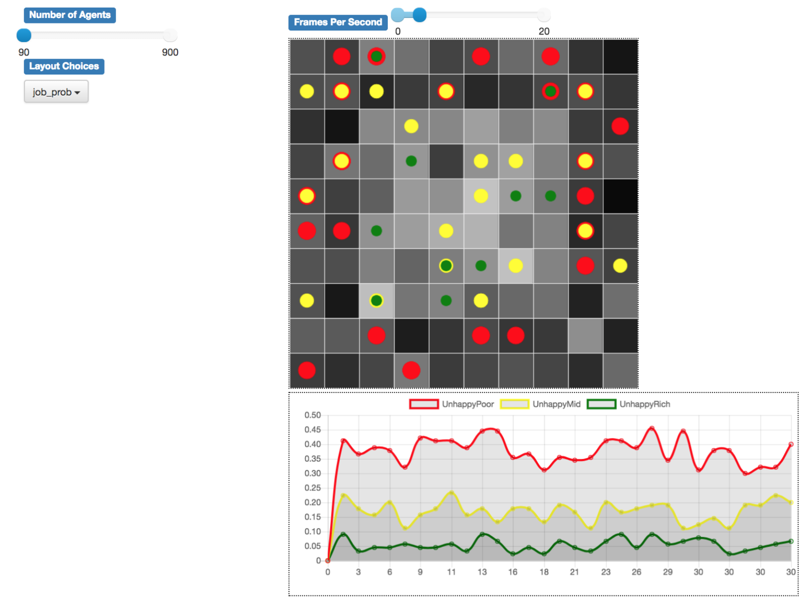

Figure 1: Default Model Layout with 90 agents.

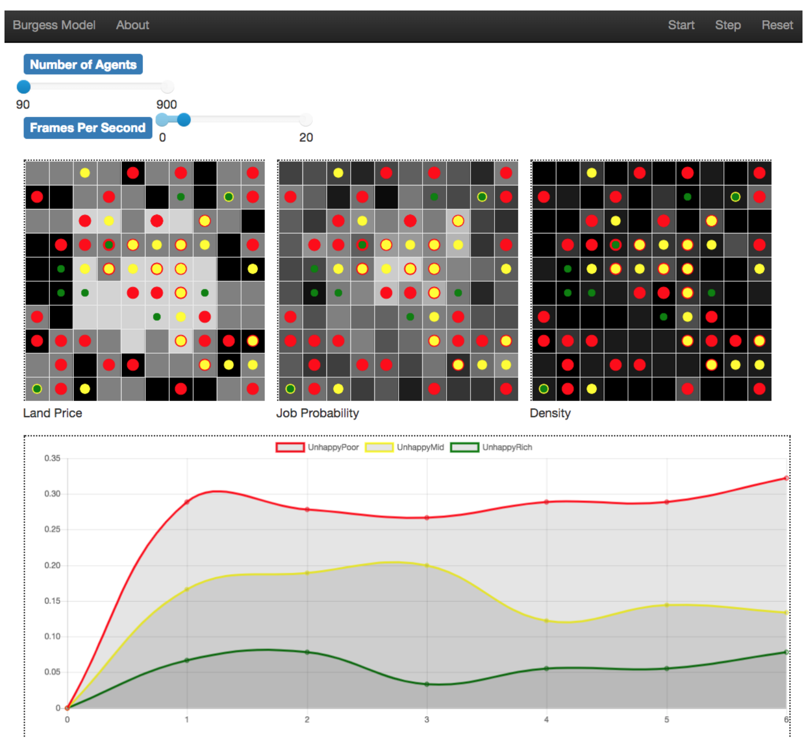

Figure 2: Improved Model Layout with 90 agents.

Model Interpretation

1) Model with Only Income and Land Price Interaction

In such a model, agents will just move to one of the neighbors (within a radius of 5) of which the land price is affordable under their income. Since the searching range is large and no other mechanism is in place to stir the market, agents just search for land that they can pay for and find their best spots within one step. Due to the pre-defined distribution of land price and job probabilities, rich people are more likely to occupy the center, while middle and low-income people are mixed and circled around the expensive inner square.

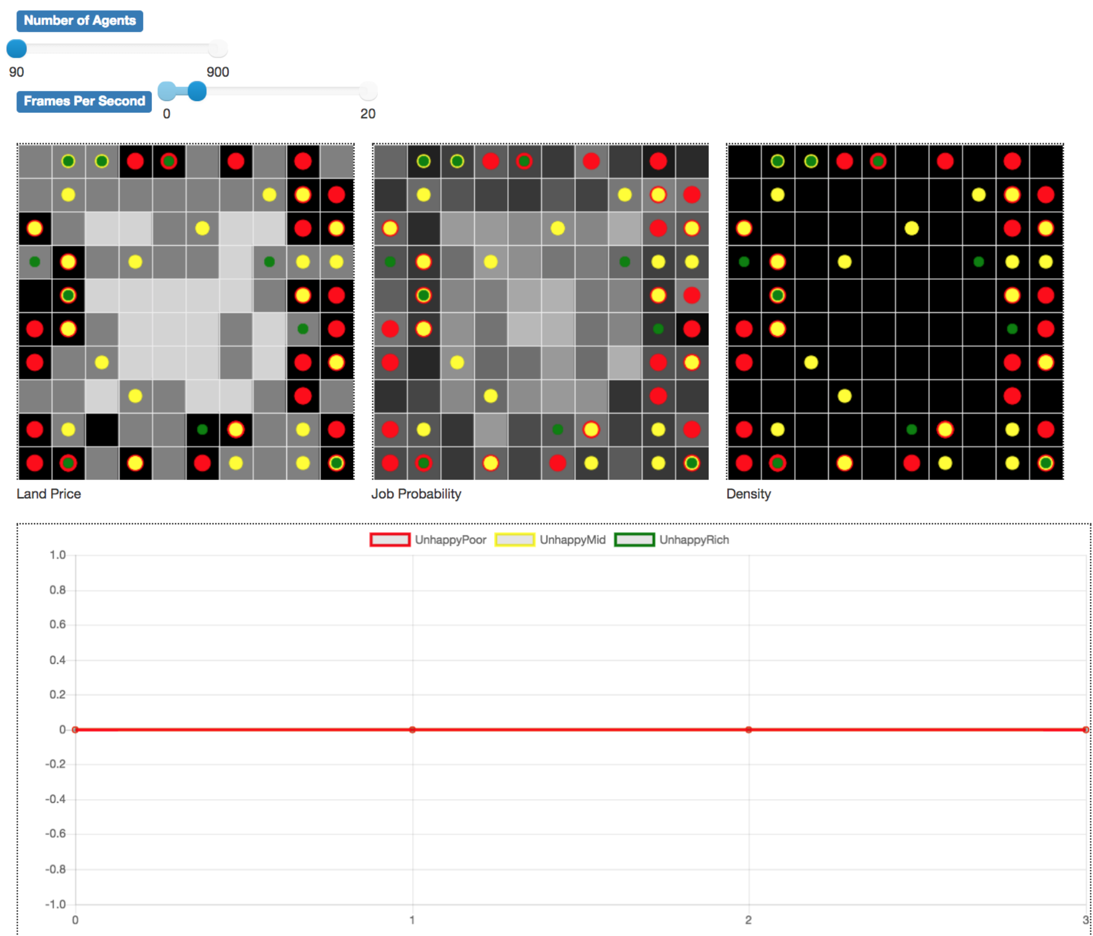

Figure 3: Model 1 with 90 agents. Noted that Job Probability and Density Canvas are disabled here because they do not factor into the model.

2) Model with Income, Job Probability, and Land Price Interaction

Adding job probability to the model destabilizes the interaction between income and land price and thus enables movements beyond one step. The visual outputs with a random selection of initial states are similar to those of model 1. However, in a long time, it is predictable that rich people (green dots) will tend to converge to the center since they can afford the price and enjoy higher stability of jobs.

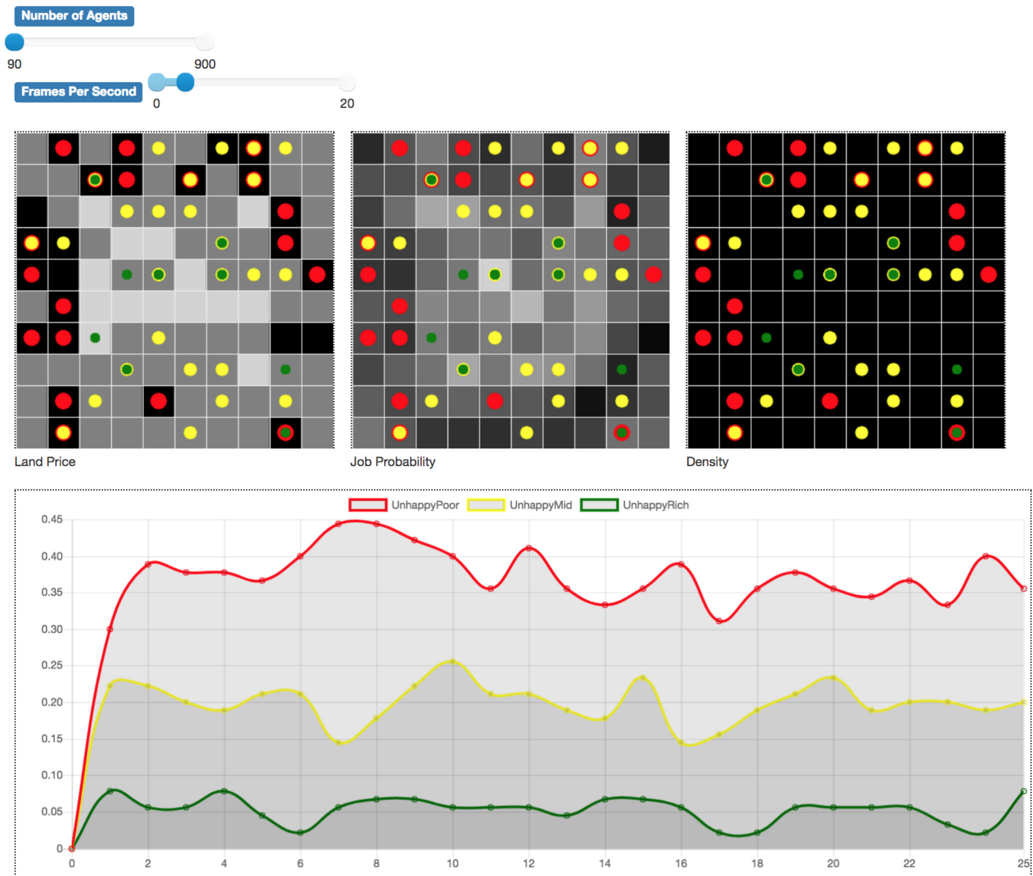

Figure 4: Model 2 with 90 agents. Noted that Density Canvas is disabled here because it does not factor into the model.

3) Model with Income, Density-sensitivity, Job Probabilities, Land Price Interaction

The original intention to add density-sensitivity as a criterion for happiness is to force rich people to move away from the city center though they can afford living there. This is an assumption in Burgess's concentric model and I decided to follow it for simplicity. Though now green dots (rich people) have more motivations to move away if overlaps with others, they still occupy the center of the city for two reasons. First of all, if the population is low, then they will happily occupy the center alone as no one else can compete with them, and 2) if the population is large, then they just have to keep moving as no vacant spots left. This alerts me to differentiate land price and housing price in the fourth model because the latter can be compensated with density, which is the strategy poor people use to afford to live at city centers (see Figure 5 and Figure 6).

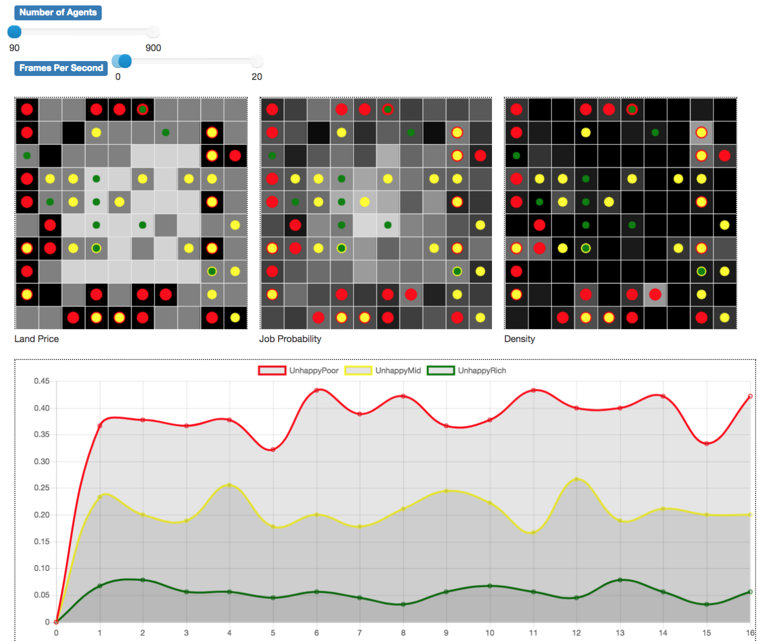

Figure 5: Model 3 with 90 agents.

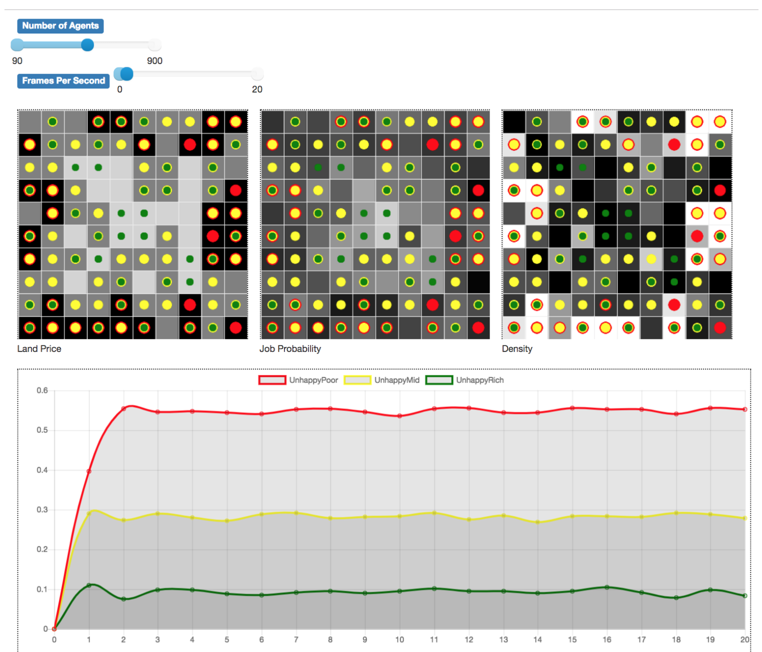

Figure 6: Model 3 with 504 agents.

4) Model with Income, Density-sensitivity, Job Probabilities, Land Price, and Housing Price Interaction

Housing price is calculated as Land Price divided by Density. In Figure 7 and 8 we can see that green dots (rich people) are definitely got pushed away from city center and red dots (poor people) can finally enter the city center using density to lower housing price for them. There is also a lot more overlap between green, yellow, and red, that is so much less spread compared with the third model that operationalize on the same number of agents. The reasoning for this phenomena is not investigated yet, and may just due to idiosyncrasies of initial states.

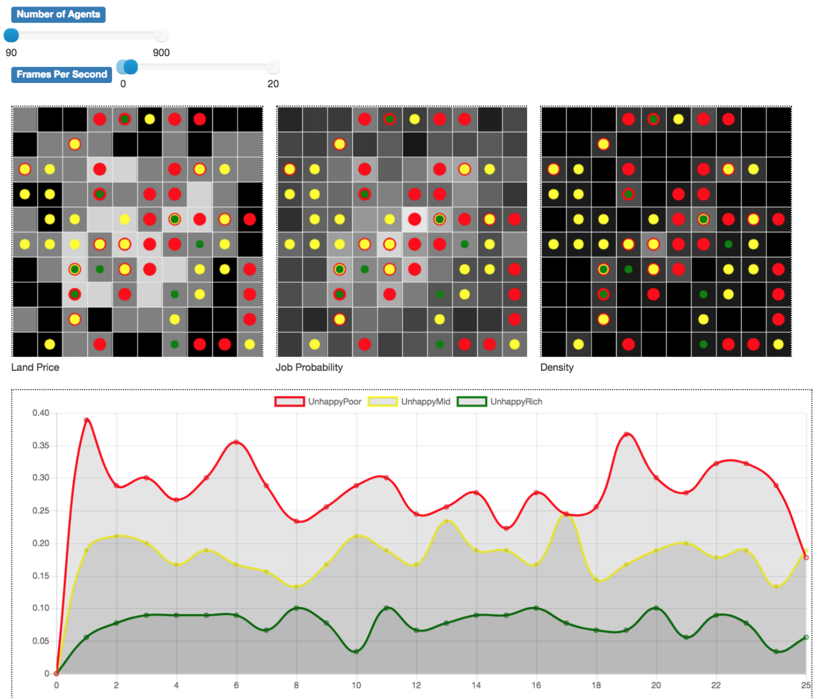

Figure 7: model 4 with 90 agents.

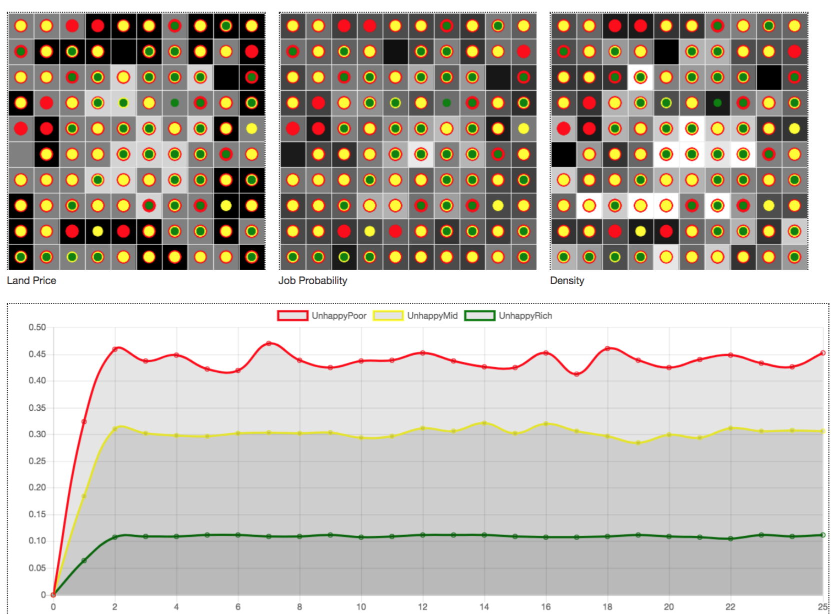

Figure 8: model 4 with 504 agents.