CX 4230 Project 3 Initial Report

Lawrence Moore, Rafael Blanes, Saleh Hamadeh

Introduction:

In the past 30 years, technological innovation reduced the prices of transportation and communication dramatically. This led to an increase in worldwide trade, which greatly expanded our economy. The increased economic activity transformed some countries and built cities where none existed before. For this project, we will simulate the economy and vitality of such a city. Ideally, we hope to understand how and why different starting conditions, such as the wealth and the disposition of its citizens, affect the overall prosperity. This information could be of great use to policy makers in identifying the effect of potential laws. Of course, several simplifying assumptions must be made. The rest of this report will detail the basic approach we will employ to bring the project down to the appropriate scale while retaining as much validity as possible.

Related Literature:

Creating a model of a city is hardly a new idea, and in the paper "Multi-agent simulations of residential dynamics in the city" by Itzhak Benenson, a thorough approach is presented. In this model, Benenson starts from the top down by breaking the city down into several categories and parts. He then models the local behavior of each agent, eventually leading to global behavior.

Agent based models were further extended by Joshua M. Epstein and Robert Axtell in their book *Growing Artificial Societies.* Those concepts were then compiled into a multi-agent dynamic system named Sugarscape, which was considered to be the first large scale agent model. In this simulation, the environment consists of a two dimensional grid populated by several agents. Those are supported by a set of rules that govern what sort of interactions can take place within each agent with other agent or/and with the environment. Regarding the environment, every cell can contain different amounts of sugar (or spice). In every step agents look around, find the closest cell filled with sugar, move and metabolize. They can leave pollution, die, reproduce, inherit sources, transfer information, trade or borrow sugar, generate immunity or transmit diseases - depending on the specific scenario and variables defined at the set-up of the model. One interesting idea that was included in this model was the notion that agents are able to modify the environment and lead to the creation of complex behavior originated from agent-agent interaction. Also, the notion of spice used by the author can be used in other scenarios to represent financial incentive, social willingness or any particular agent "preference".

On the other side of the spectrum, Helen Couclelis and M. Phipps developed urban simulation models that use a bottom-up approach. In their models, they based their simulations by using the local dynamics to create the global dynamics. In their pure forms, their models represented cells that transition between states based solely on the individual cell's attributes and neighbors.

In our model, we use techniques from both ends. We use a top-down approach in creating predetermined states and transitions for the cells. At the same time, we use a bottom-up approach by letting the local city dynamics affect each individual cell. By using elements of both research experiments, we hope that our experiment will produce a result that is not biased to its implementation.

Our Model: its assumptions and Simplifications:

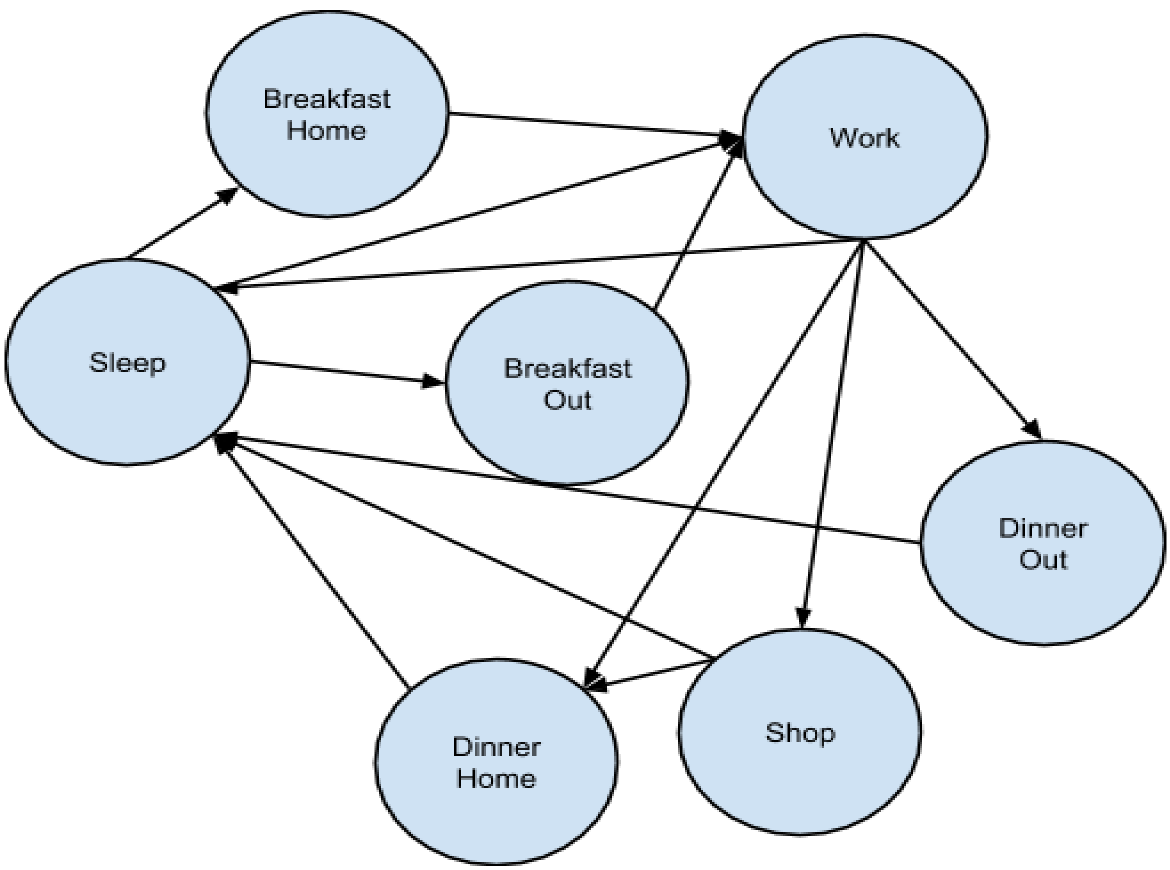
Like Benenson's, our simulation will be an agent-based model. Each individual will represent an agent, and the interaction between individuals and the rest of the city will dictate how the city progresses over time. Each agent will have its own basic needs and objectives, and these influences will govern how the agents interact. Also like Benenson's, we will break the city down into different types of areas. In our model, we will have four areas: residential, food markets, work sites, and entertainment / dining establishments. These areas will spread throughout the map to replicate an actual city, and within each area, the buildings can be distributed according to some distribution. Overall, we will be recreating Benonson's model, but on a smaller scale and with a few different assumptions about how the different constituents of the city interact.

Model of the Individual

Each individual will have three basic needs: food, shelter, and fun. Individuals will also have four attributes: skill, ambition, contentment, and preferred area of employment. To create a varied population, each person will have a different "personality," defined by the rate at which people respond to their basic needs over time and by their attributes. For instance, some individuals may be much more sensitive to boredom, while others place a nice home above everything else. To interact with the world, individuals need money. This is where the skill, ambition, contentment, and type of employment attributes come into play. Ambition dictates how much an individual wants money, and skill dictates how valuable they are at a job. Thus, the more skilled and ambitious the employee, the more likely they are to succeed at a company. In the model, there are five types of businesses: tech, sales, manufacturing, finance, and research. Preferred area of employment means that an individual performs better in certain types of jobs. The precise definition of "performs better" will be given later when the makeup of businesses in the model is discussed. Contentment dictates how likely an individual is to buy a new home or get a new job and is calculated according to a person's current financial state compared to their ambition.

Obviously, people are not immortal. There are two ways for people to die in the simulation. The first is of old age; the older a person, the more likely they are to die by some random illness. The other is if the individual is deficient in any of the basic needs for a certain period of time. The level of deficiency needed to kill an individual is determined by their personality. Individuals satisfy their basic needs by interacting with the four areas of the map. Going to work provides people with money and influences their happiness according to their preferred line of work. Buying food at stores gives individuals food and a moderate amount of joy depending on the quality of a store. By having a quality home, individuals are more sheltered.   By going to restaurants and entertainment stores, individuals can both reduce hunger and increase joy, but this is more expensive than just going to the grocery store.   When individuals reach a high enough contentment level, they will have kids. To avoid the complexity of modeling a family, we assume the child is produced through asexual budding of one individual. Until the child is 18 years old, he or she lives in the house of adult without working; extra food costs must be incurred. After that, the child moves out and lives their own life (the parent is thrilled of course).

Individuals also have a daily routine, dictated by their basic needs and preferences. The basic structure is shown below:



In the morning, everyone wakes. Then, they have the option of having breakfast at home, having it at a restaurant, or not at all. This depends on their current income. After this, they go to work. Once the workday is over, the individual will receive a daily income. Around dinner time, the individual may have dinner outside, go shopping, or go home. If he did not have dinner outside, he may either have dinner and sleep or not have dinner at all. These decisions are all dictated by a linear combination of their attributes and needs, where the weighting of each depends on their personality.

Model of the Business

As mentioned before, there are five types of companies: tech, sales, manufacturing, finance, and research. Further, individual companies have the following attributes: type, qualification level of work, pay, and number of employees. The initial net worth of a company can be estimated based on these four characteristics; The bigger the company and the more skilled the work, the more the company is worth. To be hired, an individual's skill level times his or her ambition must meet or exceed the qualification. Once hired, an individual performs better or worse depending on their personality. For instance, if the type of work and pay matches a person's preferences, the person will likely perform well, assuming his or her basic needs are met. To this effect, a score for each employee will be generated, which reflects how much the company and the employee match along with the employee's overall well-being. To evaluate the state of a company, we find the "productivity score", which is simply the summation of every employee's score. Then, based on the size and type of company, a benchmark score will be generated; if the productivity score exceeds this value, the company's net worth increases. Given a big enough increase, the company will expand by hiring new workers. In contrast, if the company consistently fails to meet the benchmark score, the company will lay off workers and eventually shut down. The workers pay is proportional to the networth of the company (the actual ratio will be estimated using data from real companies).

Residential Model

Residential areas occur throughout the map. The cost of houses can be easily estimated by the average net worth of the companies around it weighted by their distances. The better the jobs in the area, the more expensive the house. When people buy a home, they pay a mortgage on the house for the next 5 years with some interest (say 8%). If no houses are available, an individual can build their own if they have enough money, ambition, and skill. Houses will have two attributes: quality and price. The higher the quality, the greater the improvement to the individual's shelter and contentment. When an individual goes to buy a new house, three factors are taken into account: proximity to workplace, price, and quality. Depending on the personality, each factor takes on a different weight.

Model of Restaurants and Shops

The citizens of our beautiful city must relax and enjoy life, and the restaurant and shops district give them just that. After work, individuals will go to this section with a probability proportional to their need for fun, money, and personality. To measure the popularity of the area, each shop will have a capacity. If the capacity is consistently met, the size and number of the restaurants and shops will expand.

Clock

Time is handled in this model through a synchronous clock. If we refer back to the state machine above, we can see several natural break points. At each of these times of the day, behavior across the entire model will be synchronized. This allows for both a straightforward and natural way of handling time.

Map Generation

The initial setup of the city plays a central role in the simulation. So by using different distributions in generating the companies, restaurants, residential areas, and the individuals themselves, the outcome of the experiment will vary dramatically. There are two broad categories of experiments we intend to perform: generating random maps with the same group of individuals, and generating random groups on the same map. At least 3 distributions will be used: uniform, Gaussian, and exponential.

Implementation Outline

C: Implementation checkpoint 1: Friday, April 3 - create the barebones classes of the model. Namely, have the classes representing the individual and each component of the map mostly fleshed out. After this checkpoint, we should have a solid grasp on the challenges and scope of our implementation.

D: Implementation checkpoint 2: Friday, April 10 - connect everything from part C to give a basic model. This should be fairly intensive, as the model will have several working parts. Ideally, the software should be functioning at a basic level by the end of this milestone.

E: Implementation checkpoint 3 & preliminary results: Friday, April 17 - implement extra features and begin to run experiments as described in the conceptual model. Depending on time, we may be able to expand a great deal on the model, or hardly at all. If we really find ourselves with some time to spare, we will develop a basic visualization for the model, which will picture the map and give updates on the activity of the city as time progresses.

Part B: “The Plan” [Friday, March 27] — Submit via git repository
Your plan is a document that contains the following: a literature review, a conceptual model, and an implementation plan.

A literature review (or survey) is a short summary of work related to your project. This may include background papers or books about your topic, as well as any prior attempts (if any) to model or simulate your target phenomenon. You shouldn’t just list a bunch of papers and books related to the topic; you should try to synthesize this material by comparing and contrasting techniques or results, identifying gaps in prior work, or characterizing the work in an interesting and compelling way.

Your conceptual model should clearly state a) the problem you are modeling & simulating; b) who the (hypothetical) “customer” of your project is (besides us); and c) outline your modeling approach (a la Mini-Project 2). Since you will also have done a literature survey, you should relate your modeling approach to prior work — that is, are you replicating prior work? Adding a new twist? Taking a completely different approach?

Your implementation plan should outline the major goals for your implementation of parts C, D, and E. That is, what do you hope to accomplish at each of these checkpoints? You should also describe the simulation experiments you are planning, as well as what sources of data you would need (e.g., census reports and from where you expect to get it).

Submit a single PDF file containing your plan. As with Mini-Project 2, you should create a source code repository somewhere we can access it. (You can use Bitbucket as before, or you can switch to Github or any other service; but you need to tell us how to access it if you use something else.)

outside literature:

http://ccl.northwestern.edu/cities/.

http://www.opencity.info/.

http://sugarscape.sourceforge.net/

http://en.wikipedia.org/wiki/Sugarscape

http://www.stat.berkeley.edu/~aldous/Research/Ugrad/Bowen_Huang.pdf

http://www.pnas.org/content/99/suppl_3/7280.full - Why agent based models help to reduce computational complexity and allow for the creation of complex behaviors due to small interactions between agents i.e. the whole does not capture all

http://www.sciencedirect.com/science/article/pii/S0198971598000179 - Multi-agent simulations of residential dynamics in the city