Final Project Literature Review

CX 4230 - Dr. Rich Vuduc
Group 1 - Ausaf Ahmed
Liam Frank
Mudit Gupta
Rahul Katre

Modeling Flow of Pedestrians on GT Campus

For our topic, we want to simulate pedestrian traffic flow on campus at a microscopic scale, meaning that we would be simulating individual "students" moving between buildings. The students would be following a schedule, meaning that throughout the day they would travel between the buildings on campus, remaining at a building until the correct time. Using the simulation, one could identify points of congestion on campus, and how the students navigate around these points of congestion to reach their destinations. For microscopic modeling, we would use either cellular automata or particles in a vector field. With a generalized version of cellular automata, each cell would represent a student. The color of the cell would determine the destination building of the student. Once the student has reached the destination building, they would probabilistically change to a different color to indicate that they are heading to a new destination.

However, there are limitations to typical cellular automata models. One paper by Sarmady, Haron, and Talib talks about some of them, as well as ideas to work around them. Typical models have difficulties with smoother and accurate movements due to coarse grain discretization of space, in addition to limited choice of speed. The Fine Grid Model utilizes small cells, with pedestrians having varying shapes and sizes (i.e. a pedestrian would take up multiple cells versus a single cell). Transition rules and next cell calculations only consider a center cell, with collision avoidance considering all cells of the pedestrian. Also, typical models only have pedestrians moving at a normal speed until reaching an obstacle or another pedestrian. This model uses perception of density, where an individual pedestrian assesses the local density around them and picks a specific speed correlating to that density from an empirical speed-density graph. In addition, typical models make pedestrians move the same speed in cardinal and ordinal directions. However, the displacement is different for each type of direction, which can skew the actual distance covered in time moving diagonally. This model has the pedestrian select cells which give optimal speed values that produce the least error from a desired movement speed, capping the movements of each pedestrian in each second of the simulation if the combination of the movements results into a displacement bigger than the free flow speed of the pedestrian. By implementing these ideas, the cellular automata model is improved to act more realistically regarding position representation, movement, direction, and speed.

In their paper on human mobility patterns, Serok N. and Blumenfeld-Lieberthal E. explain their spatio-temporal agent-based simulation techniques. Though this technique was not exactly a cellular automaton, it used a map divided into thousands of small cells, each with a certain classification (residential, employment, entertainment, public space, etc). On this map, there would be many agents with a unique set of parameters including age, marital status, employment status, etc. These parameters would determine where each agent wanted to be at different times of day.

These simulation techniques are quite analogous to our goals of simulating pedestrian flow on GT's campus. Different parts of the map will be either part of a walkway, class building, residence building, or something else, and there will be many different students with unique schedules that determine where they want to go and when.

Another relevant detail from this paper is that different agents sometimes have non-routine destinations (going to an entertainment place at night), which may be analogous to GT students stopping somewhere to eat/study while waiting between/after classes.

With particles in a vector field, each particle would follow a vector field that directs them to their destination, but the presence of other nearby particles would affect their own field, meaning that areas of high congestion would naturally be avoided by newly arriving particles due to a large field surrounding the high congestion area pointing away from it. This is similar in concept to the social force model introduced by Helbing & Molnar [3] which describes how forces would model a person's motivations for certain movements, such as acceleration and velocity, keeping a distance from other pedestrians and borders, and being drawn towards other elements in the environment. In their paper, they found how a simulation following this model led to the creation of lanes based on walking direction, and people waiting for a doorway to be cleared by people going the opposite direction. Given that human behaviors can be observed using this model, it would be useful for modeling the movement patterns of students on campus without rigidly defining specific rules for movement.

Another model that could be used for our project is a queueing network, which was used by Løvås [4] to model pedestrian traffic in an evacuation simulation. In their paper, they simulated a building with multiple rooms and doorways, and a walkway network going through each doorway terminating at an exit node. Each room, represented by a node, has a capacity limitation, and each doorway has an "effective width" limiting the amount of people that can move through the door at a time step. The simulation tool they created, EVACSIM, models each person individually as a queueing network customer in order to incorporate things like reaction time and other human behavior. If we used a queuing network for our project, then in theory a network could be made from different patches of the environment, forming a graph upon which paths would be routes between buildings on campus. The capacity of each node would represent the number of people that could fit in that node, just as how the room capacity works in the evacuation simulator. The width parameter of connections between nodes would represent attributes like path width, which would limit the amount of students that could move between nodes. Paths in our graph would have to be bidirectional because not all people in the simulation would have the same destination. To incorporate things like schedules and other behaviors, we would also model each person individually.

References

1. A Simulation Model for Intra-Urban Movements. Serok, Nimrod & Blumenfeld-Lieberthal, Efrat. https://doi.org/10.1371/journal.pone.0132576
2. Simulation of Pedestrian Movements Using Fine Grid Cellular Automata Model. Sarmady, Siamak, Haron, Fazilah, & Talib, Abdullah Zawawi. https://doi.org/10.48550/arXiv.1406.3567
3. Modeling and simulation of pedestrian traffic flow. Løvås, Gunnar G. https://doi.org/10.1016/0191-2615(94)90013-2
4. Social force model for pedestrian dynamics. Helbing, Dirk & Molnar, Peter. https://doi.org/10.1103/PhysRevE.51.4282

Note: Lower pages are simply raw notes from each paper which will be used by us throughout our research & development process.
Current code progress: https://editor.p5js.org/muditg317/sketches/lOcxwj4fI

Paper 1: A Simulation Model for Intra-Urban Movements

Link to original source:
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0132576
PDF link:
https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0132576&type=printable
Copied file in Google Drive:
https://drive.google.com/file/d/1bdEu1TjldGYevyCZ71s309zdbNWroRJa/view?usp=sharing

Summary

- Uses cellular automata
  - Each cell is given a type (residential, employment, public space/building, etc)
- Also has different agents types
  - Student, employee, etc based on some parameters (age, marital status, etc)
  - Each agent has a unique set of locations they go - home, work/school, etc
- Destinations for agents are chosen based on time-of-day and probability (based on how far they are from their goal location - work/school/home)
  - Transportation mode is also based on their current location and destination
- There are also non-routine destinations (night club more likely for young adults than older people)
  - This is analogous to students stopping for lunch occasionally for our simulation
  - Some probability of different rest points (food/library/apartment/etc) between long gaps in classes
- We can record position history for certain particles and then log that information for nice visualizations after simulation
- Different locations on the map had different attractiveness
  - This can be analogous to different lunch/study spots

Is this applicable to our project? If yes, how will it be used? If not, why is it not useful?

Yes, this paper is definitely applicable because they not only have different location types throughout the map, but also different agent types with different goals. This ties in directly with our goals for having student particles, each with a unique schedule of which buildings to go to and when.

Paper 2: Social force model for pedestrian dynamics

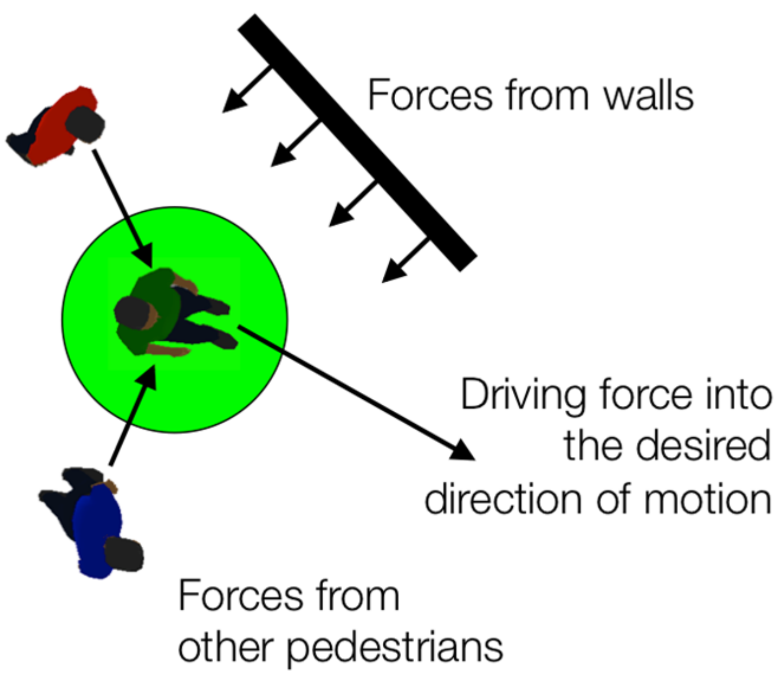
Link to original source: https://arxiv.org/abs/cond-mat/9805244
PDF link: https://arxiv.org/pdf/cond-mat/9805244.pdf
Copied file in Google Drive:
https://drive.google.com/file/d/1g-Los4sXZxtXwIWPjq_vrYWS5xskC4q9/view?usp=sharing

Abstract

It is suggested that the motion of pedestrians can be described as if they would be subject to 'social forces'. These 'forces' are not directly exerted by the pedestrians' personal environment, but they are a measure for the internal motivations of the individuals to perform certain actions (movements). The corresponding force concept is discussed in more detail and can be also applied to the description of other behaviors.

In the presented model of pedestrian behavior several force terms are essential: First, a term describing the acceleration towards the desired velocity of motion. Second, terms reflecting that a pedestrian keeps a certain distance to other pedestrians and borders. Third, a term modeling attractive effects. The resulting equations of motion are nonlinearly coupled Langevin equations.

Computer simulations of crowds of interacting pedestrians show that the social force model is capable of describing the self-organization of several observed collective effects of pedestrian behavior very realistically.



http://futurict.blogspot.com/2014/12/social-forces-revealing-causes-of.html (from author's blog)

Paper 3: Simulation of Pedestrian Movements Using Fine Grid Cellular Automata Model

Link to original source: https://arxiv.org/abs/1406.3567
PDF link:
https://arxiv.org/ftp/arxiv/papers/1406/1406.3567.pdf#:~:text=In%20regular%20cellular%20automata%20models,same%20body%20size%20and%20speed.
Copied file in Google Drive:
https://docs.google.com/document/d/1hbkcoAyjQH8URCUDAs7tv-YhynQjDx4gTwLz3xIUmMw/edit

Summary

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- Fine Grid Model utilizes small cells, with pedestrians having varying shapes and sizes (i.e. a pedestrian would take up multiple cells versus a single cell)
- Transition rules and next cell calculations only consider a center cell, with collision avoidance considering all cells of the pedestrian
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Is this applicable to our project? If yes, how will it be used? If no, why is it not useful?

Cellular automata has limitations, but this paper discusses how to get around some of them.

Paper 4: Modeling and simulation of pedestrian traffic flow

Link to original source: [put the link to the journal page thing for the article]
PDF link: [if available, a link to the pdf online or whatever]
Copied file in Google Drive: [make a copy of the pdf and put it in our drive folder and link here]

Abstract

Questions about the efficiency and safety of pedestrian traffic systems are of major importance in the planning and design of such systems. As the use of functional—or performance-based—requirements becomes more popular, there is also an increasing need for methods and tools which can be used to evaluate if these functional requirements are met. This article presents a stochastic model based on the following assumptions: Any pedestrian facility can be modeled as a network of walkway sections. Pedestrian flow in this network can be modeled as a queueing network process, where each pedestrian is treated as a separate flow object, interacting with the other objects. Such a microscopic model is useful because it makes detailed modeling of human behavior possible. This article also presents a simulation tool, of which the main objective is to estimate the relevant performance measures of the pedestrian traffic system. The article includes two examples.

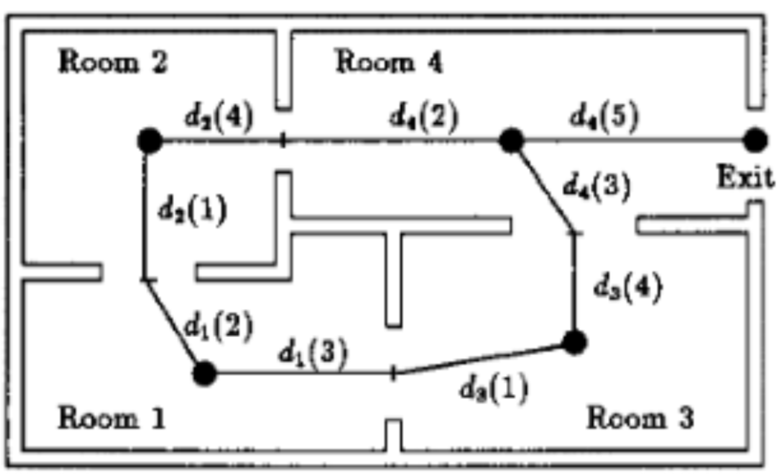

Fig. 4. A building with its walkway network.