CSE6730/CX4230
Project Checkpoint 1

Tusheet Goli, Matthew Dacey-Koo, Tushna Eduljee, Aarun Srinivas

Question 1

Abstract

In this project, we model traffic flow at Georgia Tech using campus road networks as they currently stand. This simulation will allow users to adjust various parameters such as traffic flow while putting in place terrain-changing obstacles such as road blockades and intersection shutdowns which alter traffic flow. Previous attempts at charting automobile routes around campus include PassioGO and GT Buses (which both map GT bus routes in real time). While these help students navigate campus, a key challenge is smoothly navigating all road traffic around campus even under perturbations that change traffic patterns. As such, traffic patterns under perturbation can be observed and used to identify pain points in the campus road networks for city planning in the future. The conceptual model that we plan to use to model this system is a cellular automaton where cars and traffic lights affect their surroundings at each timestep.

System Description

The system that we are modeling includes all Georgia Tech campus roads where automobiles such as cars and trucks can drive. This ranges from the intersection between North Avenue and Techwood Drive in the South East to the intersection of Curran Street and 14th Street in the North West. It is important to know that all Georgia Tech bus routes are also contained within this perimeter. These are the roads upon which we will visualize all traffic through campus. As our simulation is meant for use in redirecting traffic given perturbations in regular flow (such as intersection blockages or road closures), the system will feature all of the same road rules as those present in the real world. This includes all the same traffic patterns due to features such as one-way streets or limited turning lanes. Our system also includes traffic lights, important road signs (ie. stoplights), and speed limits - sourced thru Google Maps and Waze APIs - for all streets within the perimeter.

Conceptual Model

We plan to construct a conceptual model of Georgia Tech's road system by utilizing a series of lane and traffic light objects. The lane object will be implemented as a Python class and will contain a queue that will be used to keep track of all the cars currently driving on the lane. The traffic light object will also be implemented as a Python class and will be used to connect lanes coming from different directions together and direct traffic through their intersection. In addition to keeping track of the cars present in the lane, the lane object will also contain a variable that can be set to close it off as well as a variable that can be set to determine the direction of traffic in the lane. The capacity of the lane will be calculated using the lane's distance which will be determined upon instantiation and each car's length that is present on the lane. In a sense, this model of Georgia Tech's road system which uses lane and traffic light objects functions as a cellular automaton. This is because the movement of a car is directly dependent on its neighbors. In particular, if one car is located in front of another car, the back car's speed is dependent on how fast the front car is moving. Furthermore, as more cars join the lane, they will be affected by the cars in front of them. In addition to cars affecting the speed of surrounding cars, traffic lights can also affect surrounding cars. Thus, the combination of cars influencing other cars at each time step as well as traffic lights influencing cars makes this a cellular automata model. It is however important to note that although this cellular automata model appears deterministic, most of the cars present on the road system do not behave deterministically as they sometimes will randomly speed up or slow down. Thus despite its appearance, there is some stochasticity present when talking about how cars affect other cars' speed.

Platforms of Development

As our project is specifically focused on Georgia Tech, we want to create a tool that both accurately represents the system and is easy to use for clients without background knowledge of the project. For this, we will use a combination of d3.js for front-end data visualization and python for back-end data processing. This choice was made because d3 is a powerful tool for interactive visual models, but it doesn't have the same data processing power that python does.

Front End

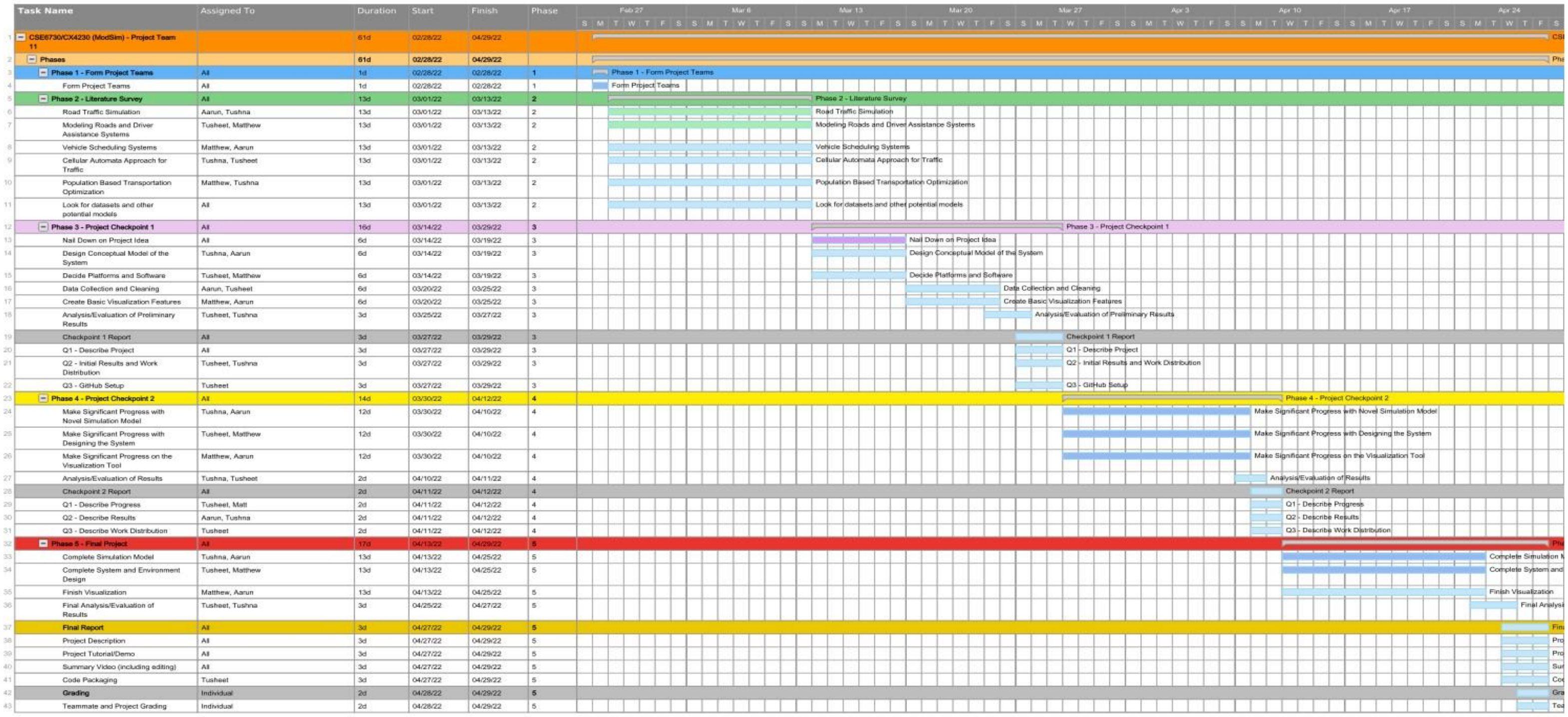
The front end will be an HTML page that hosts the d3 visualization. With HTML, we can make the page interactive, so the user can select different parameters such as time of day, whether there's a football game, freshmen move-in, and more. The d3 code will be used to create the visualization, likely a top-down view with coloring to signify chokeholds or free-moving traffic. To talk with the python backend, we'll make use of a Flask app and the Jinja template.

Back End

With a definite Flask application, we will be able to pull parameters from the site using Flask's "request" function. Using this, the application will process using our functions defined to represent the model and return data to the page in a JSON format.

These platforms were partially selected because we have experience with all of them, so we should be able to complete our goals without having to learn a completely new framework, accelerating progress.

Question 2



	Task Name	Assigned To	Duration	Start	Finish	Phase
1	CSE6730/CX4230 (ModSim) - Project Team 11		61d	02/28/22	04/29/22	
2	Phases		61d	02/28/22	04/29/22	
3	Phase 1 - Form Project Teams	All	1d	02/28/22	02/28/22	1
4	Form Project Teams	All	1d	02/28/22	02/28/22	1
5	Phase 2 - Literature Survey	All	13d	03/01/22	03/13/22	2
6	Road Traffic Simulation	Aarun, Tushna	13d	03/01/22	03/13/22	2
7	Modeling Roads and Driver Assistance Systems	Tusheet, Matthew	13d	03/01/22	03/13/22	2
8	Vehicle Scheduling Systems	Matthew, Aarun	13d	03/01/22	03/13/22	2
9	Cellular Automata Approach for Traffic	Tushna, Tusheet	13d	03/01/22	03/13/22	2
10	Population Based Transportation Optimization	Matthew, Tushna	13d	03/01/22	03/13/22	2
11	Look for datasets and other potential models	All	13d	03/01/22	03/13/22	2
12	Phase 3 - Project Checkpoint 1	All	16d	03/14/22	03/29/22	3
13	Nail Down on Project Idea	All	6d	03/14/22	03/19/22	3
14	Design Conceptual Model of the System	Tushna, Aarun	6d	03/14/22	03/19/22	3
15	Decide Platforms and Software	Tusheet, Matthew	6d	03/14/22	03/19/22	3
16	Data Collection and Cleaning	Aarun, Tusheet	6d	03/20/22	03/25/22	3
17	Create Basic Visualization Features	Matthew, Aarun	6d	03/20/22	03/25/22	3
18	Analysis/Evaluation of Preliminary Results	Tusheet, Tushna	3d	03/25/22	03/27/22	3
19	Checkpoint 1 Report	All	3d	03/27/22	03/29/22	3
20	Q1 - Describe Project	All	3d	03/27/22	03/29/22	3
21	Q2 - Initial Results and Work Distribution	Tusheet, Tushna	3d	03/27/22	03/29/22	3
22	Q3 - GitHub Setup	Tusheet	3d	03/27/22	03/29/22	3
23	Phase 4 - Project Checkpoint 2	All	14d	03/30/22	04/12/22	4
24	Make Significant Progress with Novel Simulation Model	Tushna, Aarun	12d	03/30/22	04/10/22	4
25	Make Significant Progress with Designing the System	Tusheet, Matthew	12d	03/30/22	04/10/22	4
26	Make Significant Progress on the Visualization Tool	Matthew, Aarun	12d	03/30/22	04/10/22	4
27	Analysis/Evaluation of Results	Tushna, Tusheet	2d	04/10/22	04/11/22	4
28	Checkpoint 2 Report	All	2d	04/11/22	04/12/22	4
29	Q1 - Describe Progress	Tusheet, Matt	2d	04/11/22	04/12/22	4
30	Q2 - Describe Results	Aarun, Tushna	2d	04/11/22	04/12/22	4
31	Q3 - Describe Work Distribution	Tusheet	2d	04/11/22	04/12/22	4
32	Phase 5 - Final Project	All	17d	04/13/22	04/29/22	5
33	Complete Simulation Model	Tushna, Aarun	13d	04/13/22	04/25/22	5
34	Complete System and Environment Design	Tusheet, Matthew	13d	04/13/22	04/25/22	5
35	Finish Visualization	Matthew, Aarun	13d	04/13/22	04/25/22	5
36	Final Analysis/Evaluation of Results	Tusheet, Tushna	3d	04/25/22	04/27/22	5
37	Final Report	All	3d	04/27/22	04/29/22	5
38	Project Description	All	3d	04/27/22	04/29/22	5
39	Project Tutorial/Demo	All	3d	04/27/22	04/29/22	5
40	Summary Video (including editing)	All	3d	04/27/22	04/29/22	5
41	Code Packaging	Tusheet	3d	04/27/22	04/29/22	5
42	Grading	Individual	2d	04/28/22	04/29/22	5
43	Teammate and Project Grading	Individual	2d	04/28/22	04/29/22	5

The chart is also available on our team's GitHub repository - https://github.gatech.edu/tgoli3/gt-modsim-s22-team11/blob/main/charts/Gantt%20Chart.jpg

Division of Labor

We have created a detailed Gantt chart to showcase all the progress we have made for this project and the task we plan on completing for the upcoming checkpoints with appropriate due dates and members assigned.

For a brief summary, we have divided the entire project into five phases based on the five deliverable deadlines for the project. Please refer to the Gannt chart for more details.

Phase 1 - Form Project Teams (Done)

Phase 2 - Literature Survey (Done) - Gantt chart shows work distribution for the assignment

Phase 3 - Project Checkpoint 1 - Includes finalized project idea, conceptual model, platforms/software of development, and initial data cleaning and collection. All these tasks have been equally split up among the team members.

Phase 4 - Project Checkpoint 2 - Includes tasks that make significant progress on items from checkpoint 1 as well as better analysis and evaluation of preliminary results. All these tasks have been equally split up among the team members.

Phase 5 - Final Project - Includes tasks that culminate progress and efforts from previous phases to deliver a complete project with a project report (with final results and analysis), tutorial/demo, and code packaging. All these tasks have been equally split up among the team members.

Project Direction Changes

We have not diverted the broad idea behind our project, i.e. analysis of traffic and road systems. During this project checkpoint, we have successfully been able to streamline our main idea and add a novelty aspect to our project to distinguish it from previous works. We have also come up with a proper plan by tasking each of our project phases effectively to produce a complete and novel project. Hence, we have successfully narrowed down our idea from our original proposal to effectively produce a novel and well-done project.

Project Progress

As you can infer from our answers to part 1 of this report, we have a well-thought-out novel project idea with sufficient resources, datasets, research, and inspiration material. We made good progress at narrowing down and streamlining our idea to ensure novelty as well as making sure it is doable and fits within the scope of this class. We have nailed down our conceptual model and platforms/software that we are going to use for this project. We have also collected datasets and APIs that we are potentially going to use for the traffic simulation.

Simulation Resources:

- https://traffic-simulation.de/
- https://github.com/iMinichrispy/GT-Buses
- https://www.anylogic.com/road-traffic/

Datasets/APIs:

- https://www.itsmarta.com/app-developer-resources.aspx
- https://gtbuses.herokuapp.com/
- https://www.kaggle.com/code/muonneutrino/wikipedia-traffic-data-exploration

These resources are in addition to what we had found and collected from the literate survey assignment. We now have a proper project idea with all the resources and data/APIs to help us perform our simulation. In the upcoming checkpoint 2 assignment, we plan on coding out a good portion of the fundamental system, models, and visualization/simulation to produce preliminary results based on the visualization tool.

Question 3

Link to GitHub Repository - https://github.gatech.edu/tgoli3/gt-modsim-s22-team11
Repository Permissions - Private Repository
Collaborators - Tusheet Goli (Team Member), Tushna Eduljee (Team Member), Matthew Dacey-Koo (Team Member), Aarun Srinivas (Team Member), Rich Vuduc (Professor), and Takahiro Furuya (TA)
Initial Upload - Has README, gitignore, and all submitted deliverables for the various project phases (in the documents folder)

Literature Review - Group 11

Project Overview: Our team is planning on working on a project that is trying to simulate road behaviors like traffic, merging, etc. For this literature review, we wanted to keep our literature search broader by expanding this to other services like trains, metro systems, bus services, etc. Our goal through this modeling and visualization is to better understand the usage patterns of such services and aim to optimize these networks based on the models we create.

1. The paper titled “Trends in Real-time Traffic Simulation” discusses the various types of software tools that are being used to model traffic. Specifically, the paper analyzes 17 different traffic simulation software tools to determine the shortcomings and strengths of traffic simulation software as a whole. From its analysis, the paper comes to the conclusion that traffic simulation software still is unable to simulate the conditions present on complex heterogeneous road requirements due to the fact that it cannot identify patterns when presented with a small amount of real-time data. From this paper, we have identified several tools that could aid us in the development of our application. Specifically, the traffic simulation software tools Quadstone Paramics and SITRA-B+ might serve as good sources of inspiration for our project.

2. Another paper that offers some insights that could be utilized in our project is titled “Traffic Simulation Modeling of Rural Roads and Driver Assistance Systems.” It discusses how microscopic traffic simulations can be used to analyze different road systems. Specifically, the paper attempts to utilize this simulation technique to analyze traffic present on rural roads and how driver assistance systems can affect traffic. The primary contribution this paper makes to the field of traffic simulation modeling is a simulation called RuTSim which stands for Rural Traffic Simulator. In particular, the paper utilizes RuTSim to simulate traffic present on a Swedish two-lane rural road and on a Dutch two-land rural road. In the chance that we would like to construct a model to describe a phenomenon that does not have much data, the ideas proposed in this paper could be very beneficial in that they can help serve as a starting point.

3. Unlike other papers which have worked to simulate traffic in the 2D space, the paper titled “Continuum Traffic Simulation” attempts to simulate traffic in the 3D space. Specifically, it attempts to provide a more accurate simulation of traffic in the real world in a fast and efficient way by describing the movement of several vehicles in a single computational cell. The paper further proved that its approach was much more efficient than state-of-the-art 3D simulation methods. This paper provides us with an idea of how to go about tackling 3D simulations in a fast and efficient way. Thus, the main idea presented in this algorithm which is approximating real traffic by describing the movement of several vehicles in a single computational cell could serve as a good starting point when constructing our own model of how traffic behaves.

4. The paper titled “Population-based simulation optimization for urban mass rapid transit networks” can help us in our simulation model for our project. Depending on whether we decide to look into metro rail-based transportation or road traffic, we can incorporate some hypothetical future population-based work into our simulation. This could be helpful if we are motivated to focus on the city of Atlanta for our simulation. We could propose a way to create more efficient rail, bus, or roadways for our city based on some of the ideas for population-based simulation optimization discussed in this paper.

5. Wang et al. create multiple different models and compares them to data collected in China over a 10-month span. The researchers created the following models: Linear Regression, Spatial Lag, Spatial Error, and Time-Fixed Effects Error. To create these models, they consider both spatial and temporal features, creating equally-sized traffic analysis zones (rectangles for grouping data for analysis). The researchers found that the time-fixed effects error model, one that considers both spatial and temporal effects to be superior. From this, our group has identified a few models that we can pursue in our own research of traffic, along with possible inspiration for methodology.

6. This link is a grouping of various resources used for a class on transportation at the University of Lisbon. Similarly, it provides many examples of models used to analyze various forms of transportation, for which our team can take inspiration to apply to our own individual topics. The methods and models listed are as follows: Multiple Linear Regression, Factor Analysis, Cluster Analysis, Generalized Linear Models, Panel and Spatial Regression Models, Discrete Choice Models, Ordered Models, Hazard-Based Duration Models.

7. Andrade-Michael et al. take a look at the bus vehicle and reliable driver scheduling problem. It attempts to take two NP-Hard problems - the Vehicle Scheduling Problem and Crew Scheduling Problem, and proposes an exact constraint programming model that is claimed to greatly improve efficiency when considering the reliability of drivers. This paper could be very useful if our team ends up pursuing research on local transportation systems like those of Marta or Georgia Tech. It’d be useful to utilize the proposed model and apply it to our local systems to determine where improvement could be made.

8. The paper titled “Modeling and simulation of highway traffic using a cellular automaton approach”. If we do in fact aim to solve a traffic flow-related problem with our simulation, then we can utilize this paper to understand how cellular automata can be applied to simulate a traffic flow-related problem. Something like this can be helpful for us in describing the influence of a car accident in single-lane vs double-lane traffic flow models. Although this research project implemented the code in Matlab, we may use similar ideas to understand how to structure our inquiry in the space.

References

Andrade-Michel, A., Ríos-Solís, Y. A., & Boyer, V. (2021). Vehicle and reliable driver scheduling for public bus transportation systems. Transportation Research Part B: Methodological, 145, 290–301. https://doi.org/10.1016/j.trb.2021.01.011

Ding, D. (2011). Modeling and simulation of highway traffic using a cellular automaton approach.

Modelação da Procura de Transportes. Tecnico Lisboa. https://fenix.tecnico.ulisboa.pt/disciplinas/MPTra/2020-2021/1-semestre/materiais-de-apoio

Pell, Andreas & Meingast, Andreas & Schauer, Oliver. (2017). Trends in Real-time Traffic Simulation. Transportation Research Procedia. 25. 1477-1484. 10.1016/j.trpro.2017.05.175.

Schmaranzer, David & Braune, Roland & Doerner, Karl. (2020). Population-based simulation optimization for urban mass rapid transit networks. Flexible Services and Manufacturing Journal. 32. 10.1007/s10696-019-09352-9.

Sewall, J., Wilkie, D., Merrell, P., & Lin, M. C. (2010, May). Continuum traffic simulation. In *Computer Graphics Forum* (Vol. 29, No. 2, pp. 439-448). Oxford, UK: Blackwell Publishing Ltd.

Tapani, A. (2008). Traffic Simulation Modelling of Rural Roads and Driver Assistance Systems (Ph.D. dissertation, Linköping University Electronic Press). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-12428

Wang, W., Yuan, Z., Yang, Y., Yang, X., & Liu, Y. (2019). Factors influencing traffic accident frequencies on urban roads: A spatial panel time-fixed effects error model. PLOS ONE, 14(4). https://doi.org/10.1371/journal.pone.0214539