Multi-Agents System Project

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Public Transport Mobility Simulation

Group Members:

Samar HAMDI
samar.hamdi@edu.univ-eiffel.fr

Nadine Elleuch
nadine.elleuch@edu.univ-eiffel.fr

Yosr MOALLA
yosr.moalla@edu.univ-eiffel.fr

Project Supervisor

Dr. Linda BELKESSA
Researcher, Univ Gustave Eiffel

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Chapter 1

Introduction

In metropolitan settings, public transit is essential to people's everyday commutes. The effectiveness and dependability of public transportation networks are being tested more and more as cities continue to expand. We can gain a better understanding of how public transportation systems function both normally and during disruptions by simulating the behavior of both passengers and vehicles.

Our goal in this project is to create and put into use a multi-agent system that mimics how people and public transportation move across a metropolis. Roads and bus stops make up the grid that represents the city, and the agents are in charge of walking or taking public transportation between areas.Public transportation vehicles adhere to set routes and schedules, and passengers are assigned precise starting and destination sites inside the city.

This simulation's primary goal is to simulate how disruptions, like traffic jams or car accidents, affect travel times and passenger experiences. By introducing these disruptions into the system, we can see how they impact the transit system's overall effectiveness and pinpoint possible areas for development.

The simulation's design and implementation are described in depth in this study, which then analyzes the effects of several disturbances on the transportation system.

Chapter 2

Agents and City Definition

2.1 Inputs of the Model

The simulation model is driven by several key inputs:

2.1.1 City Layout

- The city, which is depicted as a 10x10 grid, has a number of bus stations where people can get on buses. In order to replicate the movements of both passengers and vehicles (buses), the city plan is essential.
- Although it is not yet covered in the code, the grid structure also takes into account possible disturbances, such as traffic jams or roadblocks.

2.1.2 Public Transport Routes:

- The buses have predefined routes, represented as sequences of grid coordinates that the buses follow to pick up and drop off passengers. For example, bus1 follows the route [(1, 0), (2, 7), (3, 9), (5, 9)], and bus2 follows a different route [(2, 2), (1, 5), (0, 8), (5, 1)].

2.1.3 Passengers Behavior

- Passengers are added randomly to the simulation at each step, each having a starting position and a destination. Passengers will either walk or use the buses to reach their destinations.
- Passengers attempt to minimize their travel time, considering both walking distances and waiting times for buses, though this heuristic is simplified in the code.

2.2 Communication Between Components

- **Passenger-Vehicle Interaction:** Although the current solution reduces this to just adding a passenger at each simulation step, passengers board buses at bus stops based on their positions and destination. Passengers waiting for buses to arrive at bus stops represent the interaction between passengers and vehicles.
- **Passenger-Environment Interaction:** Passengers can also move around the grid, avoiding obstructions or disruptions. If public transportation is unavailable or not the best option, they use the roads to go to bus stations or to their destination.

- **Vehicle-Environment Interaction:** Buses pick up passengers at designated bus stops and adhere to the road network. Their speed and arrival timings may be impacted by road construction, traffic jams, or other impediments.

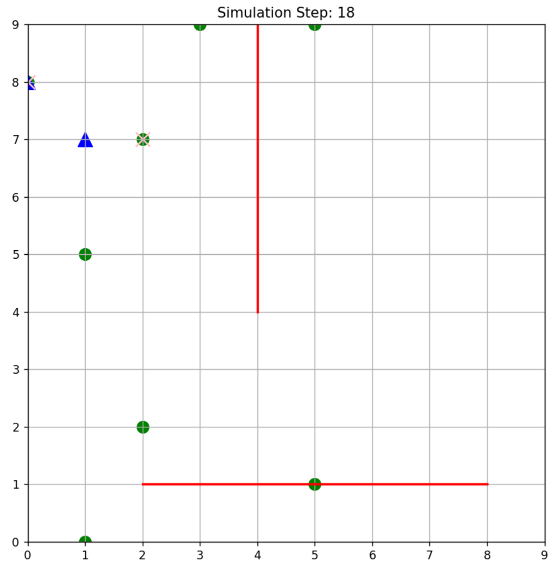


Figure 2.1: Example of Implementation

The city environment and agents in our transportation simulation model were described in this chapter. The city is a two-dimensional grid with roads, bus stops, and open spaces. The agents of passengers and vehicles interact within this grid to simulate real-world transportation dynamics, with passengers trying to reduce travel time and vehicles adhering to predetermined routes and schedules. The interactions between agents and their environment, such as managing disturbances, give the simulation realism, which enables us to effectively explore and analyze urban transit scenarios.

Chapter 3

Simulation

3.1 Rationale Behind the Formulation

The necessity to use an agent-based model (ABM) to simulate the dynamics of urban transportation is the main reason for the model formulation that was selected. The model's main components, such the grid layout and bus routes that are predetermined, enable:

- **Simplicity and Modularity:** he approach is simple to implement and test, allowing for easy debugging and incremental feature addition (e.g., handling passenger behavior, adding disturbances).
- **Scalability and Adaptability:** The grid-based model is scalable, and the agents can easily be expanded or modified for more complex behaviors.
- **Realism:** Even though disturbances are not fully modeled yet, having a flexible structure means they can be added in future iterations to simulate real-world complexities like traffic delays, accidents, or road closures.

3.2 Performance Evaluation

The simulation offers a baseline assessment of the transportation system's effectiveness in the absence of disturbances:

3.2.1 Passenger Metrics:

- This refers to the amount of time each passenger takes from boarding the bus to reaching their destination. This time includes all factors such as waiting time, travel time, and possible delays due to traffic or blocked routes.
- This is calculated as the average number of steps taken by all passengers who completed their journey. It provides insight into how long passengers typically take to reach their destination within the simulation.

3.2.2 Total Throughput:

- The entire number of passenger movements (boarding and disembarking events) in the simulation is referred to as the total throughput. This figure covers every time a traveler gets on and off a bus.

- It's critical to differentiate this figure from the total number of passengers because if passengers board and disembark more than once during the simulation, throughput may be higher. Every traveler successfully finished their journey if this number matches the total number of unique passengers.

3.2.3 Average Grid Utilization:

- This measure shows the proportion of the grid (city plan) that was in use, including bus stops, passengers, obstructed routes, and occupied bus stops.
- By comparing the number of grid cells occupied by buses, passengers, and obstructed routes to the overall grid size, the grid utilization is determined.

3.2.4 Total Number of People Transported:

- This is the number of travelers who have made it all the way from the beginning to the end.
- It indicates that every passenger who embarked on their journey has arrived at their destination without any problems if the number corresponds to the total throughput. Since this should ideally match the total number of passengers transported, a greater number could indicate a computation problem.

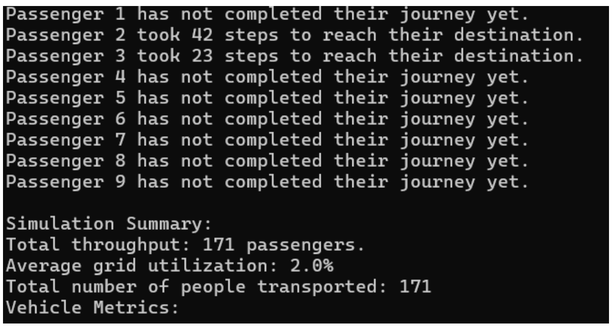
3.2.5 Vehicle Metrics:

Total Bus Stops Served:

- This determines how many different bus stops the busses visited overall during the exercise.
- The total number of bus stops covered and the bus routes used should equal this value. A higher number can suggest a high density of bus stops or frequent route adjustments.

Total Passenger Loads:

- This is the total number of people that busses picked up throughout the experiment.
- The entire number of distinct passengers picked up by buses should be reflected in this value. This figure may be greater if passengers board different busses on a regular basis. The total number of passengers serviced during the simulation is represented by the value.



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Passenger 1 has not completed their journey yet.
Passenger 2 took 42 steps to reach their destination.
Passenger 3 took 23 steps to reach their destination.
Passenger 4 has not completed their journey yet.
Passenger 5 has not completed their journey yet.
Passenger 6 has not completed their journey yet.
Passenger 7 has not completed their journey yet.
Passenger 8 has not completed their journey yet.
Passenger 9 has not completed their journey yet.

Simulation Summary:
Total throughput: 171 passengers.
Average grid utilization: 2.0%
Total number of people transported: 171
Vehicle Metrics:
```

Figure 3.1: Example of Metrics

Chapter 4

Disturbance

Disturbances play a critical role in urban transit systems, representing real-world challenges such as traffic congestion, roadblocks, accidents, and construction. These events disrupt the normal flow of traffic and impact the movement of both passenger and vehicle agents, making them an essential component of any realistic transportation simulation. This section elaborates on how disturbances are modeled and their implications for the simulation.

4.1 Type of disturbances

- **Traffic Congestion:**Represents regions where traffic congestion results from a vehicle density that is higher than the capacity of the road. It affects the efficiency and speed of the vehicle, which causes delays in the pickup and transfer of passengers.

- **Accidents:**Sudden, unexpected events that block roads or intersections, impeding traffic flow.Vehicles and passengers may need to be rerouted due to accidents, which may lengthen wait times.In order to simulate their effect on agent movement, these occurrences are also shown on the grid as blocked cells.

- **Unforeseen Events:** Incorporate significant disturbances like bad weather or city-wide activities.Both passenger and vehicle behavior are impacted by these unforeseen disruptions that occur across various forms of transportation. Unexpected events that impair grid cell accessibility in impacted areas, such as blocked roads, are generalized in the simulation.

The simulation concentrates on the results of disruptions rather than the intricacy of modeling their precise origins because disruptions are universally represented as stopped highways and they appear randomly all over the city grid. This abstraction offers a precise framework for examining how agents adjust to difficulties and how this impacts the functionality of the system as a whole.

4.2 Agent Behavior in Response to Disturbances

4.2.1 Passenger Agents:

Decision-Making:

- In order to reduce their overall trip duration, passenger agents dynamically assess the situation.

- They can choose different bus stops with less traffic or walk straight to their destination if public transportation is delayed.
- Bus arrival times, the proximity of disruptions, and their effect on routes are among the variables that passengers evaluate.

Adaptive Walking Patterns:

- By altering their walking routes to avoid grid cells that are impacted by disruptions, passengers can increase their journey distance while decreasing overall delays.

Waiting Behavior:

- If the delay reaches a particular point, passengers at bus stops may choose to wait for buses that are delayed or to give up on the wait completely.

4.2.2 Vehicle Agents:

Rerouting:

- In order to avoid obstructed or crowded cells, vehicles dynamically modify their routes within the grid.
- When roads are closed, cars take the shortest other route, which could lengthen the time passengers travel time.

Capacity Management:

- Vehicles may experience increased passenger demand at stops during delays, possibly surpassing their capacity and forcing some passengers to wait for the next bus.

Schedule Adaptation:

- Although vehicles make an effort to stick to schedules, disruptions have an impact. Extended delays could have a domino effect on other stops and routes.

4.3 Interaction of Agents with Disturbances

4.3.1 Passenger-Vehicle Interaction:

- While vehicles modify stop durations to handle increased demand due to congestion, passengers modify their boarding decisions in response to vehicle delays.
- When a vehicle finds itself blocked on the road, the passenger will choose to get off and go by himself to another stop or to his destination.
- Because both agents respond constantly to changes in circumstances, the interaction shows bottlenecks at bus stops during disruptions.

4.3.2 Passenger-Environment Interaction:

- Passengers choose routes that minimize overall travel time while taking into account delays as they avoid disruptions such as accidents or road construction.
- During disruptions, passenger strategies are influenced by the proximity of alternate routes or bus stops.

4.3.3 Vehicle-Environment Interaction:

- Automobiles maneuver past or around obstructions and crowded locations, which can slow down traffic flow in general.
- Vehicles dynamically adjust their routes in response to disturbances by employing Dijkstra's shortest path algorithm. This allows them to identify and follow the most efficient alternative path to their destination.
- In severe cases, cars could have to stop completely until the disruption passes, which would result in a buildup of delays.

4.4 Impacts on the Simulation

- **Increased Travel Times:** Delays affect both vehicle and passenger agents, which lowers the transportation network's overall effectiveness.
- **Adaptive Efficiency:** By dynamically modifying their actions, such as rerouting or selecting different modes of transportation, agents demonstrate resilience and somewhat lessen the impact of disruptions.

By simulating disruptions as blocked roads, real-world issues like traffic jams and collisions are captured and their effects on urban transit networks are highlighted. Important problems like longer journey times, clogged bus stops, and emerging traffic patterns were exposed by the simulation. These effects were lessened by solutions such as adaptive passenger choices, vehicle schedule modifications, and dynamic rerouting utilizing Dijkstra's algorithm. These tactics demonstrated the agents' ability to withstand disruptions and increased network efficiency, providing insightful information for handling actual transit problems.

Chapter 5

Challenges and solutions

We ran across a number of obstacles during the project's development that needed careful handling in order to preserve an accurate and useful model of the urban transportation system. Concerns ranged from visualization issues to pathfinding restrictions. Every issue was resolved to raise the simulation's overall performance and accuracy.

5.1 Technical and theoretical challenges

Table 5.1: Challenges Encountered and Solutions Implemented

Challenges	Solutions
Pathfinding for Buses: Initially, the buses followed random paths, which did not account for dynamic disruptions or disturbances.	-Implementing **Dijkstra's algorithm**, which made it possible for the cars to dynamically modify their paths in response to current circumstances. This technique made sure that buses could find and follow the most effective route even in the presence of obstructions like blocked roads.
Passenger Behavior After Reaching Their Destination: One major problem was that each time a passenger agent arrived at their destination, they would go back to where they had started, which broke the flow of the simulation.	-Creating a function that properly handled passenger movement after reaching their destination, ensuring that they do not unnecessarily return to the start and instead continue with their next goal or exit the simulation.
Integration of Blocked Paths: One of the key issues involved the integration of blocked paths into the simulation. Initially, blocked roads were ignored by vehicle agents, and this was not accurately reflected in the simulation.	-Modifying the vehicle behavior so that they could detect and avoid these blocked paths, ensuring that vehicles rerouted dynamically and followed the most efficient alternative routes when faced with disruptions.
Modeling Realistic Passenger Behavior: Simulating passengers' decision-making processes realistically while maintaining computational efficiency.	-Instead of implementing complex AI for passengers, a heuristic was used where passengers randomly decide to use public transport or walk.
Fixed Roads Not Appearing in the Plot: While the simulation was capable of reading the fixed road data and using it for agent movement, these roads were not appearing correctly in the plot, making the visualization unclear.	- Adjusting the plotting code to ensure that the fixed roads were visually represented in the simulation, providing a clear map of the urban environment.
Simulation Speed and Visualization Issues: Another challenge was the simulation speed when using Flask, which caused lag and made it difficult to clearly observe the simulation in real-time.	-Switching to a regular plot using animation. This approach allowed the simulation to run smoothly, offering clear and responsive visualizations of the entire transportation system, even during complex scenarios involving disruptions.

By conquering these obstacles, the simulation was greatly improved. In addition to enhancing functionality and agent behavior, the solutions put in place guaranteed enhanced real-time performance and more fluid visuals. In the end, these improvements made it possible to depict urban transit systems in a more dynamic and accurate way, offering important new perspectives on the effects of interruptions on transportation networks.

5.2 Alternative Consideration

- **Using a continuous-space model** Because of its simplicity and convenience of use in a discrete simulation, the grid-based technique was chosen over the continuous-space model.
- **Passenger choice complexity:** By not simulating intricate decision-making algorithms, the complexity of passenger choices was reduced; however, subsequent iterations might investigate machine learning or more complex heuristics for passenger routing.

Chapter 6

Design and Coding Approach

6.1 System Design

6.1.1 Class Diagram

The class diagram was created to represent the key components of the system and their relationships, providing a clear overview of how the system's classes interact.

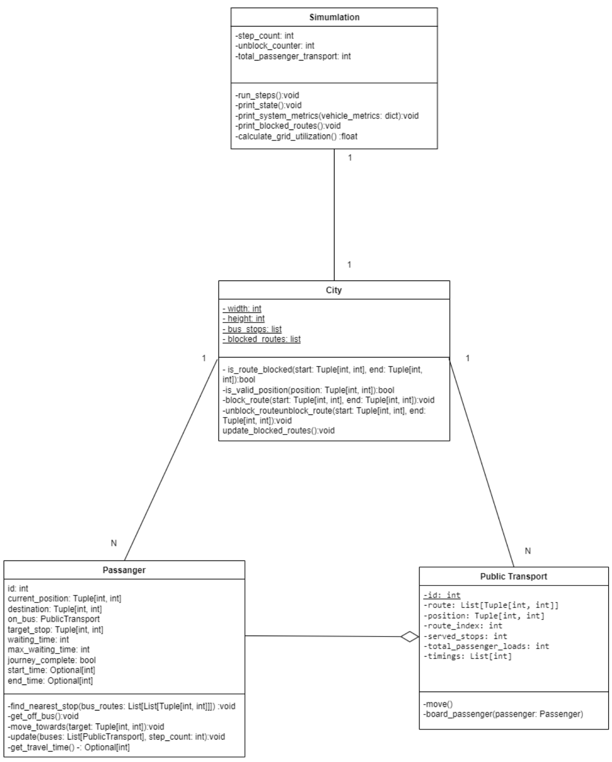

Figure 6.1: Class diagram

6.1.2 Flowchart Model

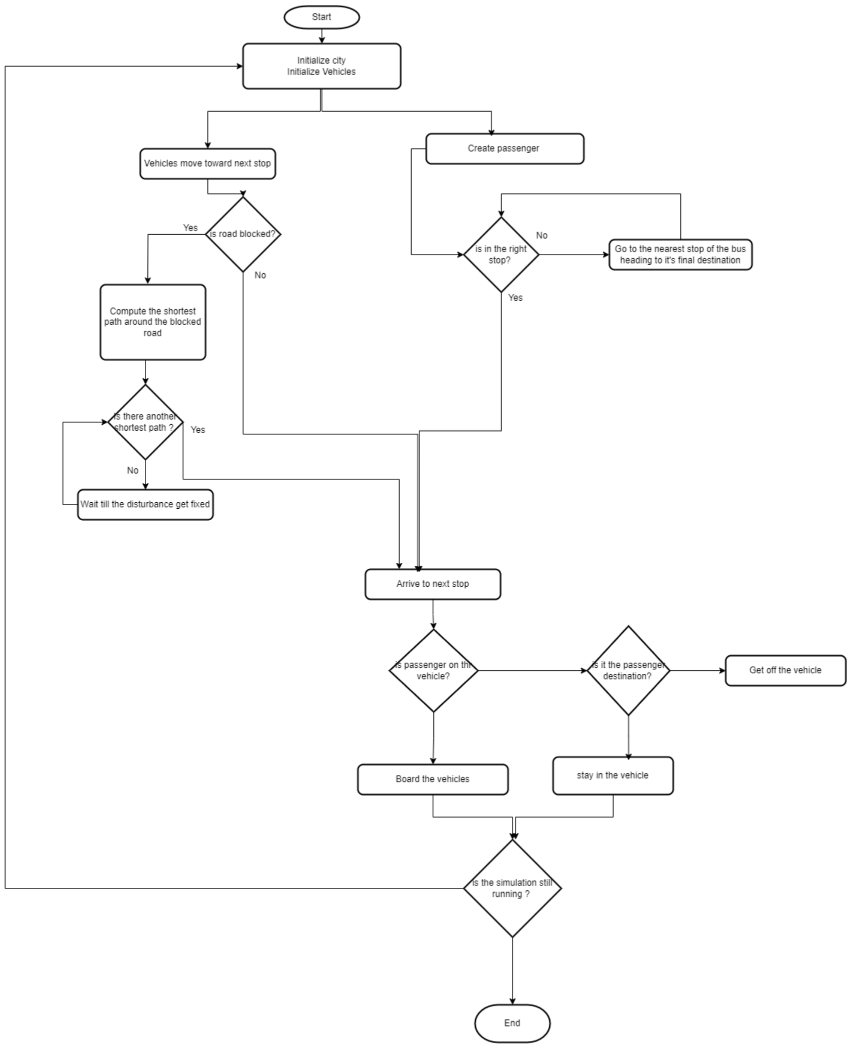

Figure 6.2: Flowchart Model

The flowchart model was designed to illustrate the step-by-step process of the simulation, detailing the flow of actions and decisions made during each simulation cycle.

6.2 Coding Tasks and Decoupling

6.2.1 Team Collaboration

To guarantee a methodical and effective approach, the report and simulation model creation were separated into several sections:

1. **Development Tasks:**

    - **Environment Behavior:** One team member focused on creating the city's environment, which includes defining the 10x10 grid, the placement of bus stops, and the grid structure necessary for agent interactions and also the disturbances appearing and disappearing.
    - **Passenger Behavior:** Another team member was responsible for defining the passenger agents, including random passenger generation, movement, and decision-making logic for traveling between stops and destinations.

- **Vehicle Behavior:** A third team member worked on the bus (vehicle) agent, defining its routes, movement, and interactions with passengers at bus stops and disturbances.

2. **Report Tasks:**

    - **Report Structure and Content Division:** In order to parallel the development activity, the report tasks were also distributed among the team members. The City Model, Agent Models, Challenges, and Solutions were among the components of the report that each member was tasked with writing.
    - **Integration of Report Sections:** The separate contributions were combined to create the final report. To guarantee uniformity in the report's general organization and technical correctness, each team member examined and contributed to portions that were not their own.

6.2.2 Code Decoupling

- **City:** The city handles the grid structure, bus stops, and future disturbances.
- **Passenger:** The passenger class handles individual agents, including their random starting points, destinations, and movement.
- **Vehicle (Bus):** The vehicle class manages bus routes, positions, and stops.
- The clear separation of concerns helped keep the code clean and easy to extend.

Chapter 7

Conclusion

With the help of this research, a multi-agent simulation of an urban public transportation system was successfully created, capturing the dynamic interactions between drivers, passengers, and environmental disturbances. The simulation provided important information on how transportation networks operate in different scenarios by simulating real-world problems such as traffic jams, accidents, and unanticipated events. Throughout the project, a number of challenges were faced, such as those related to passenger behavior, dynamic bus routing, integrating blocked paths, and visualization problems brought on by the Flask framework's constraints. Nevertheless, these difficulties were successfully overcome by employing algorithms such as Dijkstra's for vehicle rerouting, unique functions for controlling passenger behavior, and animation to enhance the simulation's visual representation. The project output provides a starting point for further research and development of urban transportation systems. It emphasizes how crucial it is to include disruptions in transportation simulations so that planners can better understand how unanticipated events affect public transportation. Enhancing the effectiveness and resilience of actual urban transportation networks may be possible with the help of the project's lessons learned and solutions.