CS166 LBA

Traffic Simulation

Minerva Schools at KGI

Introduction

In this paper, we built a simple traffic simulator to simulate the traffic behavior in the ‘greater road’ area in the Rajshahi. We estimate the car time and the car density with two different types of light signals. Lastly, we compare the average density found in the simulation with a simplified theoretical model.

Modeling: Assumptions and constraints

We selected the roads around a city block and using google map we found the traffic flow estimates of the roads. To make a simplified model, we assumed that each road is a one-lane road. In Figure 1, we show our assumed direction of the roads around the block.

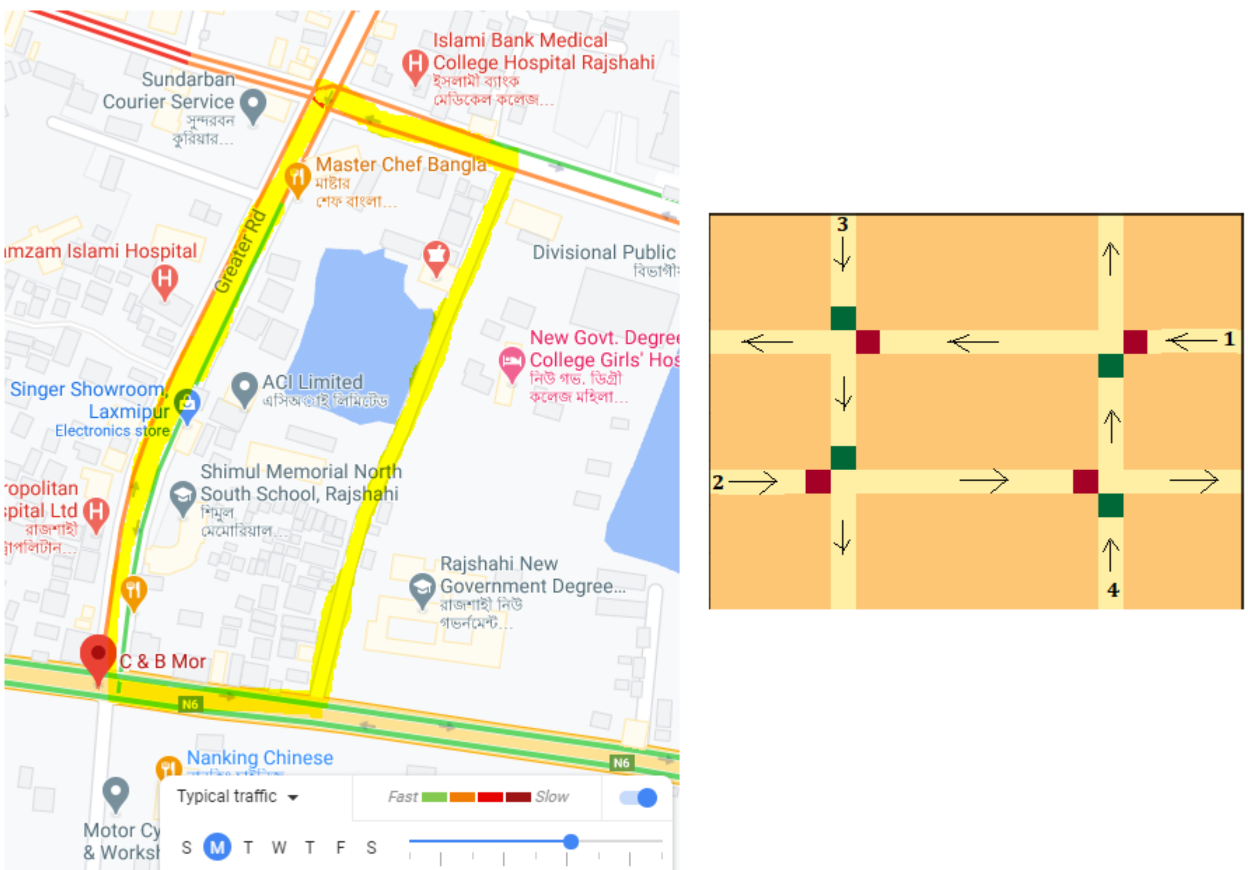

Figure 1: The city block and our simplified model. Note that we rotate the city block 90 degree for a better representation, then assumed each road to be a one-lane road. We also assumed the traffic lights are synchronized along a road.

We assumed that a road with fast traffic flow corresponds to a road where the arrival rate of the cars is lower. Where the roads with slow traffic flow have a higher arrival rate at the starting point. We defined the ‘Greater Rd’ as road 1 in our model and other roads are represented as roads 2, 3, and 4 as shown in figure 1. Thus ‘C&B Mor’ is the interaction of road 1 and road 3. As road 1 and road 3 have fast traffic flow, we assumed their arrival rate as 0.2. For its slow traffic flow, the arrival rate given for road 4 is 0.4. Road 2 is very narrow and not part of the highway. Thus we assumed that it should also have a 0.2 arrival rate.

There are not any traffic light in the real scenario, only traffic policeman controls the traffic flow whenever necessary. For simplicity, we modeled their behavior by assuming that they work synchronously and change the traffic flow in every 10-time step.

Variables and their update rules

In this simplified model, the cars will go ahead one cell if there are no cars ahead of them and if the light is green. It can slow down (i.e. not move even with an empty space ahead) with a slowing probability. If there is red light, it will check the connected road to see if there are any cars at the intersection or behind the green light (which will come to the intersection). If there are no cars, then with a turning probability it can turn to another road. Every car has a velocity of 1 in this model.

Empirical Model using Simulation

To build the simulation, we first make the grid and add traffic light in each roads before each intersection. The traffic lights is synchornized and it is same for two consecutive intersection of a similar road i.e. for road 1, both intersection should either be green or red. The vertical and horizontal roads have different traffic light at a given time.

Then we make a class of each road where we work with generate a car at the beginning of the road and move the cars of the road according to the traffic lights and the update rules. Then the traffic simulation works with all the roads in the system and their interaction. When a car left the road or turn to other road we decreases the number of cars in that road and we increased the number when a new car enters the road or turns into the road from another road. The density is defined as the total car per the length of the road. At each time step, the roadtime of a car is increasing and we store the roadtime when the car leaves the road.

The figure 2 and 3 shows these two metrics of the simulation with the original traffic light change time of 10 and with the modified light change time of 5 respectively along with a snapshot of the system after 54 timestep.

In both simulation, we can see that the car density is varies across the road. Road 1 and 2 follows a similar trend, where road 3 and 4 follows just the opposite. This is expected as when there are green light in road 1 and 2, thus the traffic flow faster and density is smaller, the light is red for road 3 and 4, making the traffic slow and car density higher. We can also see that while road 1 and 2 density stays close to each other, road 4 density is very higher than road 3 density. This is because we have a high arrival rate for road 4, thus there are more cars coming in and creating more density. Because horizontal and vertical road car density follows opposite trend, the total density follows a linear curve.

The same behaviour of car density plot can also be seen with the modified model where light changes in 5 time step. But the average density is becomes bit smaller, around 0.25 where it was around 0.27 for the original model. The most clear decrease of car density happens in road 4 (from around 0.3 to 0.2). Also the avg roadtime for a car decrease slightly for this model.

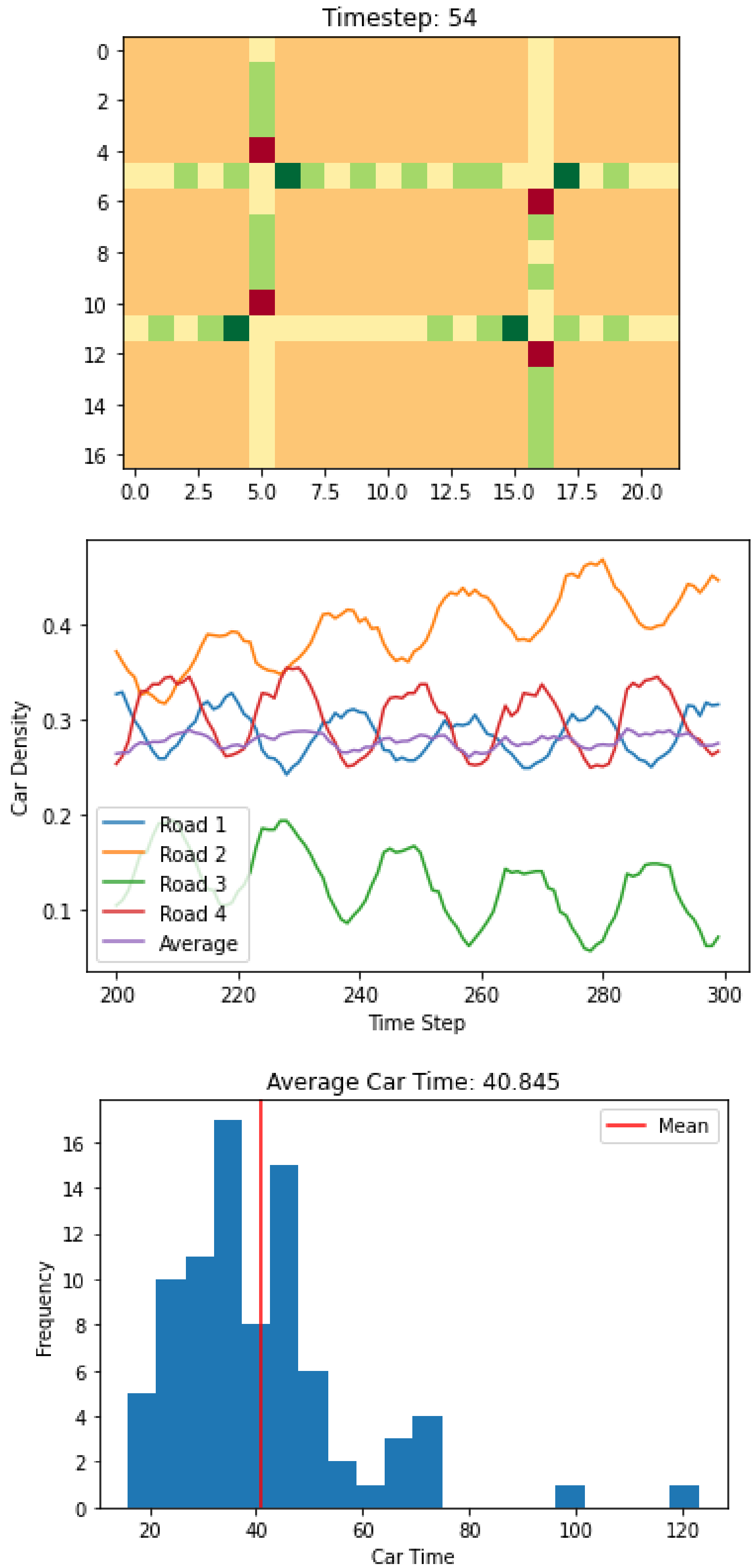

Figure 2: The simulation and the metrics with traffic light change time of 10. The car density plot shows that density in road 1 and 2 follows similar trend and road 3 and 4 follows the opposite.

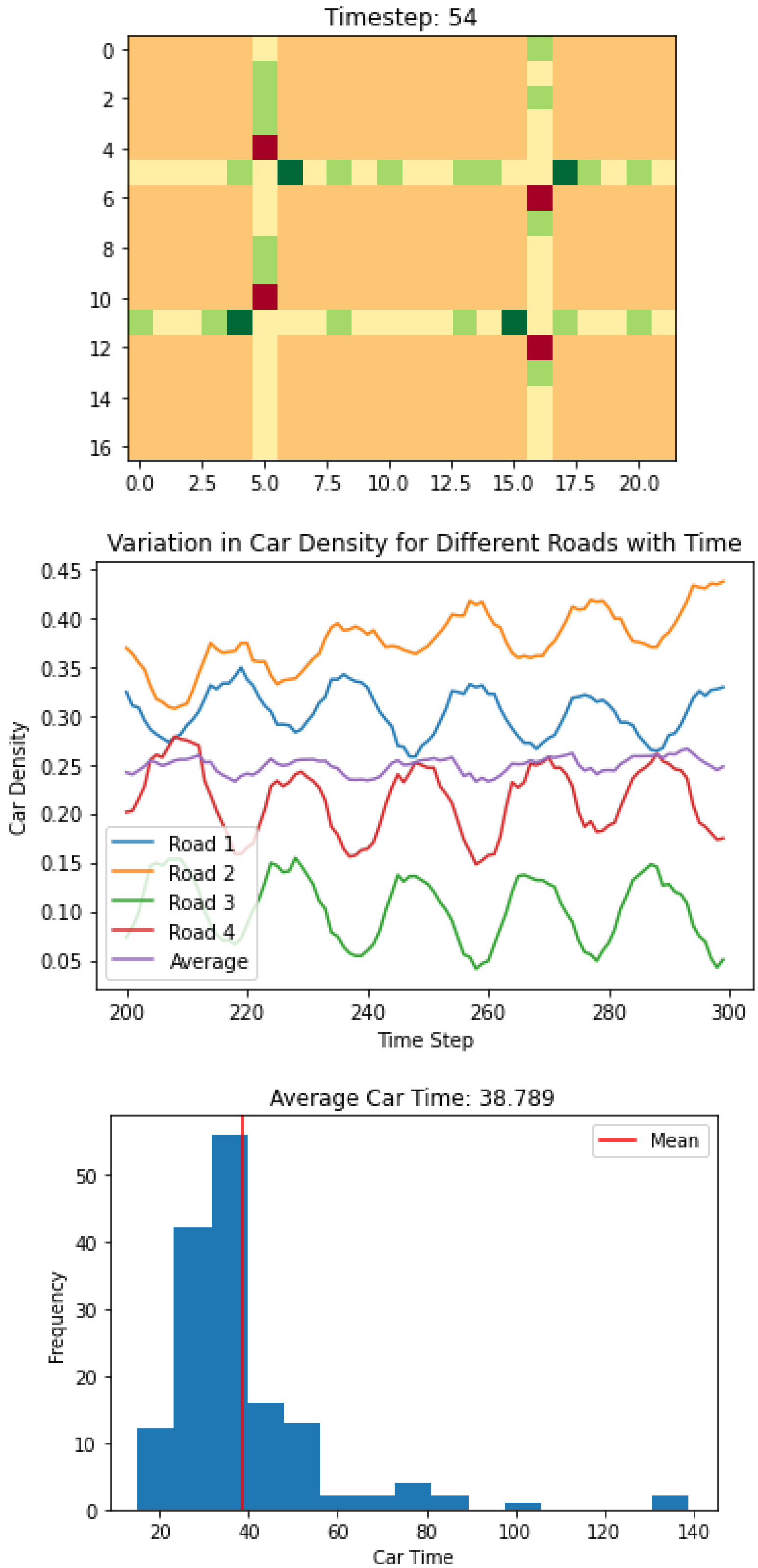

Figure 3: The simulation and the metrics with traffic light change time of 5. Again the density plot shows the opposite trend for road 1-2 and road 3-4. The avg car waiting time is higher.

One possible reason can be that when the traffic light takes longer to change, the car need to wait longer and queue gets bigger, thus the density of the road become higher and the time for a car to pass the road become higher.

Theoretical Model

For theoretical analysis, we approximated the density of a single road using the arrival rate, road length and the light change time. On average in each time step the car coming to the system equals the "arrival_rate". In equilibrium, they need to wait while a light is not changing but the car arriving continues until the road got full. So the total car during that time = arrival_rate * time before light change. So, the density will follow the formula:

density = arrival_rate * time before light change / road length

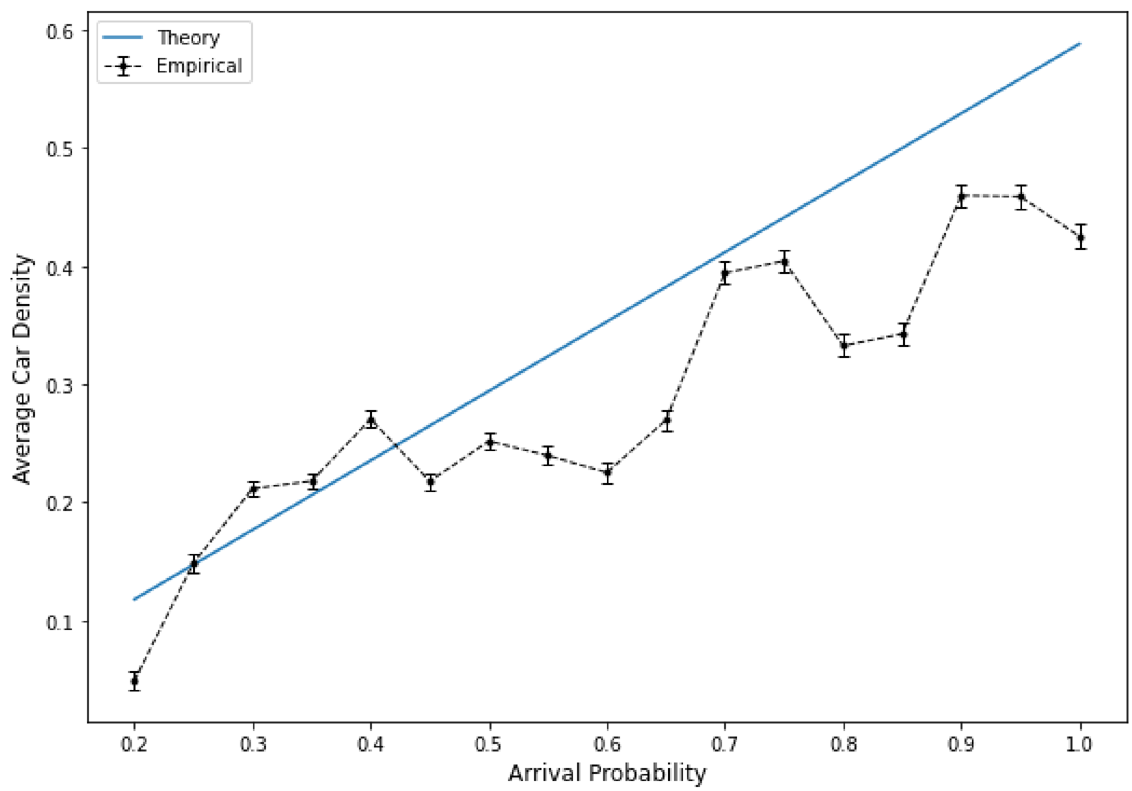

Figure 4: The theoretical and empirical estimate of the average density with varying arrival probability shows that the density is generally increasing if we increase the arrival probability.

The limitation of this theoretical formula is that it takes account for the road section before the traffic light, but the cars are not staying stopped on the section after the traffic light (or intersection). Also we didn't consider the fact that car can also come from other roads with a turning probability and similarly some car can go to the other roads while waiting in a red light. This is why we can see the between theory and empirical analysis. But overall both shows a increase in density as we increase the arrival probability. The smaller confidence intervals suggests more certainty on the values from the empirical analysis.

Appendix

Notebook Link:

https://colab.research.google.com/gist/mahmud-nobe/f6e23a52d5b802e70a4099476e22ff48/copy-of-cs166_lba.ipynb