Peachtree Street Traffic Simulation

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Problem Description

When modeling traffic flows along a busy, congested street, minimizing average travel time to traverse portions of streets is key. The objective of this project is to compare the average travel time for vehicles traveling along a portion of Peachtree Street in Midtown Atlanta between a model using synchronized traffic lights versus unsynchronized traffic lights.

Conceptual Model

Objectives

- Measure impact of synchronization on traffic signals and output parameters of traffic system.

Input Parameters

- Signal timings
- Total simulation time
- Global inter-arrival time
- Vehicle length
- Safety distance (driving/queuing)

Output Parameters

- Average travel time per vehicle
- Average wait time at a signal

Assumptions

- No pedestrians/bikers
- No construction
- No weather
- No accidents

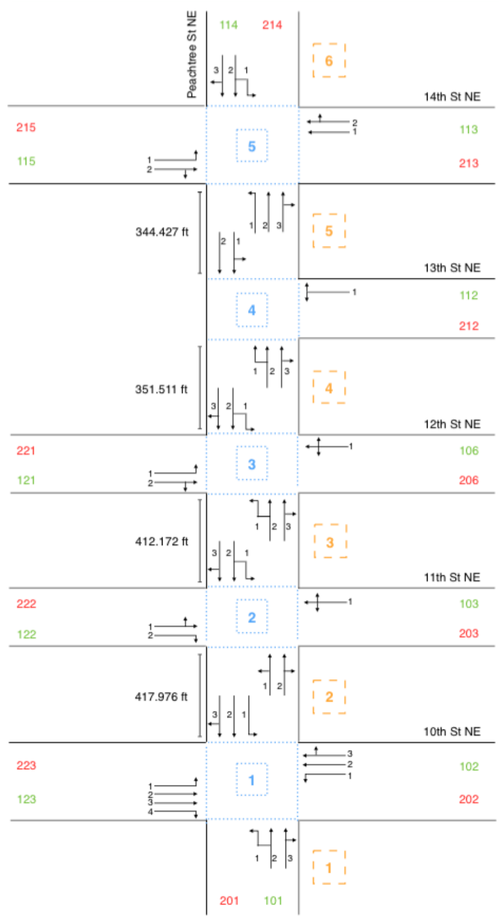
Content

- Entities(vehicle, intersections, street suctions, queues)
- Activities(vehicle waiting in queue, traveling through streets)

Simplifications

- No u-turns
- Constant vehicle speed
- Identical vehicles

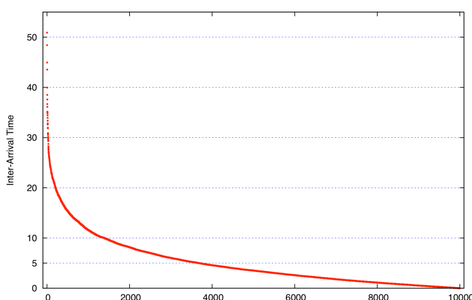
Road Topology



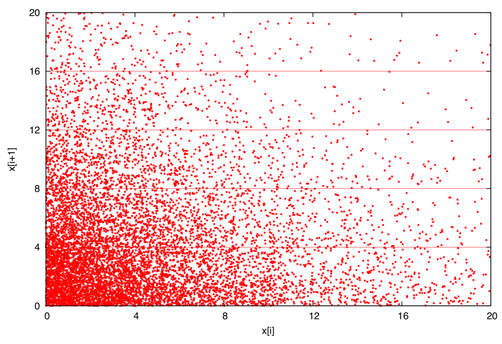
Verification

Random Variables

The C standard library rand() function is assumed to return uniformly distributed random values in the (0, R) interval such that rand()/R is uniform in (0,1), where R is an integral constant defined in the library. All input parameters were mapped to a uniform distribution except the inter-arrival time between vehicles, which uses an exponential distribution.



This plot shows the inter-arrival time for a sample size of n= 10 000 and expected mean= 5, sorted in decreasing order.
The curve has a shape that is typical for an exponential distribution.



This plot shows the correlation of Inter-Arrival Times. The spread with no particular trend shows our random variables are Independent and Identically Distributed: ([xi;xi+1], uncorrelated)

Trace Analysis

The path and event timestamps for a single vehicle are checked against the topology and signal timing at intersections the vehicle must cross. The trace below (blue) shows a vehicle traveling from south to north, crossing all intersections.
Trace analysis was done for multiple sample configurations to verify the correct vehicle path, vehicle-intersection interaction, and vehicle-vehicle interaction.

```
 0.95, Intersection 1 Signal Event; old phase:  0, new phase:  1, phaseLength:  3.60
 2.03, Intersection 2 Signal Event; old phase:  8, new phase:  0, phaseLength: 18.30
 2.33, Intersection 5 Signal Event; old phase:  7, new phase:  8, phaseLength:  1.10
 3.43, Intersection 5 Signal Event; old phase:  8, new phase:  9, phaseLength: 22.40
 4.55, Intersection 1 Signal Event; old phase:  1, new phase:  2, phaseLength:  2.40
 5.04, Intersection 3 Signal Event; old phase:  3, new phase:  4, phaseLength:  3.60
 5.19, GLOBAL_ARRIVAL       , Vehicle ID:   1, Origin Zone: 101, Destination Zone 214
 5.19, IS_1_ARRIVAL         , Vehicle ID:   1, Origin Zone: 101, Destination Zone 214
 6.95, Intersection 1 Signal Event; old phase:  2, new phase:  3, phaseLength: 34.90
 7.95, IS_1_ENTERING        , Vehicle ID:   1, Origin Zone: 101, Destination Zone 214
 8.64, Intersection 3 Signal Event; old phase:  4, new phase:  5, phaseLength:  0.00
 8.64, Intersection 3 Signal Event; old phase:  5, new phase:  0, phaseLength: 61.20
 8.84, IS_1_CROSSING        , Vehicle ID:   1, Origin Zone: 101, Destination Zone 214
12.42, IS_1_DEPARTURE       , Vehicle ID:   1, Origin Zone: 101, Destination Zone 214
20.33, Intersection 2 Signal Event; old phase:  0, new phase:  1, phaseLength: 23.20
20.65, IS_2_ARRIVAL         , Vehicle ID:   1, Origin Zone: 101, Destination Zone 214
20.65, IS_2_ENTERING        , Vehicle ID:   1, Origin Zone: 101, Destination Zone 214
21.54, IS_2_CROSSING        , Vehicle ID:   1, Origin Zone: 101, Destination Zone 214
22.55, GLOBAL_ARRIVAL       , Vehicle ID:   2, Origin Zone: 114, Destination Zone 201
22.55, IS_5_ARRIVAL         , Vehicle ID:   2, Origin Zone: 114, Destination Zone 201
23.20, IS_2_DEPARTURE       , Vehicle ID:   1, Origin Zone: 101, Destination Zone 214
25.19, GLOBAL_ARRIVAL       , Vehicle ID:   3, Origin Zone: 122, Destination Zone 202
25.19, IS_2_ARRIVAL         , Vehicle ID:   3, Origin Zone: 122, Destination Zone 202
25.19, IS_2_ENTERING        , Vehicle ID:   3, Origin Zone: 122, Destination Zone 202
25.83, Intersection 5 Signal Event; old phase:  9, new phase: 10, phaseLength:  3.70
26.07, IS_2_CROSSING        , Vehicle ID:   3, Origin Zone: 122, Destination Zone 202
29.43, IS_2_DEPARTURE       , Vehicle ID:   3, Origin Zone: 122, Destination Zone 202
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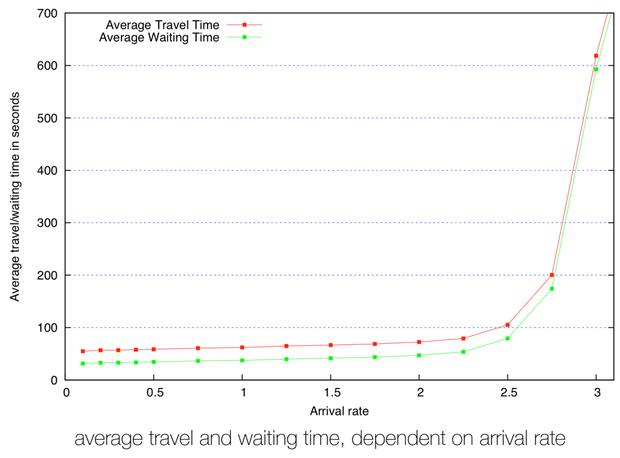
Validation

The following plot is the average travel and waiting time, dependent on arrival rate. It demonstrates the changes in behavior of wait and travel time when the capacity is at certain point of utilization that simulates the SUI functioning at full capacity.

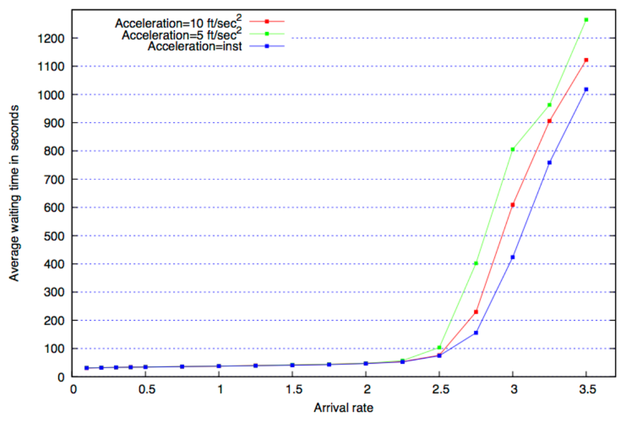


average travel and waiting time, dependent on arrival rate

Output Analysis

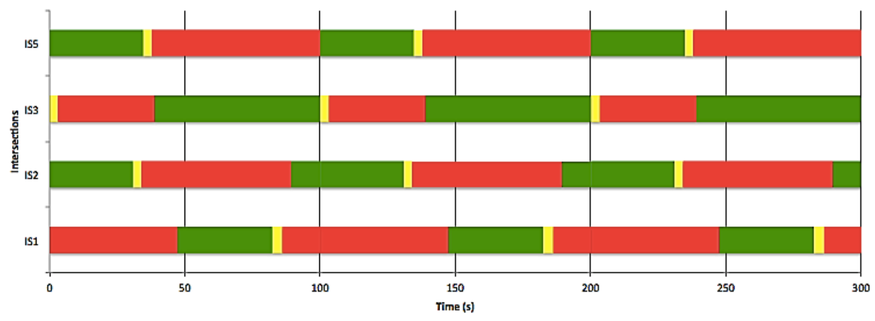
Acceleration Results

We ran our study multiple times since it relies on random variables. Here, we plot the average total waiting time, dependent on acceleration.

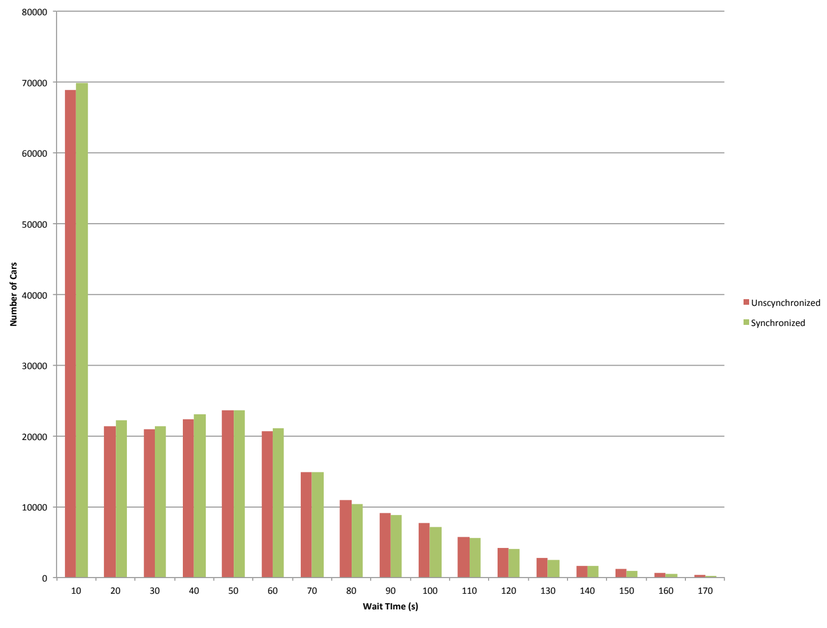


average total waiting time, dependent on acceleration

Synchronization



Below, we ran our simulation 11 times, and plot the individual wait times for cars in our system. This plot shows the number of cars in each wait time interval.



Individual wait time vs number of cars per interval

Conclusions

Though we have made several modifications to our model in both simplifications and assumptions, we believe our traffic model is accurate enough to simulation realistic scenarios for our intended purpose. Through the input analysis, we have verified the exponential distribution of our random variables to show our values are independent and identically distributed. Our validation experiments proved the consistency of our model's behavior and correct anticipated behavior for varying input parameters. The output analysis then gleaned information from our results given multiple runs of the simulation. Using these results, we were able to create a traffic light synchronization. Our comparisons of the synchronized and unsynchronized timings validate our synchronized model. Average wait times grow smaller as arrival rate increases and there are more cars with lower wait times than larger for our traffic synchronization.