Emergency Vehicle Dispatch System

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COMP-SCI 404: Introduction to Algorithms and Complexity

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Summary

For my project, I chose to create an emergency vehicle dispatch system emulator. I accomplished this primarily by using graph theory and Dijkstra's algorithm.

I've created a graph to emulate what the road network of the Kansas City Northland looks like (figure 1). I then created zip codes (represented by vertices) and roads (represented by edges) where the weight of the road is the time it takes to travel on that road between two zipcodes (figure 2).

To choose a suitable vehicle for a call request, you have to check whether a vehicle is available and whether or not it is the right type of vehicle. The project contains three types of vehicle (an enum class): ambulance, fire_truck, and police. I use Dijkstra's to check the closest node to the source, and check if a vehicle is there; if it is, we send that vehicle, if it's not, we check the next closest node to the source until we find one.

In order to demonstrate the algorithm, I created an emulator that emulates time (one "tick" of the emulator is considered 1 minute real time).

Through this project, I have abstracted away the need for someone to be able to discover the closest vehicle. They can input the zipcode of the call and type of emergency, and the dispatch system would do the rest if it were hooked to the necessary external sources of data such as GPS.

Assumptions

With any program, certain assumptions have to be made about the scope.

Input has not been sanitized; this is already a very lengthy project, and adding input sanitization as well as try/catch blocks are important, however, they will make the program unwieldy unreadable to a grader, and I’m already well experienced in those manners—in other words, they aren’t what I’m testing myself on, so I felt little need to include them.

I have also assumed that it’s not needed to store the vertices and edges in a dynamically sized data structure. In a real world scenario, it would be absolutely necessary to use dynamically sized data structures in order to delete and insert new data. However, as the same problem exists for the previous paragraph, adding two-three lines of code every time I want to do anything with the vertices or edges would be confusingly unnecessary.

I also made an assumption about the amount of time it takes to get from zipcode A to zipcode B. I used Google Maps to calculate the time it takes from wherever Google Maps decided that the zipcode is located at. I also assumed that traveling within your own node takes 5 minutes (so if a call is within the node an emergency vehicle is at, it would take 5 minutes to respond). The last time assumption is that it takes 10 minutes for a vehicle to resolve the call once it arrives. This means that once a vehicle is assigned a job, it is busy for:

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5 (to travel within its node) + 10 (time to do the job) + distance to B
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Diagrams & Graphs

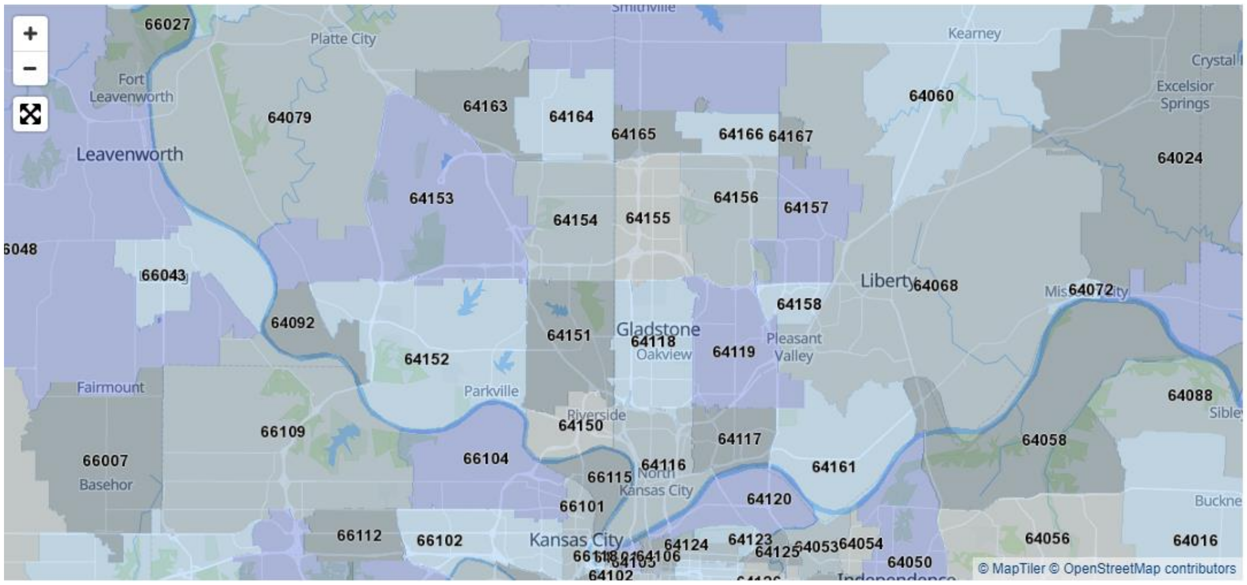


Figure 1: The road network of Kansas City Northland.

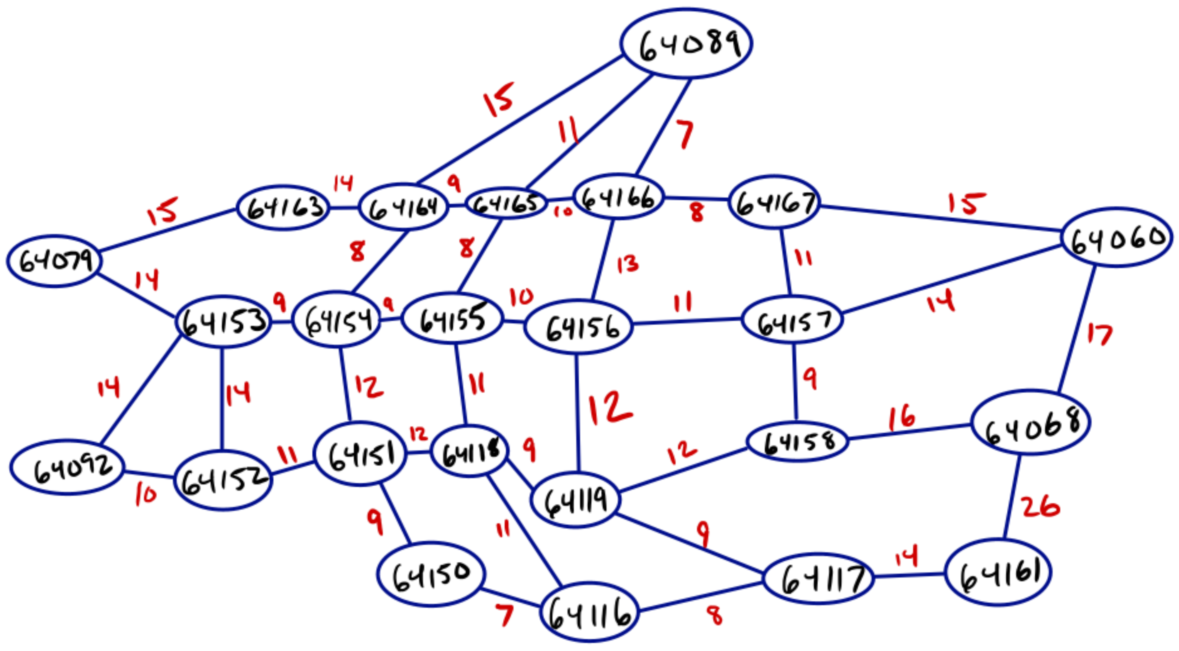


Figure 2: A graphical representation of the road network of Kansas City Northland. The edges are the time taken to travel from zipcode to zipcode on Google Maps.

UML Diagram

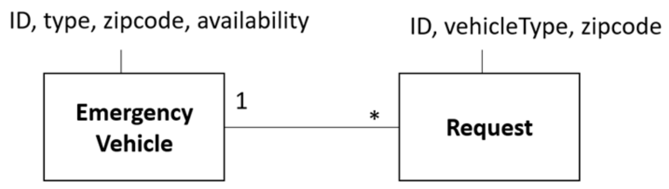
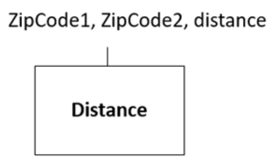


Figure 2



I did not feel the need to modify the UML Diagrams as given by my instructor. The UML diagrams were given as an example, and I managed to fit all the constraints of my project within the existing UML structure as provided.

Time Complexity

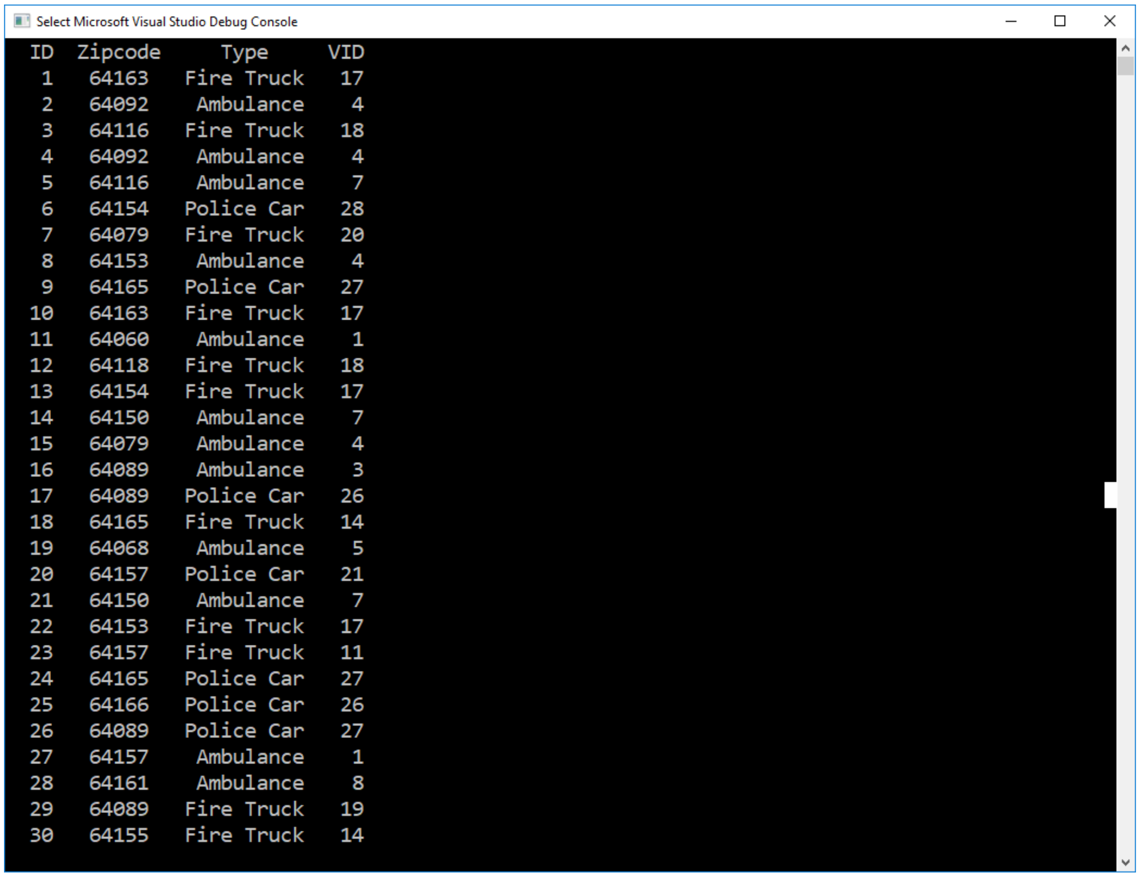
The most intensive function in the entire project is the Dijkstra's algorithm (Request::assign_vehicle in Request.cpp) that calculates the closest vehicle. In general, Dijkstra's is O((n+m)log n) where n is the vertices and m is the edges of a graph. For this project, Dijkstra's would become faster, as we terminate as soon as an emergency vehicle is found instead of calculating the closest distance to every single vertex. We also use many data structures to represent distance, previous nodes, and the next node to check. These would be O(n) space complexity.

I believe there is one way to make the time complexity of the function more efficient without sacrificing crucial features of the program. Using memoization and heuristics, we can calculate the closest nodes for each node, and just look at those accordingly.

The vast majority of the functions in the program are getters, setters, and random number generators which are O(1). There are also variable loops that help initialization data sets and read data (such as the CSV from the file). These are all O(n), and the size of n is extremely small in these cases.

Output

The output of the program are the fulfilled requests and which vehicle completed them. (see next page)



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 ID  Zipcode     Type      VID
  1   64163   Fire Truck   17
  2   64092    Ambulance    4
  3   64116   Fire Truck   18
  4   64092    Ambulance    4
  5   64116    Ambulance    7
  6   64154   Police Car   28
  7   64079   Fire Truck   20
  8   64153    Ambulance    4
  9   64165   Police Car   27
 10   64163   Fire Truck   17
 11   64060    Ambulance    1
 12   64118   Fire Truck   18
 13   64154   Fire Truck   17
 14   64150    Ambulance    7
 15   64079    Ambulance    4
 16   64089    Ambulance    3
 17   64089   Police Car   26
 18   64165   Fire Truck   14
 19   64068    Ambulance    5
 20   64157   Police Car   21
 21   64150    Ambulance    7
 22   64153   Fire Truck   17
 23   64157   Fire Truck   11
 24   64165   Police Car   27
 25   64166   Police Car   26
 26   64089   Police Car   27
 27   64157    Ambulance    1
 28   64161    Ambulance    8
 29   64089   Fire Truck   19
 30   64155   Fire Truck   14
```

Further Questions & Future

In the future, some possible changes to the project could include:

- Add sanitization to any user input and a GUI/API to abstract the need to be a computer power user.
- Adjust the graph so that the data structures are dynamic.
- I'm more familiar with SQL in which case it is very easy to do something such as primary keys; I created global variables here, and adjusted them accordingly as they were used. I assume there is a better way these should be done.
- In this program, it would realistically never happen that all vehicles would be busy. However, the program does test for this, and it waits for one to be available. It would be wise to have separate queues for different emergency types so that

they can be operated on in similar fashion without sacrificing the reason for using a queue.

- If all vehicles of one type is busy, a flag could be set to false signify that if a call is for police, don’t even try to iterate across the graph looking for an available police car. When a police car becomes available, it would set the flag to true.
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