ECE297 Milestone 3
Pathfinding and Directions

"If you don't know where you are going, you'll end up someplace else."

– Yogi Berra

"If you don't know where you're going, any road will take you there."

– Lewis Carroll

Assigned on Monday, March 14

Due on Friday, April 1 at 11:59 pm

User Interface and In-lab demo = 6/16

Autotester = 8/16

Coding Style and Project Management = 2/16

Total marks = 16/100

1 Objective

In this milestone you will extend your code to find good travel routes between two points embedded in a graph. Algorithms to find paths in graphs are important in a very wide range of areas, including GIS applications like yours, integrated circuit and printed circuit board design, networking / internet packet routing, and even marketing through social media.

By the end of this assignment, you should be able to:

1	Implement and optimize an important graph algorithm: shortest path search.

2	Develop a user interface for finding and reporting travel directions.

2 Path Finding

Your code should implement the two functions shown in `m3.h`; we will automatically test these functions with unit tests. Your `loadMap` function will always be called by the unit tests before we call any of the functions in Listing 1. Some tests of each function will be public and available to you to run with `ece297exercise 3` while others will be private and run only by the automarker after you submit your code.

```
1 /*
2  * Copyright 2022 University of Toronto
3  *
```

```
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 */
#pragma once

#include "StreetsDatabaseAPI.h"

#include <vector>
#include <string>

// Returns the time required to travel along the path specified, in seconds.
// The path is given as a vector of street segment ids, and this function can
// assume the vector either forms a legal path or has size == 0.  The travel
// time is the sum of the length/speed-limit of each street segment, plus the
// given turn_penalty (in seconds) per turn implied by the path.  If there is
// no turn, then there is no penalty. Note that whenever the street id changes
// (e.g. going from Bloor Street West to Bloor Street East) we have a turn.
double computePathTravelTime(const double turn_penalty,
                             const std::vector<StreetSegmentIdx>& path);


// Returns a path (route) between the start intersection (1st object in intersect_ids
    pair)
// and the destination intersection(2nd object in intersect_ids pair),
// if one exists. This routine should return the shortest path
// between the given intersections, where the time penalty to turn right or
// left is given by turn_penalty (in seconds).  If no path exists, this routine
// returns an empty (size == 0) vector.  If more than one path exists, the path
// with the shortest travel time is returned. The path is returned as a vector
// of street segment ids; traversing these street segments, in the returned
// order, would take one from the start to the destination intersection.
std::vector<StreetSegmentIdx> findPathBetweenIntersections(
                  const double turn_penalty,
                  const std::pair<IntersectionIdx, IntersectionIdx> intersect_ids);
```

Listing 1: m3.h

A key function in `m3.h` is `findPathBetweenIntersections`. This function must pass 3 types of tests; you can obtain part marks if you pass some of the checks but fail others, but you will have to pass them all to obtain full marks.

- The route must be legal – that is, it must be a sequence of street segments which form a connected path from the start intersection to the end intersection. You must also respect one way streets, and not try to travel down them in the wrong direction. Note that it is also possible that no legal route exists between two intersections, in which case you should return an empty (size = 0) vector of street segments.
- Your route should have the minimum possible travel time between the two intersections, where travel time is defined below.
- You should find the route quickly; you will fail performance tests if your path-finding code is not fast enough.

The travel time required to traverse a sequence of street segments is the sum of two components.

- The time to drive along each street segment, which is simply the length of the street segment divided by its speed limit.
- The time to make turns between street segments. We assume that no turn is required when you travel from one street segment to another *if they are both part of the same street* – that is, we are assuming you hit only green lights when you are going straight down a street. When you travel from a street segment that is part of one street (e.g. *Yonge Street*) to a street segment that is part of another street (e.g. *Bloor Street*) however, you will have to make a turn and this will cost **turn_penalty** extra time. **turn_penalty** models the average time it takes for you to wait for a break in traffic and/or a traffic light to turn green so you can turn.

See Figure 1 for an example of driving paths and travel times.

To make it easier to verify that you compute turns and travel times correctly, `m3.h` requires you to implement `compute_path_travel_time` and `ece297exercise` provides unit tests for it. Make sure you pass these unit tests, as you will not be able to find shortest travel time routes if this basic function is incorrect.

3 User Interface

Implementing your path finding algorithm is only part of this milestone; you also need to make this functionality usable by end users. You should decide on commands that will be typed and/or entered with mouse clicks by the user to specify what path he/she is interested in finding. The required features of your user interface are:

- Your program must work with any map without recompilation, so the user should be able to specify the map of interest.
- Users must be able to enter commands that exercise your code to find a path between two intersections (specified by entering street names at each intersection, e.g. Yonge Street and Bloor Street).
- Your interface must have some method that allows users to specify partial street names (e.g. Yong) instead of full street names to identify the street.

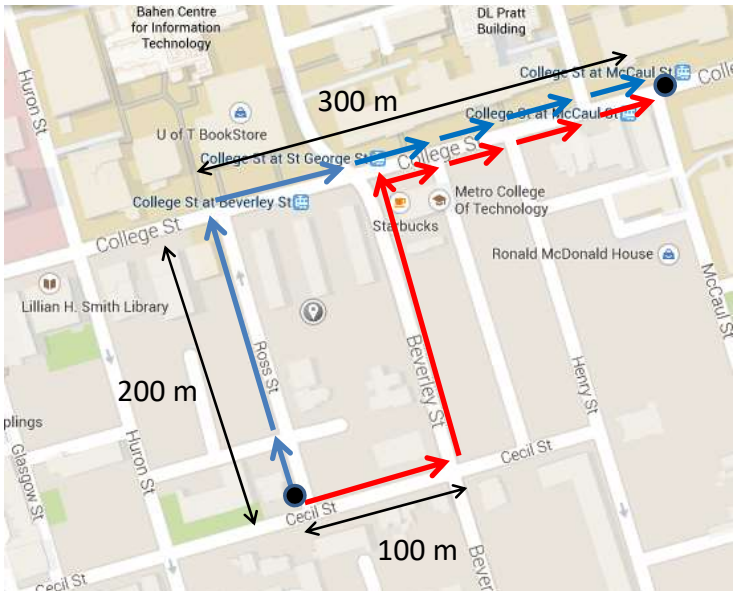

Figure 1: Two driving paths between Cecil & Ross and College & McCaul; one has a lower travel time than the other. The turn_penalty is 15 seconds in this example.

- Users must also be able to find paths between intersections by mouse clicking on intersections.
- You must display the found path in the user interface; for full marks this path should be easy to understand and give a good sense of how to follow it.
- You must print out detailed travel directions to the console or in the graphics. For full marks, these travel directions must be sufficiently detailed and clear that a typical driver could follow them.
- You must give informative error messages if the user mistypes something (e.g. an invalid street or map name).
- You must have some method (e.g. a help GUI button or notes in dialog boxes) so new users can learn the interface.

Beyond meeting the basic requirements above, your user interface will be evaluated on how user-friendly and intuitive it is. You should produce *user-friendly* walking and driving directions, using both text and graphical drawing. For example, directly printing the sequence of street segment ids that your path finding code returns would be a completely unusable user interface! Print out clear directions giving all the information you would want if you were being given driving directions. Draw an informative picture of the route to follow. Integrating both your intersection input and driving directions output into the graphics will generally lead to a more user-friendly design than having the user type and read text at the command prompt.

When creating a user interface like this it is a good idea to test it on people who are

not part of the development group. Feedback from a person not involved in the design (friends, family, etc.) is very useful in identifying what is intuitive and what is obscure in your interface.

One part of making your interface more user-friendly is to support good matching of (partial) input text to street names. You can use your milestone1 functions to achieve a partial name matching, but you can also explore other options to do more than match string prefixes. One option is using the regular expression `< regex>` feature in the C++ standard library, which lets you match general patterns in strings.

4 Grading

- 8/16 marks will come from the autotester.

  The auto tester will test basic functionality, speed and that your code has no memory errors or leaks (via a valgrind test).

- 6/16 marks will be assigned by your TA based on an in-lab demo of your interface.

  Your interface should meet all the requirements listed above, be easy to use, and feel fast and interactive.

- 2/16 marks will be based on your TA's evaluation of your code style and project management, which includes planning and tracking tasks on your wiki and using git effectively.

  Your TA will review git logs and your wiki page, and ask team members questions about the design and each member's contribution to it.

Please see the milestone 3 rubric on quercus for more details on grading of the user interface, code style and project management. If a team member has made a small contribution or shows poor knowledge of the design, his or her mark may be reduced and if merited some marks may be transferred to other team members.