Design Document

Problem Statement -

Navigation systems optimize for the shortest or fastest route However, they do not consider elevation gain. Let's say you are hiking or biking from one location to another. You may want to literally go the extra mile if that saves you a couple thousand feet in elevation gain. Likewise, you may want to maximize elevation gain if you are looking for an intense yet time-constrained workout. The high-level goal of this project is to develop a software system that determines, given a start and an end location, a route that maximizes or minimizes elevation gain, while limiting the total distance between the two locations to x% of the shortest path.

The functional requirements that we have considered for this system are as follows:

- The application must provide a valid route between 2 points in such a way that it maximizes or minimizes elevation gain under the constraint that the total distance outputted by the system cannot be more than x% of the shortest path.
  The inputs to the application are -
  1. Source address
  2. Destination address
  3. A choice between maximizing or minimizing elevation gain between the source and destination
  4. The acceptable percentage within which the system can provide the path length

  The expected output of the application is a numerical value for the path length and a map showing the visual representation of the exact route chosen by the system from source to destination.
- The system validates the inputs and instructs the user in case of invalid input values.

The non-functional requirements that we expect the system to fulfill are:
Understandability, Readability, Testability, Portability, Usability, Modularity. We will later explain how each of these requirements are satisfied by the system.

Software Development Phases

Planning and Design Decisions :

Choice of Server - A **flask** server was chosen for this application given after analyzing the scale of the application. Flask is a micro server which is easy to set up and provides inbuilt method invocations that accelerate the development process.

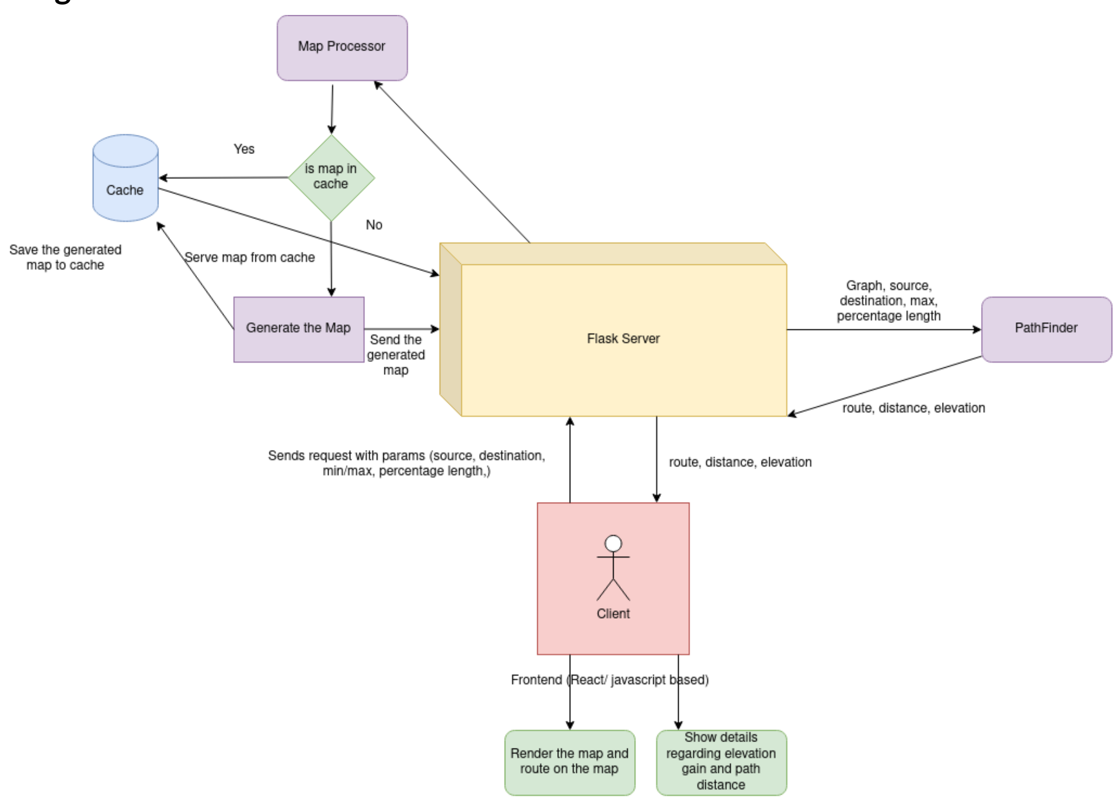
Choice of API for getting Elevation Gain - **Open elevation API** was selected as it is a free and open source alternative to Google's elevation API.

Choice for map generation - **OSMnx library** was chosen as it is an open source map generation library that abstracts the process of converting maps to networkX graphs. The generated graphs can use all functionalities of networkX graphs.

Choice of cache method - The graphs generated are way too large and would occupy a huge amount of space if stored as it is. Hence while caching, they have been dumped as **.pkl files** which compress the content when storing.

Choice of path finding algorithm- We chose 2 algorithms to implement - Dijkstra's algorithm and A* path finding algorithm. Dijkstra's ensures that we find the shortest path between two points while A* which is a heuristic based algorithm that can provide a different output. As our requirement specification aims to find an optimized path including elevation as an added factor we chose these algorithms and have analyzed their outputs before providing the user with the most suitable output.

Design and Architecture:



We have proposed the above design for the application. The application follows both Client- Server and MVC architecture patterns.
After analyzing the requirements we concluded that the language of choice for implementing the application would be python for backend and JavaScript for frontend.

Development and Implementation:

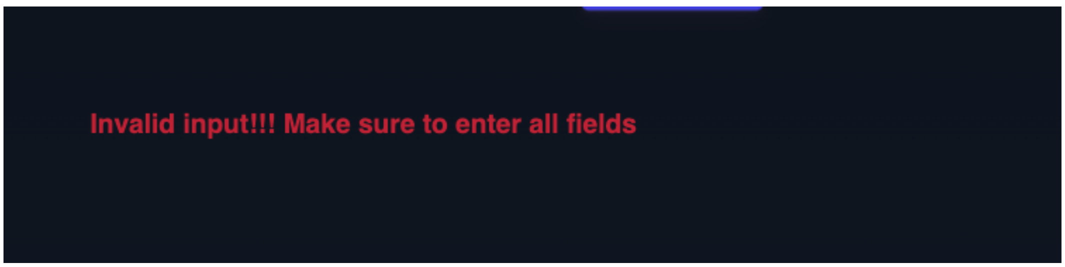
The modules of the application are described below:

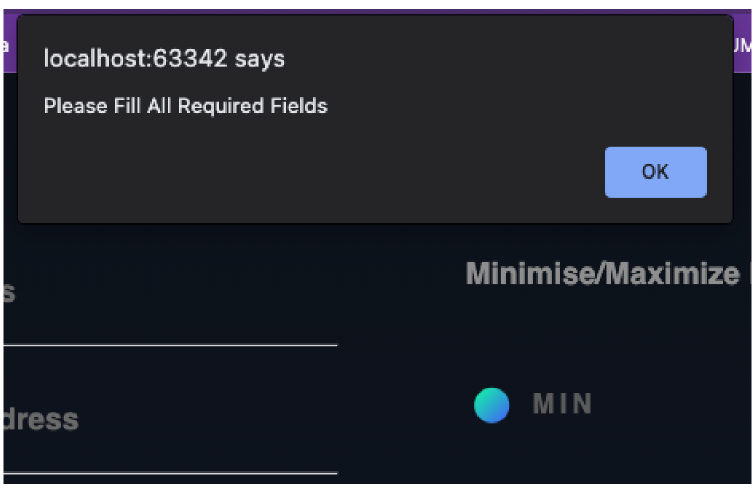
- **Client** - Our client is written in JavaScript. It consists of a form that takes input from the user and sends form data to the server. Our source and destination input is integrated with Google's Autocomplete Places API that facilitates entering location for the user. The user can enter source , destination in the form, choose either minimum/maximum elevation gain and choose percentage to limit shortest distance to. When the client receives a response from the server, we pass the route information to Google's Direction API which plots the route on the generated map.
- **Backend Server** - A Flask based backend server. It receives the input from the client and calls the map generator module to generate a map for the specified city. It will then call the pathfinder module to generate the most optimized route for the given user input. The generated map and optimized route along with elevation gain info will be sent back to the client for frontend rendering.
- **Map Generator** - Map generator module will be responsible for fetching latitude and longitude for source and destination using geoPy and generating map of input city and state using OSMnx library. Osmnx provides a method which attaches elevation data to each node of the generated graph using Google's elevation API. Since Google's elevation API is not free, we have modified this method to use Open-elevation API which is an open source version of Google's elevation API.
  Using the Open-elevation API is a time consuming process, thus to improve the response time of the application we have introduced a cache. This module caches any newly generated maps to avoid redundant calls to the API.
- **PathFinder** - PathFinder module is responsible for finding an optimized path for a given user input. The optimized path is found through a 2 step process. In the first step, it finds the path elevation based route using 2 algorithms - Dijkstra's and A*. A* is a heuristic based algorithm and hence in certain situations might not yield the most optimized solution. Hence in the second step, the module's algorithm picker analyzes the output of both the algorithms and choses the one which is most aligned with the user's preferences.

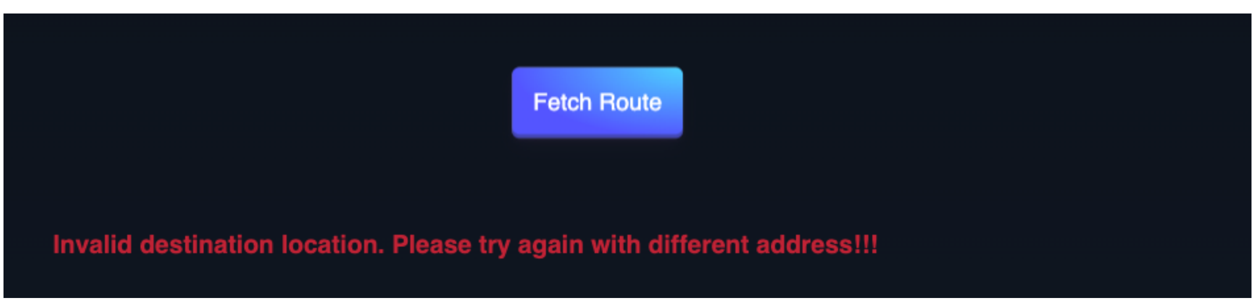
Error Handling-

- **Server side -** We have handled error handling in the server side by sending explicit status codes and detailed error messages along with the response. The error cases handled are - invalid addresses, location not in same city/state, response timeout. Exceptions are also handled in our code.
- **Client side** - We have checked for input validation in the UI, and handled errors in cases of Directions API request failing. We display all response errors received from the server on the UI.

Examples :







Testing:

The testing is done to ensure that the entire application works according to the requirements. The map generator, helper and pathfinder modules were unit tested for edge cases and happy path functionalities which ensured that the system behaved as expected. Map generator functionality was verified by testing if the application outputs a valid graph with correct number of nodes and edges, considering the google map values as the absolute truth. For the pathfinder module we tested the length and elevation of the output path to check if it's within an acceptable range. We have also tested the helper module functionality for valid address fields and route length.

- Integration tests- server
    - An exhaustive test suite has been developed for the application including unit tests, integration tests and coverage report has also been generated.
- UI testing:
    - For UI testing, we made 2 frontends, and asked our peers to try our application and give feedback on the UI elements. We also asked them about our design choices and if they liked the way our UI looked. A friend of ours suggested the slider percentage changer which we changed after the feedback, it was a number field before.
- Manual Testing:
    - We tested our server using Postman using different locations and scenarios.
    - We tested edge cases and error situations manually as well.