CSC 510 MILESTONE 1

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1. Introduction

We assume the position of a software engineer at DriveBot Labs, a cutting-edge and innovative startup dedicated to building a smart routing engine for autonomous vehicles – specifically cars. This milestone seeks to:

- Define a problem statement and identify its constraints.
- Explore potential algorithmic solutions.
- Convey our ideas with images embedded from draw.io.

Thus far, our strategy leverages dynamic graph structures to represent a road network, polynomial heuristics for pricing, and pragmatic handling of hazards like blocked roads or congestion.

2. Problem Statement and Scope

Let C denote the set of traversable roads in the state of California (with freeways excluded) and graph $G = (V, E)$ representing a subgraph of C. We seek to:

1. Minimize time to destination under dynamic constraints.
2. Avoid hazards, congestion, and non-traversable segments.
3. Ensure adaptive and fair pricing for customers.
4. Optimize routing to minimize vehicle downtime and energy usage.

We define "smart routing" to be the minimal edge subset $M \subseteq E$ connecting vertices $v_1, v_2 \in V$ such that M is a valid and efficient path under prevailing conditions.

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3. Pricing Function and Heuristic Structure

Let $P : \mathbb{R}^n \to \mathbb{R}$ be a polynomial-based pricing function:

$$P(x) = a_1 x^{c_1} + a_2 x^{c_2} + \cdots + a_n x^{c_n},$$

where x denotes a vector of factors including (but not limited to):

- Travel distance (or edge count in M),
- Position in the demand queue,
- Traffic index (local congestion or slowdown factor),
- Availability of vehicles in the local region.

Given the scope of our class, convex optimization methods are explicitly avoided; we favor polynomial heuristics with tunable coefficients to simulate flexible pricing without overfitting.

4. Hazards, Failures, and "Stuck" Conditions

We classify failure conditions as follows:

1. **Disconnected route:** A path $P = \{e_1, \ldots, e_k\}$ where some $e_i \notin E$.
2. **Zero-speed segments:** Path contains blocked or severely delayed edges.
3. **Suboptimality:** The selected path P is not minimal in time or energy.

We address these conditions via dynamic graph representation: edge weights evolve in time, and traversal options are evaluated per update tick.

5. Modeling Considerations and Roadmap

Our model involves:

- **Dynamic weighted graphs:** G_t updates as traffic and road conditions change.
- **Real-time recalculation:** Rerouting functions triggered on edge invalidation.
- **Search strategies:** Primarily greedy and Dijkstra variants, avoiding A* unless admissible heuristics are well-defined.
- **Minimal use of probabilistic models:** Traffic indexing via simple moving averages or window-based smoothing functions.

6. Illustrative Diagrams

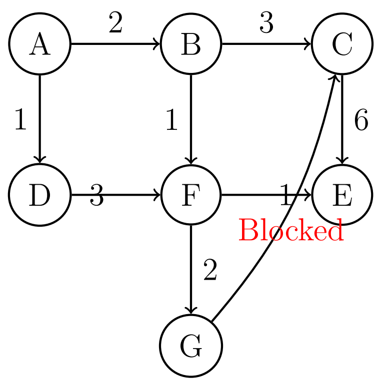

Figure 1. A dynamic road network with edge cases: blocked route (red), alternative paths, and rerouting potential

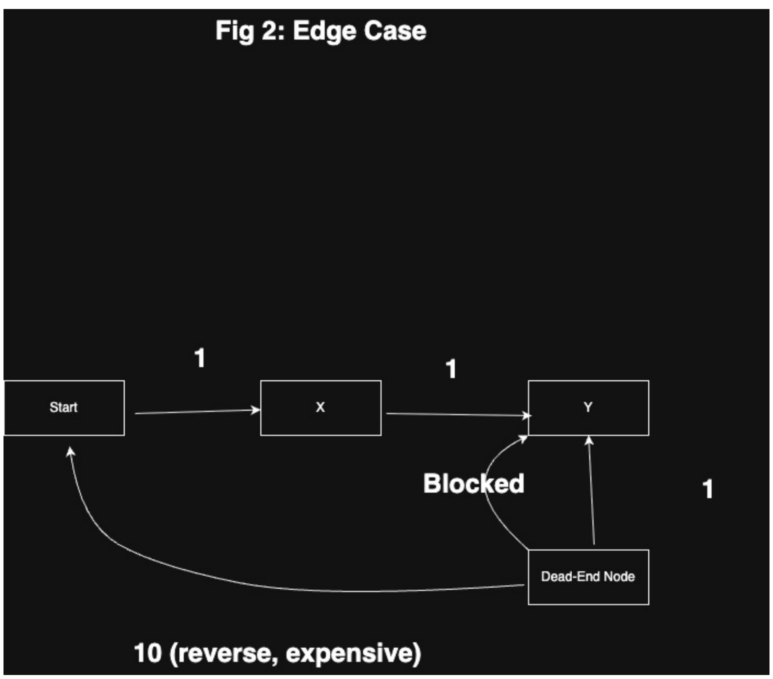

Figure 2. Draw.io diagram: dead-end with delayed update and costly reversal.

References

1. T. Cormen, C. Leiserson, R. Rivest, and C. Stein, *Introduction to Algorithms*, MIT Press, 3rd Ed.
2. R. Tarjan, "Data Structures and Network Algorithms," SIAM, 1983.
3. San Francisco Open Data, Traffic and Road Conditions API.

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