Demo: E2Pilot: An Energy-Efficient Navigation System for Long-haul Timely Truck Transportation

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ABSTRACT

We implement a new version of E2Pilot, the first energy-efficient navigation system for long-haul timely truck transportation with fast response time and user-friendly interfaces. Given the origin, destination, and delivery time window, E2Pilot provides the path and speed instructions shown on the user interfaces for the truck drivers to transport freights on time with minimum fuel consumption. E2Pilot has two user interfaces: a publicly available website, and a GPS-like smartphone application that provides in-place driving instructions along with off-route detection and re-routing.

CCS CONCEPTS

• **Applied computing** → **Transportation**; • **Information systems** → *Spatial-temporal systems.*

KEYWORDS

energy-efficient operation, timely transportation, navigation system

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1 INTRODUCTION

More than 10 billion tons of freight are transported by heavy-duty trucks in the United States, representing 72.5% of total domestic tonnage shipped [1]. Meanwhile, fuel consumption of heavy-duty trucks is more than 43 billion gallons of fuel in 2018 and is also one of the major operating costs (24-34%) for the individual truck owners. These numbers make it critical to reduce the fuel consumption. Moreover, transportation deadline is a common requirement in the trucking industry. In fact, timely delivery is not only necessary for perishable goods such as food, but also commonly adapted in service-level agreements to guarantee delivery delay.

By considering both the cost-effectiveness and the timely delivery requirement, researchers propose and study the *Energy Efficient Timely Transportation* (E2T2) problem [3, 4]. E2T2 aims to minimize the overall energy consumption for a truck traveling over the national highway network from the origin to the destination via optimizing path planning and speed planning, subject to a strict deadline constraint. Previous works [3, 4] show that a well-designed operating strategy can significantly reduce the energy consumption of heavy-duty trucks, as much as 20%.

Despite its importance and available algorithms, the E2T2 problem has not been well addressed by available general-purpose navigation systems (e.g., Google Maps and HERE Maps) nor tailored online platforms for trucks (e.g., Sygic and SmartTruckRoute).

In this paper, we implement a new version of E2Pilot, the first energy-efficient navigation system for long-haul timely truck transportation with fast response time and user-friendly interfaces. As compared to the previous version [5], we make our website interface publicly available with a more friendly user interface[1]. We also develop a GPS-like smartphone application, which provides in-place instructions and interactively assists the driver in saving the fuel cost. We also improve the backend framework and collect a more comprehensive dataset for faster and more accurate computation.

2 MODELING AND APPROACH

Consider a national highway network modeled by a directed graph $G \triangleq (V, E)$. An edge $e \in E$ represents a road segment, and a node $v \in V$ represents a connecting point. Without loss of generality, each road segment is assumed to have a homogeneous grade and surface resistance. Each edge e has a length D_e and a minimum (resp. maximum) traveling speed $r_e^l > 0$ (resp. $r_e^u \geq r_e^l$). We define the fuel rate speed function $f_e : [r_e^l, r_e^u] \to \mathbb{R}^+$ (unit: L/km) for a truck to travel through a road segment e, where the shape of f_e mainly depends on the grade of the road segment e.

An *Energy Efficient Timely Transportation* (E2T2) problem is defined on a national highway network with the corresponding speed range, grade, and fuel rate function for each road segment. Given the origin, destination, and a hard time deadline constraint, the E2T2 problem aims to minimize the energy consumption while ensuring on-time arrival by optimizing path planning and speed planning. The solution of an E2T2 problem includes a path profile containing a sequence of edges and a speed profile containing the corresponding speed instruction for each edge. In this paper, we will use an efficient dual-based algorithm [3] to solve the E2T2 problem approximately. Despite the proven NP-hardness of the E2T2 problem, the algorithm is shown to produce near-optimal solutions on real-world data within seconds.

[1]The website is available at https://www.e2pilots.com/map/

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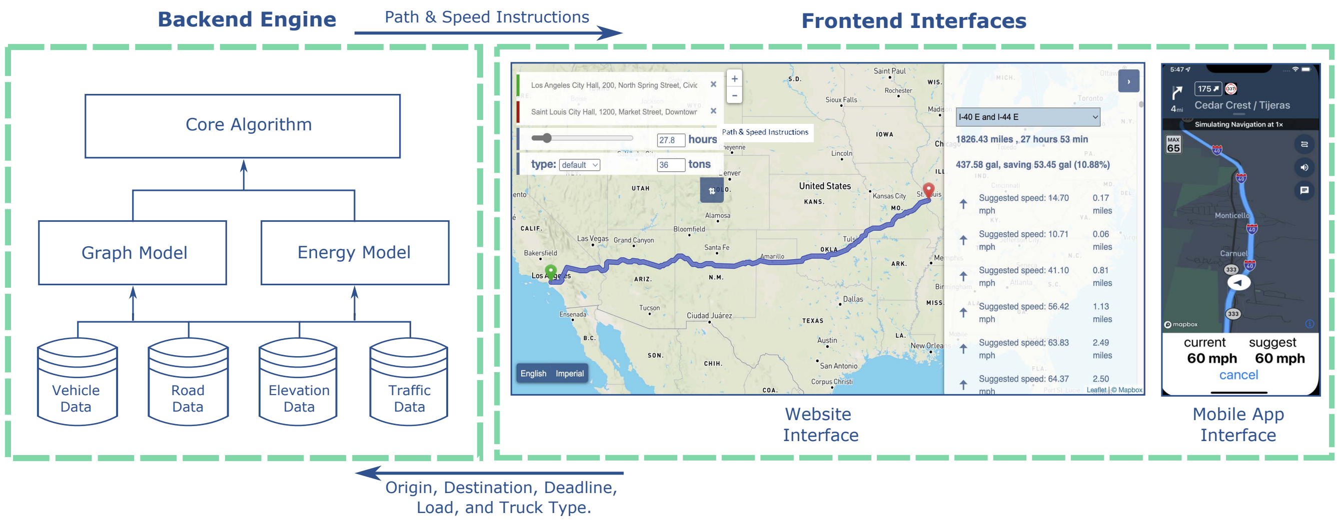

Figure 1: System architecture and user interfaces.

3 SYSTEM ARCHITECTURE

Figure 1 gives the system architecture of E2Pilot with a backend engine and two frontend interfaces. Those two parts communicate through a RESTful API. The frontend interfaces send the request (origin, destination, deadline, load, and truck type) through the RESTful API, retrieve the path & speed instructions and demonstrate them to the user.

The backend engine is shown in the left part of Figure 1. It includes the databases and our core algorithm. We collect highway network data from OpenStreetMap (OSM) and pre-process the highway network data by merging non-intersection roads with the same level of grades for fast computation. The road grade of each edge is computed from the elevations of its two end nodes collected from the Shuttle Radar Topography Mission (SRTM) project. We use the traffic data collected from HERE Maps to set the speed range for each road segment. We adopt a simple yet effective fuel consumption model proposed in FASTSim [2] such that vehicle models with different engine parameters can be easily added to the database.

The user interfaces are shown in the right part of Figure 1, including a website interface and a smartphone app interface. The website interface is implemented with Leaflet Library. The user can choose the origin and the destination by clicking on the map or entering the addresses in the boxes. The website will automatically send the request to the backend engine and display the drive instructions on the right panel. The website also provides a route summary with total distance, estimated travel time, estimated fuel consumption, and energy-saving compared to the fastest path. The user can use the range slider to change the travel time and see the tradeoff between the deadline and the fuel consumption. We also implement various options for different languages and systems of measurement on the bottom left side of the interface.

The smartphone app interface is implemented with Mapbox Navigation SDK. The user can enter the request and see the corresponding energy-efficient route through the interface. Besides the similar features to the website interface, the smartphone application interface also provides in-place drive instructions and interactively assists the truck drivers in following the plan and saving fuel costs. In addition, the smartphone application keeps track of the current speed and location and detects the off-route behaviors. The smartphone application will then re-route accordingly after the detection of off-route behaviors.

4 CONCLUSION AND FUTURE WORK

This paper implements E2Pilot, an energy-efficient navigation system for long-haul timely truck transportation with website and smartphone app interfaces. In the future, we will add more features to the system, e.g., real-time traffic data, multiple delivery location and opportunistic driving [6]. We will also incorporate the algorithm into the embedded systems for autonomous driving trucks.

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REFERENCES

[1] American Trucking Associations. 2021. Economics and Industry Data. https://trucking.org/economics-and-industry-data. Accessed: 2021-05-07.
[2] Aaron Brooker, Jeffrey Gonder, Lijuan Wang, Eric Wood, Sean Lopp, and Laurie Ramroth. 2015. *FASTSim: A model to estimate vehicle efficiency, cost and performance.* Technical Report. SAE Technical Paper.
[3] Lei Deng, Mohammad H Hajiesmaili, Minghua Chen, and Haibo Zeng. 2017. Energy-efficient timely transportation of long-haul heavy-duty trucks. *IEEE Transactions on Intelligent Transportation Systems* 19, 7 (2017), 2099–2113.
[4] Qingyu Liu, Haibo Zeng, and Minghua Chen. 2018. Energy-Efficient Timely Truck Transportation for Geographically-Dispersed Tasks. In *Proceedings of ACM e-Energy*. Karlsruhe, Germany, 324–339.
[5] Yaowei Long, Zidong Wu, Hongyi Liu, Titing Cui, Wenjie Xu, and Minghua Chen. 2019. Path and Speed Planning Online Platform for Energy-Efficient Timely Truck Transportation. In *Proceedings of the 6th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation*. 383–384.
[6] Wenjie Xu, Qingyu Liu, Minghua Chen, and Haibo Zeng. 2019. Ride the tide of traffic conditions: Opportunistic driving improves energy efficiency of timely truck transportation. In *Proceedings of ACM BuildSys*. New York, US, 169–178.