Demo Abstract: Path and Speed Planning Online Platform for Energy-Efficient Timely Truck Transportation

Yaowei Long*
Tsinghua University

Zidong Wu*
Tsinghua University

Hongyi Liu*
Tsinghua University

Titing Cui
The Chinese Univ. of Hong Kong

Wenjie Xu
The Chinese Univ. of Hong Kong

Minghua Chen
The Chinese Univ. of Hong Kong

ABSTRACT

Huge fuel consumption is a big challenge in trucking industry. Meanwhile, deadline is also a common constraint for truck transportation. Research [6, 8] has shown that truck fuel consumption can be significantly reduced by path and speed planning. However, current online route planning platform such as Google Maps, Here Map, etc. does not provide path and speed planning function specifically for energy-efficient timely truck transportation. In this demo, we implement an online path and speed planning platform for energy-efficient timely truck transportation. We design techniques to speed up the dual-based algorithm proposed in [6] and integrate it into a user-friendly and agile online platform.

CCS CONCEPTS

• Mathematics of computing → Paths and connectivity problems; **• Applied computing → Transportation**.

KEYWORDS

Energy-efficient transportation, timely transportation, online platform

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1 INTRODUCTION

70.2% of all freight tonnage is hauled by trucking industry in the US in 2017. It collects 700.1 billion dollar in gross freight revenues [5]. The number is even larger than the total GDP of Switzerland in 2017. At the same time, heavy-duty trucks consume 18% of energy in transportation sector [7] with only 4% of the total vehicle population. Additionally, fuel consumption contributes a significant fraction (26~34%) to the truck operation cost [7]. These statistics show that it is very important to reduce fuel consumption both for reducing truck operation cost and protecting the environment.

Besides the large fuel consumption, transportation deadline is very common in truck industry. We refer the reader to the discussion in [1, 4]. To save fuel while still catching the deadline, path planning and speed planning are two common design spaces to effectively save fuel, see the discussion in [6, 8].

However, current navigation solution provided by Map API such as GoolgeMaps, HereMap and MapBox, etc, mainly focuses on navigation for general vehicles. They use distance and driving time as their optimization objective and do not specifically optimize the fuel cost of trucks.

In this paper, we aim to implement an online path and speed planning platform for energy-efficient timely truck transportation. The goal of the platform is to minimize the fuel consumption of trucks subject to a hard deadline constraint by providing path and speed profile.

2 MODEL AND ALGORITHM

We use the **PA**th selection and **S**peed **O**ptimization (**PASO**) problem formulation proposed in [6]. It was formulated as

$$\begin{aligned} \min_{x \in \mathcal{X},\, t \in \mathcal{T}} \quad & \sum_{e \in E} x_e c_e(t_e) \\ s.t. \quad & \sum_{e \in E} x_e t_e \le T \end{aligned} \tag{1}$$

where set $\mathcal{X}$ restricts that one and only one source-destination path is selected, set $\mathcal{T}$ captures the speed limits of all roads. [6] showed that PASO is NP-Complete. Classical methods suffer from a long-running time when applying to a national-wide highway system. Based on Lagrangian relaxation, a fast heuristic scheme was presented for PASO in [6]. In this paper, we not only implement the heuristic algorithm but also provide some speed-up techniques. We refer readers to [6] for algorithm details.

First, when ignoring the speed limit, for a fixed value of the dual variable λ, we find that any road that has the same grade can use the same optimal speed. In the original algorithm, they computed the optimal speed for every road segment (approximate 80000 segments). In fact, we have very limited road grades(201 kinds), which means we only need to do very few calculations to get the optimal speed for each road. When calculating optimal speeds, we use the Newton-Raphson Method rather than the binary search in the original algorithm. Second, we give a much smaller upper bound for λ. In the original algorithm, there is a huge waste of time in finding the optimal λ. After some mathematical reasoning,

*These three authors contributed equally. And the work was mainly done when they were research interns with the Dept. of Information Engineering, the Chinese Univ. of Hong Kong.

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we find that the optimal λ must satisfy

$$\lambda \leq \frac{C_f - C_s}{T - T_f} \tag{2}$$

where C_f and T_f are the fuel cost and time cost for the fastest path respectively, C_s is the fuel cost when ignoring the deadline constraint, T is the deadline.

3 SYSTEM IMPLEMENTATION

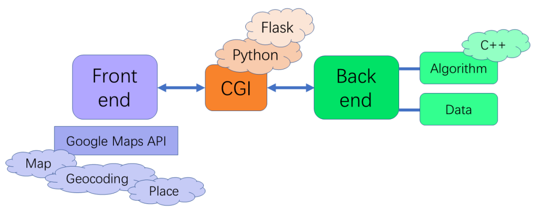

Figure 1: Platform Architecture

We implement the platform as a web application for better interaction between users and the algorithm. Figure 1 illustrates the architecture of the platform. The platform is divided into the front end and the back end parts, which will communicate through a CGI under the Flask framework. The front end will collect requests and display results to users, while the back end is responsible for handling requests, invoking the algorithm and get the solution.

The user interface, where users can submit a PASO task, is developed based on Google Maps API and libraries. Every PASO task can be defined by a start location, an end location, the truck type, the load and the time constraint. With this information, the platform can compute and show the result to users. The result contains the most energy-efficient route and several baseline routes. Besides the visible routes on the map, some parameters including time, distance and fuel cost will be shown.

The back end contains the data and the core algorithm. The data, including the US highway network, the speed limit information and the fuel consumption data, is necessary to build the model. We construct the US highway network from the Clinched Highway Mapping Project [10]. We get the elevations of different nodes by querying the Elevation Point Query Service [3]. We get the speed limit information from HERE map [2]. And we get the fuel consumption data from ADVISOR simulator [9]. See the discussions in Sec. V [6] for more details of data.

4 DEMONSTRATION AND USER EXPERIENCE

Figure 2 illustrates part of the user interface. Users can easily provide the parameters of a PASO task in the user interface and submit requests to the server. We provide multiple ways for users to select a point. For example, users can click a place on the map, search an address by a search box, or represent a point by longitude and latitude. Multiple input methods meet the majority of users' demands.

In addition to the most energy-efficient route, the platform shows other baseline routes including the fastest route and the shortest route. The parameters of these routes are compared in a table. Users can clearly see the advantages of our algorithm and make better decisions. Furthermore, we reserve the chance for users to choose the appropriate route according to their needs. The platform also gives the recommended speed and the expected time on every road of the most energy-efficient route as guidance to users. A list of buttons can quickly zoom the map to the roads that users concern.

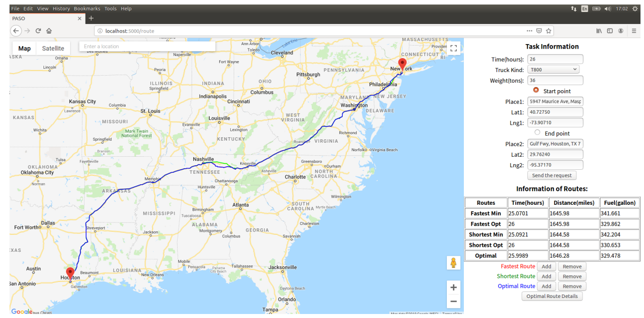

Figure 2: User Interface

By speeding up the algorithm, we reduce the response time to a task from several minutes to a few seconds, which is nearly a hundredfold improvement. Fast response makes it possible to deploy the platform in the real world.

5 CONCLUSION AND FUTURE WORK

In this paper, we implement a path planning and speed planning platform for energy-efficient timely truck transportation based on the research on the PASO problem [6]. In the future, we will add more features to the platform and improve the user interface. Furthermore, we will release the platform to the public and test it in the real world. Extending our platform into electric vehicle scenario, where route to charge station and charging time also need optimization, is an interesting future direction.

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