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Efficiency comparison of the routing algorithms used in centralized traffic management systems

Anton Agafonov[a]*, Vladislav Myasnikov[a,b]

[a]Samara National Research University, 34, Moskovskoye shosse, Samara, 443086, Russia
[b]Image Processing Systems Institute – Branch of the Federal Scientific Research Centre "Crystallography and Photonics" of Russian Academy of Sciences, 151 Molodogvardeyskaya st., Samara 443001, Russia

Abstract

The aim of the paper is to compare the efficiency of vehicle routing algorithms used in transport networks. We consider a centralized approach, in which the calculation of the routes of all vehicles is performed in a centralized traffic management system. We investigate routing algorithms based on the shortest path algorithm in a static time-dependent network, as well as the effect of the rerouting procedure on the total travel time. Comparison of the algorithms efficiency is carried out in microscopic simulation of a real-world traffic environment in the network of Samara, Russia.

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1. Introduction

Existing routing problem statements allow finding the shortest path or calculating an adaptive route in static or time-dependent, deterministic or stochastic transport networks. Used car navigation systems take into account current or forecast information about the traffic flows state to build routes that avoid road congestion and minimize travel time. Unfortunately, such systems can only react to the appearance of congestion, but not prevent their

* Corresponding author.
E-mail address: ant.agafonov@gmail.com

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occurrence. At the same time, the gradual development of autonomous vehicles can solve the problem of minimizing traffic time in terms of efficient vehicles distribution in the network. This distribution can decrease the level of traffic congestion and reduce the total travel time in the network.

There are different approaches to the vehicle routing systems classification [1].

In static systems, the routing problem is solved on the assumption that the characteristics of the transport flow are time independent. Various shortest path algorithms was considered in [2]. Dynamic systems take into account information about traffic flows in real time, which allows reacting to the transport situation changes [3, 4]. The next step in the routing problem study is the stochastic networks consideration in which the travel time of the road network segments is modeled as a random variable [5, 6, 7]. Stochastic systems require a large amount of data and computational resources to build a route, but they allow to navigate a vehicle with less travel time.

Routing systems can also be classified according to the type of information used to construct the route: real-time systems and predictive systems. In [8], the authors examined the effectiveness of various routing strategies in real-time systems. Predictive systems perform routing based on predicted values of the transport flow parameters calculated for a certain prediction horizon. In work [9] the authors studied a method for determining the shortest path in a time-dependent stochastic network, that taking into account current and forecast information about the traffic flow parameters in the network.

In the reviewed papers routing algorithms did not considered the influence of the route choice on the transport network state. The movement of the vehicle on the road segment in saturation state can lead to the traffic jam formation on this segment. Therefore, it is necessary not only to minimize the travel time of each route, but also to prevent the traffic congestions.

In paper [10] authors presented a decentralized approach to the routing on the basis of multiagent systems. Authors considered each vehicle as an agent that not only chooses a traffic route, but also reserves a slot for the vehicle at an intersection. The article [11] described the architecture of a traffic control system designed to prevent traffic congestion. Authors used an iterative approach based on Dijkstra's shortest path algorithm.

In this paper, we consider a centralized approach to the routing problem. We assume that the routes for all vehicles are built in a centralized traffic management system. We investigate routing algorithms based on the shortest path in the deterministic time-dependent transport network, as well as the effect of the rerouting procedure on the overall travel times.

The paper is structured as follows. The second section introduces the basic notation and describes the routing algorithms. The third section presents the experimental study of the algorithms in a microscopic traffic simulation environment. Finally, we draw the conclusions and discuss the future work.

2. Problem statement

2.1. Basic notation

We consider the road network as an oriented graph, the edges of which corresponds to the road segments, and the nodes correspond to the intersections. In the general case, we consider a time-dependent graph $G = (V, E)$, where V is the set of nodes, $|V|$ is the number of nodes, E is the set of edges, and $|E|$ is the number of edges.

Each road segment is characterized by reserved traffic $r_{ij}(\tau), i \in V, j \in V, e_{ij} \in E$, i.e. the number of vehicles on the road segment $e_{ij} \in E$ at the time τ.

Let U be the set of vehicles. We suppose, that for each vehicle $u_k \in U$ the origin, the destination nodes and the start time are known, i.e. $u_k = \{o_k, d_k, \tau_k\}$, where

o_k is the origin node;

d_k is the destination node;

τ_k is the start time.

Let $p_k = \{e_{ij} \in E\}$ be the shortest path of the k-th vehicle between nodes o_k and d_k.

Then the routing problem can be formulated as minimization of the total travel time:

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