

Optimization of Road Distribution for Traffic System Based on Vehicle's Priority

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Abstract. Instead of making the traffic system work fluently by focusing on each car's way to choose their routes, in this paper, we proposed a way to make the vehicles avoid being involved into the traffic congestion by allocating the roads which are regarded as one kind of resources to the vehicles. In order to make the road allocation fair, we introduce the parameter to show each vehicle's priority. We allocate the roads by regarding it as a linear programming problem and use linear programming to solve it. The experiment was done by using simulator SUMO and we testified that our proposal can make the vehicles avoid getting involved into traffic congestion and verified the usefulness of the vehicle's priority.

Keywords: Traffic simulation · Road allocation · Priority · Linear programming · Optimization

1 Introduction

With the economical development, the number of the vehicles in the world is increasing continuously. As a result, traffic congestion has become a significant traffic problem in many cities [1]. In order to reduce the happening of the traffic congestion, many researches have been done from different aspects.

In this paper, we propose a framework to find the optimal route set which includes each vehicle's own route of the traffic system based on vehicle's priority. We regard the roads as one kind of resources and try to use the idea of resource and allocation [2] to find the optimal way to allocate the roads to the vehicles that need to use the roads. At the same time, in order to insure that the road allocation is fair to each vehicle, we introduce the parameter which represents the priority of vehicle.

In the proposed framework, first, we need to find the possible routes that a vehicle can use to travel from its origin to its destination. The routes for each vehicle in the traffic system should be found respectively. Second, we need to find the optimal route combination from each vehicle's possible routes by using linear programming. After all the vehicles reaching their destination, the priority of each vehicle will be updated.

The remainder of this paper is organized as follows: Sect. 2 introduces the related work of this paper. Section 3 describes the details of the optimization of road distribution. Section 4 shows the experiment we designed to testify the proposed framework and the results we got from the experiment. Section 5 shows the conclusion of this research and the future work of this research.

2 Related Work

Many approaches have been done to try to alleviate traffic congestion. For example, in-vehicle route guidance systems are designed to help the vehicles choose a more efficient route [3,4]. New parking system [5] is developed to help drivers save more time during the parking process.

In traffic simulation, new simulation model is designed to in order to apply in more complex urban networks and get more accurate travel information [6]. Recently, multi-agent technologies [7] also have been used in different systems such as distributed resource allocation [8]. They can also be well used in transportation management such as intersection control [9]. Negotiation system also has been used in order to acquire efficient traffic flow [10].

At the same time, it should be noted that sometimes it will make the traffic congestion become worse [11] if we don't choose a effective method.

Some of the papers are focusing on searching the optimal route for each individual vehicle. It is also necessary to consider multiple vehicles in the traffic system simultaneously. Most of the papers are considering one time traffic situation. In order to control the traffic in a fair way, it is necessary to consider the traffic control in a long time way because there will be conflicts if multiple vehicles want to use the same roads at the same time and we need to decide which vehicle should use the road this time.

In this paper, we proposed a framework using the idea of resource and allocation to distribute roads to multiple vehicles and try to improve the fairness of the road distribution by considering vehicle's priority.

3 Optimization of Road Distribution

In this section, first we introduce the algorithm that we use to find each vehicle's possible routes. After that the way to find the optimal route combination is introduced. The method to update vehicle's priority is introduced in the end.

3.1 Find Each Vehicle's Possible Routes

Before calculating the optimal route combination for the traffic system. We need to find each vehicle's possible routes at first. In order to make vehicle avoid being involved in the traffic congestion which may happen in part of particular routes, instead of one possible route, multiple possible routes should be searched for each vehicle. In this paper, we adopt Yen's Algorithm [12] to find each vehicle's multiple

possible routes. Yen’s Algorithm is one kind of K Shortest Path Algorithm. The number of the possible routes that we want to find can be set in the algorithm. The possible routes that found by Yen’s algorithm are without loops and in an ascending order which starts from the shortest route.

3.2 Find Optimal Route Set

In this paper, we consider a route is made up of one road or multiple roads. Every possible route set of the traffic system is made up by choosing one route from each vehicle’s possible routes. The optimal route set is chosen by the sum cost of the route set. The way to calculate the cost of the route set is to use the objective function which is defined by Eq. (1). The restrictions are defined by Eqs. (2), (3) and (4).

$$\min \sum_{i \in I} \sum_{r_i \in R_i} C_d(r_i) \times C_{p,i} \times x(r_i) \tag{1}$$

$$s.t. \sum_{r_i \in R_i} x(r_i) = 1 \quad \forall i \in I \tag{2}$$

$$x(r_i) = \{0, 1\} \quad \forall r_i \in R_i \quad \forall i \in I \tag{3}$$

$$\sum_{i \in I} \sum_{r_i \in R_i} x(r_i) \times Num(r_i, e) \leq n(e) \tag{4}$$

In the objective function, there are three main parts which are route cost, priority cost and the restriction of choosing only one route for each vehicle from the vehicle’s possible route set.

I represents the set of all the vehicles in the traffic system. i is one individual vehicle. R_i represents the set of the possible routes of vehicle i . r_i is one possible route of vehicle i . $C_d(r_i)$ represents the route cost which is decided by the length of the route. $C_{p,i}$ represents the priority cost which is decided by the priority of the vehicle.

$\sum_{r_i \in R_i} x(r_i)$ is equal to 1 because each vehicle can be allocated with only one route eventually. $x(r_i)$ shows whether route r_i is chosen by vehicle. As a result, r_i can just be 0 or 1. 1 means that the route is chosen by the vehicle and 0 means not chosen. $Num(r_i, e)$ represents the number of road e in route r_i . $n(e)$ represents the restrictive vehicle’s number of the vehicles that can pass through road e in one unit time. $n(e)$ can be used to represent the traffic control of the road which is caused by construction or disaster. If $\sum_{i \in I} \sum_{r_i \in R_i} x(r_i) \times Num(r_i, e)$ is bigger than $n(e)$, it means there will be traffic congestion in road e .

In this paper, we use linear programming to solve the problem of finding the optimal route set.

3.3 Update the Priority of Vehicle

In this paper, the priority of the vehicle is updated when the vehicle get allocated to a route which has a longer length than the shortest route. In other words, it shows that how much did the vehicle sacrifice itself when actually there is a shorter route that can be used to get to the destination.

After all the vehicles reaching their destinations, the priority of each vehicle will be updated. If the vehicle is allocated with a route that is longer than its shortest route, it will be updated. And the way to update the priority is shown in Eq. (5). Otherwise, it will be the same as before.

$$C_{p,i} = C_{p,i} + \frac{Length(r_i) - Length(r_0)}{Length(r_0)} \quad (5)$$

where $C_{p,i}$ represents the priority of the vehicle. $Length(r_i)$ represents the length of the route that is been allocated to vehicle i . And $Length(r_0)$ represents the length of the shortest route in the possible route set of vehicle i .

4 Experiment

In order to testify whether the proposed framework can be useful to help the vehicles to avoid the traffic congestion and verify the usefulness of the introduced parameter, vehicle's priority, we did the experiment by using the simulator SUMO (Simulation of Urban MOBility) [13]. SUMO is a free and open traffic simulation suite which allows modelling of intermodal traffic systems including road vehicles, public transport and pedestrians. In the experiment, we use Gurobi Optimizer [14] as the tool to find the optimal route set which is regarded as a linear programming problem.

4.1 Setting of the Experiment

The map we use in the experiment is part of the Nagoya City's Open Street Map (OSM) [15]. Simulator SUMO can import OSM format data to use. And it is shown in Figs. 1 and 2.

As is shown in Fig. 3, in the experiment, we let 20 vehicles travel from the origin point A to destination point B. The experiment is divided into three cases which differ from each other in whether there is traffic control in the road and whether the priority is introduced.

- In case1, we do not set traffic control in the road and we do not introduce the priority of the vehicle.
- In case2, we set traffic control in the road which is red in the map but we do not introduce the priority of the vehicle.
- In case3, we set traffic control in the road which is red in the map and introduce the priority of the vehicle.

The details of the three cases are shown in Table 1.

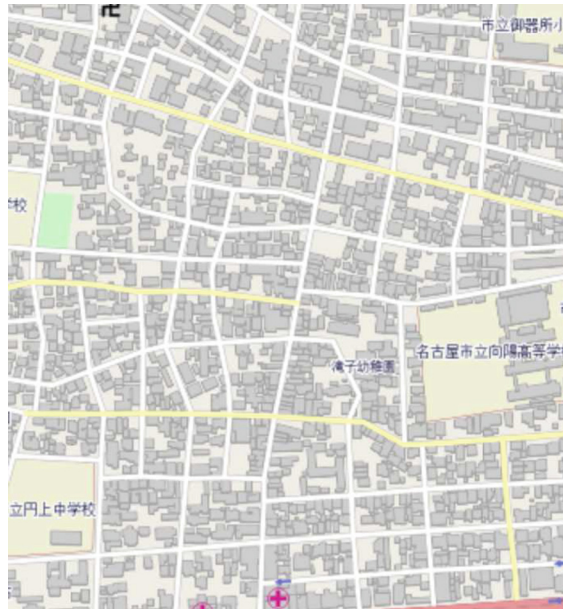


Fig. 1. The map shown in OSM

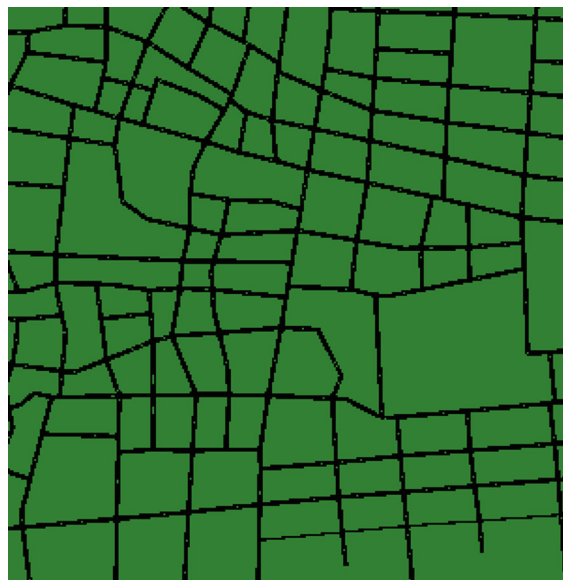


Fig. 2. The map shown in SUMO



Fig. 3. The map used in experiment (Color figure online)

Table 1. Experiment setting

Case number	Vehicle number	Simulation number	Traffic control (car/min)	Priority introduced
1	20	10	-	No
2	20	10	6	No
3	20	10	6	Yes

4.2 Results of the Experiment

After finish 10 iterations of the experiment, we collect the statistics of the sum of each vehicle’s movement distance which is shown in Figs. 4 and 5.

From Fig. 4, we can see the contrast between Case1 and Case2. In Case2, part of the vehicles traveled longer distance than in Case1. From that statistics, we confirmed that if under the condition that there is traffic control in the shortest route, some of the vehicles will be allocated with a route which is longer than their shortest route in order to avoid leading traffic congestion. But the vehicles that are allocated with a longer route than their shortest route are always some particular vehicles. As a result, we confirmed that our framework can split the vehicles from the roads where may have traffic congestion but we can not say it is fair for all vehicles.

From Fig. 5, we can see the contrast between Case2 and Case3. From that statistics, we confirmed that if under the condition that there is traffic control in the shortest route, just like Case2, some of the vehicles will be allocated with

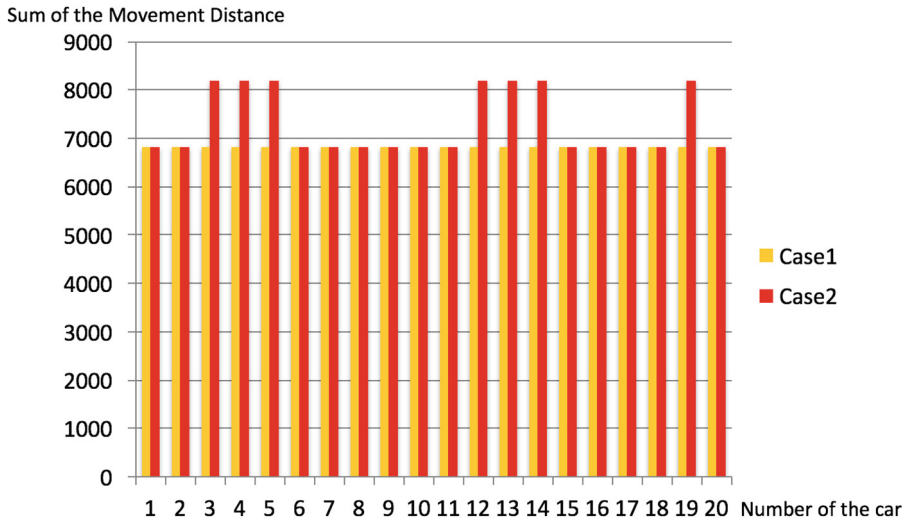


Fig. 4. The statistics of the sum of the movement distance (Color figure online)

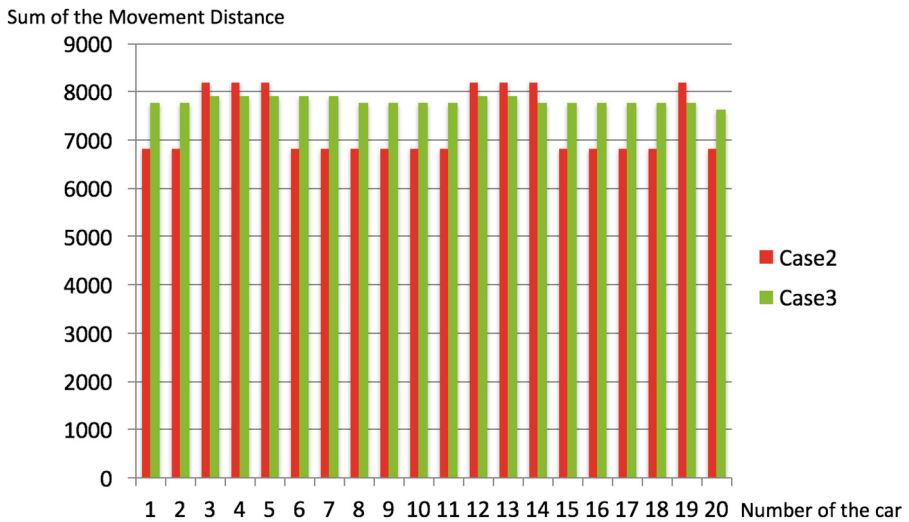


Fig. 5. The statistics of the sum of the movement distance (Color figure online)

a route which is longer than their shortest route in order to avoid leading traffic congestion in Case3. But in Case3, by calculating the standard deviation of each vehicle’s sum of movement distance, as shown in Fig. 6, we can know that the variation of each vehicle’s sum of movement distance is much smaller than that in Case2. It means that instead of particular vehicles, all the vehicles have been

Deviation of Each Vehicle's Sum of Movement Distance

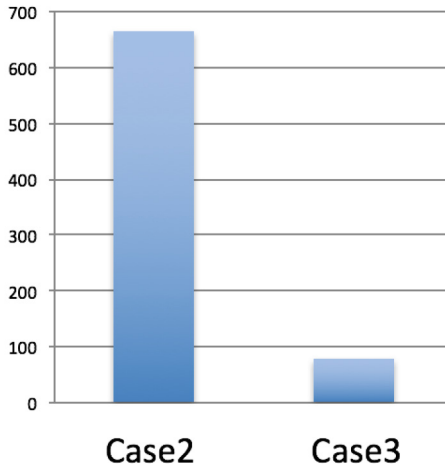


Fig. 6. Deviation of each vehicle's sum of movement distance

allocated with the route which is longer than their shortest route. As a result, we confirmed the usefulness of the priority of the vehicles that we introduced.

5 Conclusion and Future Work

In this paper, we proposed a centralized control framework and testified that it can be used to split the traffic flow to help the vehicles from being involved into traffic congestion and we verified the usefulness of the priority of vehicle which can maintain the fairness of the road allocation for the vehicles in the traffic system.

In the future, we are going to testify the framework in larger scale and improve the way to define the cost function. What's more, it will be more meaningful if we can introduce the negotiation between the vehicles into our framework. As our goal, we want our proposed framework will be useful as a part of the policy that can be applied in the automatic driving.

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References

1. Arnott, R., Rave, T., Schob, R.: *Alleviating Urban Traffic Congestion*. MIT Press, Cambridge (2005)

2. Jihang, Z., Minjie, Z., Fenghui, R., Jiakun, L.: A multiagent-based domain transportation approach for optimal resource allocation in emergency management. In: The Proceedings of the 2nd International Workshop on Smart Simulation and Modelling for Complex Systems, Buenos Aires, Argentina, 25 July 2015
3. Wei, D.: An overview of in-vehicle route guidance system. In: Australasian Transport Research Forum Proceedings (2011)
4. Zou, L., Xu, J.M., Zhu, L.X.: Application of genetic algorithm in dynamic route guidance system. *J. Transp. Syst. Eng. Inf. Technol.* **7**(3), 45–48 (2007)
5. Geng, Y., Cassandras, C.: New “smart parking” system based on resource allocation and reservations. *IEEE Trans. Intell. Transp. Syst.* **14**(3), 1129–1139 (2013)
6. Tokuda, S., Kanamori, R., Ito, T.: Development of traffic simulator based on stochastic cell transmission model for urban network. In: Dam, H.K., Pitt, J., Xu, Y., Governatori, G., Ito, T. (eds.) *PRIMA 2014. LNCS*, vol. 8861, pp. 150–165. Springer, Heidelberg (2014)
7. Ito, T., Kanamori, R., Chakraborty, S., Otsuka, T., Hara, K.: A survey of multi-agents research that supports future societal systems(1)-economic paradigm, negotiating agents, and transportation management. *J. JSAI* **28**(3), 360–367 (2013)
8. Zhang, C., Lesser, V., Shenoy, P.J.: A multi-agent learning approach to online distributed resource allocation. In: Proceedings of the 21st International Joint Conference on Artificial Intelligence, IJCAI 2009, Pasadena, California, USA, 11–17 July 2009
9. Dresner, K., Stone, P.: Multiagent traffic management: an improved intersection control mechanism. In: 4th International Conference on Autonomous Agents and Multiagent Systems, AAMAS 2005, Utrecht, Netherlands, 25–29 July 2005
10. Takahashi, J., Kanamori, R., Ito, T.: Evaluation of automated negotiation system for changing route assignment to acquire efficient traffic flow. In: 2013 IEEE 6th International Conference on Service-Oriented Computing and Applications, Koloa, HI, pp. 351–355, 16–18 December 2013
11. Braess, D., Nagurney, A., Wakolbinger, T.: On a paradox of traffic planning. *Transp. Sci.* **39**, 446–450 (2005)
12. Yen, J.Y.: Finding the k-shortest loopless paths in a network. *Manag. Sci.* **17**, 712–716 (1971)
13. Krajzewicz, D., Erdmann, J., Behrisch, M., Bieker, L.: Recent development and applications of SUMO - Simulation of Urban MObility. *Int. J. Adv. Syst. Meas.* **5**(3&4), 128–138 (2012)
14. Gurobi Optimizer. <http://www.octobersky.jp/products/gurobi/>
15. Open Street Map. <http://www.openstreetmap.org/>