

Parking assignment problem: An algorithm for balancing parking demand on multiple parking lots

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Abstract

In parking assignment problem when several parking lots are available, vehicles' drivers have to make a decision where to park. In this situation, if vehicles just tackle its parking problem, unbalancing parking demand between multiple parking lots will rise. Some parking lots have long queue while other parking lots are underutilized. It causes localized congestion and pollution peaks. Then, our focus in this study is how to balance parking demand on multiple parking lots. By considering not only number of free spaces but also number of vehicles in queue of specific parking lots, an algorithm for balancing parking demand on multiple parking lots is proposed. The simulation results using ARENA show that the number of vehicles parking in multiple parking lots is balanced.

Key word: Parking assignment problem, multiple parking lots, balancing parking demand.

1. Introduction

According to the International Parking Institute (IPI), 60 percent of the world will live in cities in 2030, and HIS Automotive, an industry research group, estimates that the number of vehicles on the roads will tally 284 million, up from 253 million today. This rapid increase leads to the high demand for parking space and during busy periods of the day, it is common for drivers to keep circling in order to search for an available spot. This activity creates many problems and frustrations for drivers. It has been shown that around 30% of the traffic in these congested areas is in fact due to cruising vehicles [1]. Moreover, a study [2] has shown that this would account for waste of 8.37 million gallons of gasoline and over 129,000 tons of CO₂ emissions. Therefore, an optimal strategy to find a parking spot can remarkably relieve traffic congestion, reduce air pollution and enhance driving comfortably effectively.

The parking assignment problem has been gaining attention from both academic and industry. From the perspective of the vehicles, solutions for parking assignment problem concentrate how to assign vehicle to a parking space with best cost and most convenient. Actually, the expenditure of finding a parking spaces of vehicles is associated with two basic cost [3], individual cost and social cost. Individual cost is the cost including searching, parking for a parking space. The social cost is the cost to the city of that same driver finding a parking space. If vehicles just tackle its parking problem, unbalancing parking demand between multiple parking lots (PLs) will rise. Some parking lots have long queue while other parking lots are underutilized. It causes localized congestion and pollution peaks. Clearly, social cost need to be considered as an important factor when guiding vehicles to choose one from multiple parking lots. Then, the problem now is how to balance parking demand on multiple parking lots.

To the best of our knowledge, only Schlote Arieh et al [3] has addressed balancing parking demand on multiple parking lots. In this study, each vehicle decides to park at parking lot j based on parking probability. For each parking lot j , this value is determined as proportion of number of free spaces in this parking lot to number of free spaces of all multiple parking lots in the same area. In this study, we also solve parking assignment problem with objective of balancing to prevent localized congestion and pollution peak. The different from [3] is in our work not only considering number of free spaces but also dealing with number of vehicles in queue of specific parking lot. The simulation results demonstrate that the proposed approach can balance parking demand on multiple parking lots. Then available free parking spaces are utilized efficiently, and localized congestion and pollution peak are reduced.

The remainder of this paper is organized as follows. Section 2 present basic algorithm for balancing parking demand on multiple parking lots. Section 3 draws simulation. Section 4 summarizes the paper.

2. Basic Algorithm

a) Notations

The parking lots broadcast a green signal, indicating their ability to accept a new vehicles. Simultaneously, it is assumed that vehicles listen to and sense green signals from parking lots. By this way, vehicles is assigned to the parking lots that have the best conditions, such as highest free spaces, shortest queue.

For each EVs i , it chooses a parking lot by considering the current condition of parking lot as we mentioned before. In this study we deal with two conditions: number of free spaces in parking lot and queue cost.

Before going to the algorithm, we introduce some notations and definitions that will be helpful in the

formulating the problem and understanding the algorithm.

- V : Set of all vehicles with parking queries.

$$V = \{v_1, v_2, \dots, v_n\}$$
- P : Set of all available parking lots.

$$P = \{p_1, p_2, \dots, p_m\}$$
- n_j : The number of free spaces in parking lot j .
- c_j : The capacity of the parking lot j .
- τ_j : The number of vehicles is parking at parking lot j .
- k_j : The number of vehicles is in queue of parking lot j .
- f_j : The occupancy cost at the parking lot j . It depends on the number of parking spaces is in use in the j th parking lots over that number of whole system. Then, it is calculated as in equation 1.

$$f_j = \frac{\tau_j}{\sum_{l=1}^m \tau_l} \quad (1)$$

- q_j : The *queue cost* at the parking lot j . It depends on the number of vehicles is in queue of the j th parking lot over that number of whole system. It is calculated as in equation 2.

$$q_j = \frac{k_j}{\sum_{l=1}^m k_l} \quad (2)$$

b) Algorithm

When vehicles' drivers need to park their car, they have to make a decision between several parking lots. Then, vehicles make a decision to travel to a particular parking lot based on Algorithm 1.

Algorithm 1: Pseudo-code for the proposed algorithm for choosing best parking lot.

- 1: for $j \rightarrow 1$ to m do
- 2: $\tau_j \rightarrow$ number of spaces is in use in parking lot j
- 3: $k_j \rightarrow$ number of vehicles is in queue at parking lot j
- 4: for $j \rightarrow 1$ to m do
- 4: calculate parking criterion (Eq.1, Eq. 2)
- 5: Go to car park j having best parking criterions.

3. Simulation

Now we present a simulation with four car parks with a capacity for 40 cars each. It is considered that

it has 1000 cars arrive according to a Poisson process with average inter-arrival time of 10 minutes. Vehicles then stay parked for an exponentially distributed time with a mean of 20 minutes. The simulation is run until all vehicles were serviced.

In this study, ARENA is used as the simulation tool. ARENA is discrete event simulation and automation software developed by System Modeling and acquired by Rockwell Automation in 2000 [4-5]. To build models with Arena, we will be using modeling shapes, called modules to define your process. There are two types of modules on a panel: Flowchart modules and Data modules. An Arena model of the parking decision of vehicles among multiple parking facilities is illustrated in figure 1.

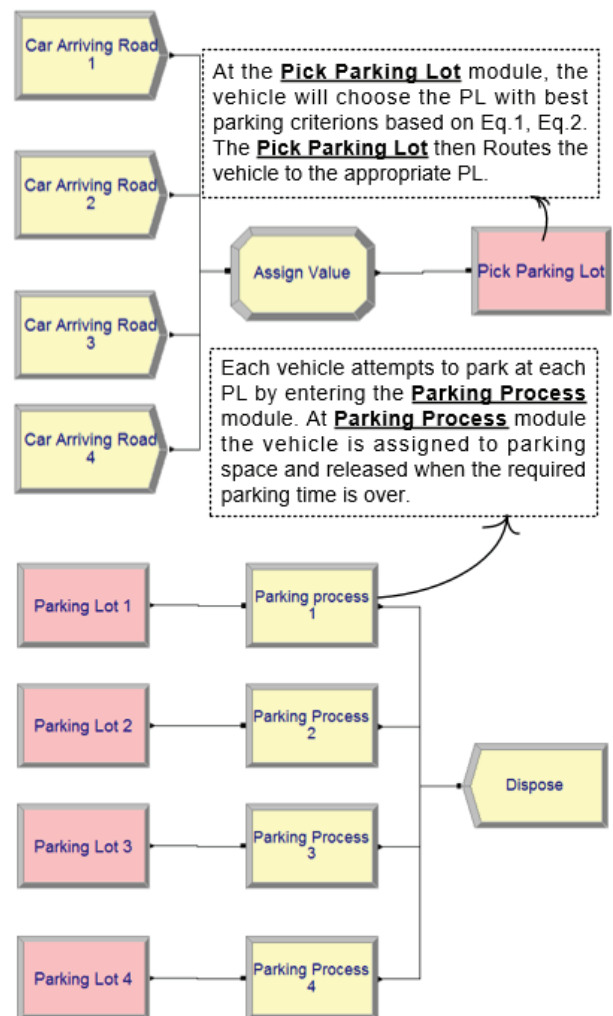


Figure 1. Arena model of the parking decision of vehicles among multiple parking facilities

As we analyzed in section 2, each vehicle will choose the parking lot to park based on parking condition that is broadcasted to vehicles. Three scenarios are examined in this study.

- Scenario 1: it is observed the free spaces at each parking lot. It means vehicles have the

trend in choosing parking lot that has maximum value n_j

$$p_j \leftarrow n_j$$

- Scenario 2: In this simulation, the number of free spaces is used as broadcasted value from parking lots to vehicles. Then, vehicles decide to park at parking lot as equation mentioned in [3].

$$p \leftarrow \frac{n_j}{\sum_{l=1}^m n_l}$$

- Scenario 3: Our proposed algorithm is implemented in this scenarios. Both parameters, free spaces and queue cost, are used in this scenario.

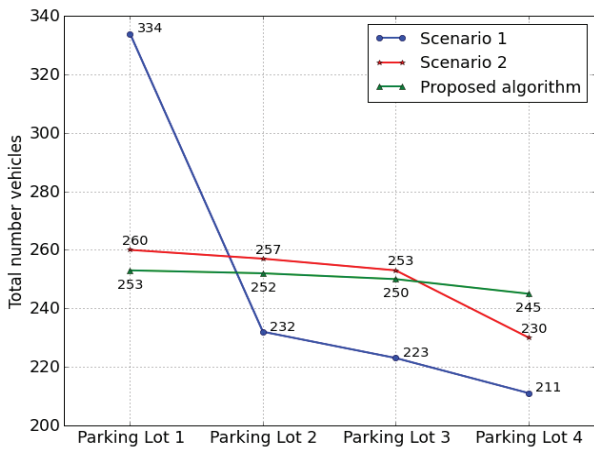


Figure 2. Balancing of parking demand between parking lots

Firstly, we evaluate parking balancing between parking lots. As shown in figure 2, when queueing cost is consider, the number of vehicles parked at each parking lot are approximately balancing. On the other hand, by only looking at the parking lot having more free spaces, probability in that vehicles select and travel to same parking lot is high. As the result, it causes localized congestion and pollution peak. Not only observing the number of free spaces but also considering how many vehicles is waiting at each particular parking lot, scenario 3 gives the best result in term of parking balancing to vehicle. Without a doubt, the red line shows the differential value of number of parking vehicles between parking lots is extremely small, with highest value is 0.015 percent.

Next, we made a sketch comparison of waiting time and total parking time to show effectiveness of three scenarios. Figure 3 illustrates that the best strategies for vehicles to make parking decision is full observation on both free spaces and queue cost. If it is only interested in how many space that parking lot currently is free, it increases risk of parking failure. In

other words, there is long waiting time. For this reason the total parking time of system also raise.

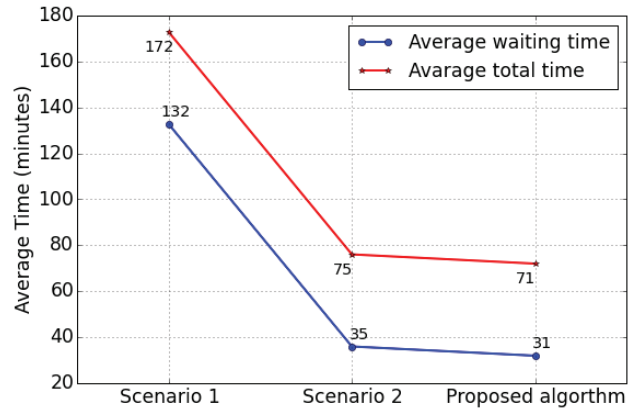


Figure 3. Comparison of average waiting time and average total parking time

4. Conclusion

In this paper, we observe a parking assignment problem where several parking lots are available. Then, vehicles' drivers have to make a decision where to park so that it can not only save its individual cost but also decrease social cost. Our focus is social cost that is known as localized congestion and peak pollution. To solving this objective, our algorithm is proposed by considering both number of free spaces and number of vehicles in queue of specific parking lots. We performed simulation using ARENA to prove that our approach can balance parking demand on multiple parking lots.

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