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Micro-Simulation of Car Drivers' Movements at Parking Lots

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Abstract

Drivers' movements across or within parking facilities contribute to various problems, *i.e.*, congestion, safety, and environmental effects. Micro-simulation can help to increase the understanding of drivers' movements and their effects on parking management. This study aims to develop a multi agent-based simulation tool to demonstrate its capability of studying driver movements across parking lots. The program was constructed using the multi-agent modeling environment NetLogo. The developed simulation tool allows to adjust features of the parking facilities. Additionally, vehicle travel time and parking occupancy indicators were integrated to investigate the efficiency of the parking.

1. Introduction

Parking facilities are important elements in the urban transportation system, especially in an era when the number of car owners is increasing. The increasing number of car users leads to an incremental demand of parking facilities. Congestion and environmental problems (*e.g.,* emission and noise) are also acknowledged as consequences of drivers search for parking [1]. According to Federal Highway Administration, parking-related accidents accounted for 49% of all mid-block crashes along major streets, 68% and 72% along collector streets and local streets respectively [2]. Additionally, when the demand of parking could not be satisfied, the parking shortages can create poor accessibility reputations of cities which might decrease the attractiveness to shoppers, tourists, and commuters.

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To satisfy the parking demand, constructing new parking facilities is one of the possible choices of many transportation experts and policy makers. However, construction of new facilities is not always possible due to lack of money, human, time, and land resources. Another solution that might be applied to meet the demand of parking is the optimization of parking facility usage. This approach seems to be more efficient since it consumes less resources. When optimizing parking facility usage, an appropriate and efficient layout of parking areas should be considered as one of the initial criteria. In order to have a proper design, understanding car drivers' movement across parking lots plays a decisive role [3]. Micro-simulation is widely considered as a method that studies the drivers' behaviors. For example, Bonsall and Palmer used PARKIT parking choice simulator to model car off-street parking behaviors of drivers [4]. Another application of micro-simulation is PARKAGENT. It is an agent-based model that was used to simulate the on-street parking behavior of drivers in Tel Aviv city [5]. However, these studies have focused on simulating the behaviors of the whole parking process or the choice of parking facility but not on the car drivers' movement across parking lots.

Among micro-simulation programs, multi agent-based modelling simulation environment of NetLogo has shown its advantages for behavioral simulation. This program allows researchers investigate the connection between micro-level behaviors of individuals, and macro-level patterns coming from their interactions. Also, NetLogo is an open-source software and quite simple but powerful and users can create their own models. Those advantages make it become a promising method for transportation researchers. Though NetLogo is quite popular in other fields, it has not been applied often in the transportation field yet [6]. Based on the current parking problem and the advantages of Netlogo, there is still need for further studies on application of NetLogo in drivers' movement simulation at parking lots. This study, therefore, aims to develop a micro-simulation of drivers' movements at the parking lot using the NetLogo environment. The developed tool will be validated with a case study using existing data [7].

2. Theoretical background

2.1. Factor influenced the parking movement at the parking lot

Parking movement at the parking lot includes two steps *i.e.*, route choice for parking strip, and route choice for parking space. These two steps are complex since they are influenced by many factors. The route choice for parking strip will be influenced by four factors. Firstly, the distance between the parking strip and the final destination affects the parking movement [4,8,9]. Secondly, the parking's attractiveness is another factor and this includes three sub-factors *i.e.*, driver's perception, the parking strip characteristics and parking strip's disutility [8,10]. Thirdly, guidance information signs and the queuing time at parking space also influence on this process [4]. Finally, the travel time of the route and the walking time from the parking strip to the desired destination also have effects on this decision [4,9].

Similar to the route choice for parking strip, the choice for parking space is also affected by many factors. The first one is the distance between the location of the parking space and the final destination. Again, the driver tends to choose the parking space which is closest to the final destination [9]. Distance between the parking space and the ticket machine also influences the choice of parking space [7]. Together with distance, the driver's gender is the second influenced factor *i.e.*, male prefers to park closer to the entrance of the parking lot. The car's size is the third one *i.e.*, bigger cars require to park at wider space while smaller cars lead drivers to choose a space which is occupied on both sides.

2.2. Parking indicators

Parking occupancy and average parking occupancy can be utilized to measure the effectiveness of the parking usage [11]. The parking occupancy indicator is a proportion of spaces occupied in a defined time interval. Based on the parking occupancy and number of observed time intervals, the average parking occupancy can be calculated. In simulation, the number of time interval influences both accuracy and duration of a micro-simulation run. The shorter time interval micro-simulation uses, the greater precision of the model results are. However, shorter time interval requires more computation [12]. Besides, the vehicle travel time, including travel time from the driver's vehicle current location at the car park and the searching time for the parking space at the parking strip will attract drivers