Vehicular Cooperation to Overcome the Car Park Challenge

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ABSTRACT

We demonstrate decentralized car parking using vehicle-to-vehicle cooperation. Extensive simulations of car parking scenarios illustrate the effectiveness of the approach in reducing car park searching time and getting nearer parking spaces.

1 INTRODUCTION

Finding car parking in a crowded area is considered by many drivers to be a massive burden associated with frustration. It was shown in [1, 2] the adverse impact of vehicles searching for parking on road traffic congestion levels, the environment, and the usage of time. The increased orientation towards urban living has effects on the tendency to own vehicles and increases the complexity of the transportation system. Many drivers, in turn, tend to use navigation applications to help them arrive at their destinations in a shorter time based on selecting a suitable route which considers road traffic information. However, they may still be shocked at arrival when they experience the difficulty in finding parking spaces. Consequently, there has been significant work investigating new car parking approaches. The remainder of this paper we will highlight the main characteristics of the proposed approaches in Section 2. In Section 3, we will explore our approach within different car parking scenarios. Finally, the conclusion is Section 4.

2 BACKGROUND OF THE CAR PARKING MANAGEMENT SYSTEMS

In general, car parking can be accomplished either by using an infrastructure or without, by using vehicles. In the first category, the infrastructure can ideally achieve optimal mapping with strategies to reduce the level of road traffic, driver conflicts, and the searching time. However, there are three issues to be addressed in designing a centralized system. Firstly, the cost for installing and maintaining the centralized system. Secondly, the complexity and scalability issue with serving a large car parking area and the large number of drivers with different requirements. Thirdly, user satisfaction, where the allocation process can be good for the system overall but may sacrifice some client wishes,making the situation worse for some drivers. Thus, shifting the decision from a central controller to the vehicles could be a feasible solution to manage the cost, scalability, complexity and user satisfaction levels. Vehicular Adhoc Networks (VANETs) facilitate the possibility of vehicles getting contextual information about the surrounding environment from others so they can adjust their routes based on the knowledge. However, the competition level among the vehicles/drivers, and the accuracy of the information related to the parking spaces and the searching vehicles are the main difficulties in implementing a practical distributed car parking system. There are a number of proposed approaches in this category aiming to manage the allocation of parking spaces with short searching time such as [3] [4]. Yet, they mainly adopt a game theoretic approach and assume a high level of accuracy about free vacant spaces and the number of drivers - it can be hard to meet these criteria in terms of an open environment.

3 OUR APPROACH

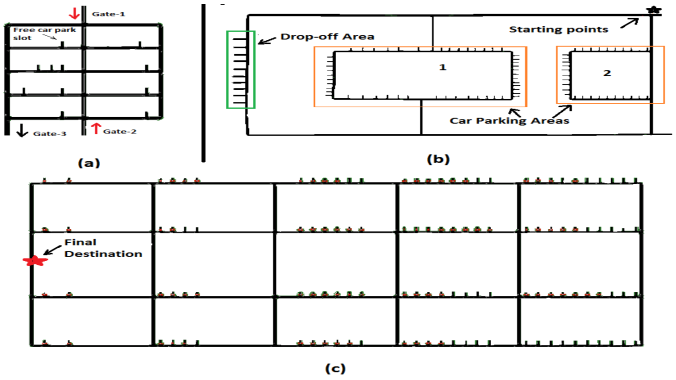

Figure 1: The simulated implementation of scenarios.

Our objective is to improve the vehicle's opportunity to get a good parking space with regards to searching time and walking distance from where car is parked to the final destination (e.g., a building entrance) based on smart software agents assumed installed in the vehicles and the capability of the vehicle to communicate with other nearby vehicles. We supposed that vehicles have same initial information about the area being search. The vehicle can enhance its opportunity to get a parking space based on strategic cooperation, instead of simply sharing information (which contributes to raising the competition level). In the other words, a vehicle can help the neighbouring vehicles while considering its own goal. Different car parking scenarios have been examined, as shown in Figure 1, based on a simulation tool which consists of SUMO [5] and JADE [6]. In [7], we investigated the searching process in parking lots with a few number of vacant parking spaces as shown in Figure 1(a). We demonstrated that vehicle cooperation through sharing intention and occupancy information can contribute towards reducing the

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searching time in comparison with random (and without cooperation) searching as shown in Figure 2. Furthermore, we expanded the car park area into a larger area as shown in Figure 1(c) with a scaling up of the number of searching vehicles. The walking distance factor has been considered in vehicle decision-making to select the preferred parking space. We proposed this version of our algorithm called CoPark-WS, the name coming from cooperative parking approach with considering waking distance and searching time parameters. Instead of dealing with the car park area as a whole area, our CoPark-WS distributes the searching process by dividing the large car park area into a number of subareas, assuming that every subarea has a number of free slots. We also assume that the slots in the same subarea are equally preferred and for efficient handling and gathering of parking information, every vehicle has partial knowledge based on their travelling routes, and share such information. Hence, the discovery aspect of parking information is not only when a vehicle arrives at a subarea, but also from other vehicles. CoPark-WS introduces two different types of cooperation messages that can be shared among vehicles when they come closer to each other (e.g., within DSRC communication range): sharing intentions, and offering advice. Moreover, the car parking (sub-)areas are evaluated by vehicles heuristically based on our proposed function as shown below:

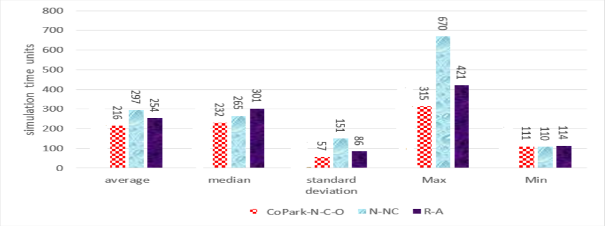

Figure 2: The Maximum, Minimum, Median, Standard Deviation, and Average values of time-to-park of 10 vehicles applying our proposed approach (called CoPark-N-C-O), without cooperation (N-NC) and random (RA) approaches.

$$U_i(k) = \alpha * Di(k) * V(k) * I + \beta * J(k) * (1 - V(k)) * (\omega_i/\omega_i - \rho_i(k))$$

where $Di(k)$ represents the demand level of the (sub-)area i - as determined by a vehicle based on receiving intention messages, $v(k)$ is the availability ratio of areas, Wi is the initial assumption of the number slots in area i, $pi(k)$ is the scanned (as the vehicle passes through the area itself) number of occupied slots at area i, I, J represent the area order/rank with respect to the distance of the area to the final destination (e.g., a building entrance) and the vehicle's position, respectively. Finally, $\alpha and \beta$ represent the smoothing factors. Experimentally, we compared CoPark-WS with another proposed approach named CoPark-GD (Greedy) that simply relies on vehicle cooperation by sharing intentions and compete on the nearest slots to the final destination. It is shown that CoPark-WS outperforms Greedy with regard to searching time as shown in Figure 3, and they converge on performance with respect to walking distance. In a different scenario, we explored the issue of dropping-off the passengers at a limited size drop-off area by autonomous vehicles as shown in Figure 1(b). It is supposed that the vehicle plan is to drop-off the passengers at the nearest allowed area, which can be either at the drop-off area or a further away car park area, as an alternative area in the case of traffic congestion at the drop-off area (with respect to the travelling time). We proposed a Cooperative Drop-Off (CDO) approach to coordinate the drop-off aspect by cooperation among the coming vehicles. There are two strategies considered by CDO. Firstly, the coming vehicles can cooperatively platoon and adjust their speeds based on cooperation with other vehicles in or near to the drop-off area in order to effectively reduce the arriving rate of vehicles to the drop-off area and give time for stopped vehicles at the drop-off area to leave. Secondly, biasing some vehicles to drop-off the passengers at the alternative place (the car park) in case a vehicle estimates an excessive waiting time at the drop-off area. Figure 4 shows a screen shot of the CDO sumulation scenario.

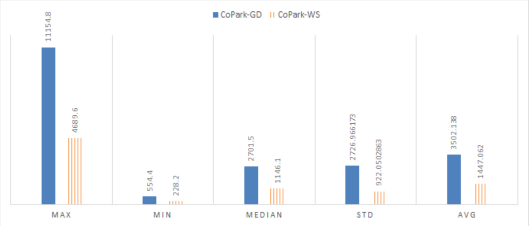

Figure 3: The Maximum, Minimum, Median, Standard Deviation, and Average values of time-to-park of 100 vehicles applying CoPark-WS and CoPark-GD approaches.

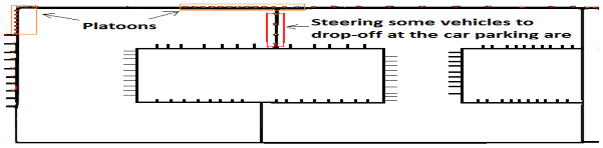

Figure 4: Scene of CDO simulation.

4 CONCLUSION

Much time can be wasted by drivers in finding parking spaces at crowded areas. We aim to facilitate the searching process by enabling cooperation among agents/vehicles, which works even without road-side infrastructure. Numerous car parking scenarios that can be experienced daily by the drivers have been simulated and assessed, demonstrating the usefulness of our approach.

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