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Intelligent Parking Management System using Dijkstra's Algorithm with Driver Preferences

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Abstract:
Abstract— Car Park is a dynamic system where cars are constantly entering and leaving the parking area. The aim of this work is to develop an algorithm, that assigns a parking slot based on the driver's criteria, especially in a mall/building Car Park. Here, the driver's preferences are considered while choosing a slot to park his/her car. Some of these preferences include driving distance, walking distance, environmental factors, and other factors. Here the driving distance is the shortest path between the entrance and the assigned parking slot. It is found out by using Dijkstra's Shortest Path algorithm. Walking distance is the Euclidean distance between the mall/building entrance and the parking slots. Environmental factors considered here are car occupancy at both sides of a slot and shape of the slot. Other factors include multiple entrances (two entrances are used in this study) and a slot assignment strategy (FIFO). The principles of fuzzy logic are being applied here for helping the driver to make a decision on which slot to choose by assigning fuzzy weights to the slots.

Keywords: *Car parking mechanism; Dijkstra's Shortest Path algorithm; Euclidean distance; Fuzzy logic.*

I. Introduction

The common method of finding a parking space in a mall/building Car Park is to find it manually which is time consuming and may lead to the worst case scenario of not finding a slot, especially if the driver is driving in high traffic conditions. The alternative is to choose a pre-defined parking space with high capacity. However, this is not an optimal solution as the car park could usually be far away from the user destination. The main motivation behind this study is the fact that not much research has been done in the area of automating the selection of a parking slot based on the driver's preferences.

"Recently, research has used vehicle-to-vehicle and vehicle-to-infrastructure interaction with the support of various wireless network technologies such as Radio Frequency Identification (RFID), ZigBee, Wireless Mesh Networks and the Internet"[4]. This work initially targeted to conduct a study of providing information about nearby parking spaces for the driver and make a reservation prior to his/her arrival to the car park using supported devices such as Smartphones or Tablet PC's. Later the work has been extended to choose a convenient parking slot in a car park

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based on driver's criteria using Dijkstra's Algorithm. While choosing a parking area, the preferences of the customer/driver play a vital role in determining the parking slot chosen. The major objective of this work is to propose the best parking slot in a car park based on drivers criteria. The scope of this study is limited to the following drivers' criteria:

1. Driving distance
2. Walking distance
3. Parking space environment
4. Other factors (Multiple entrances and exits)

The first factor is the Driving Distance which is the distance that the driver needs to drive before reaching the assigned parking slot. The Walking Distance is the other important factor while considering the car parking and it is the distance a person needs to walk from where the car has been parked to the building entrance/mall entrance. This factor is always kept as minimum as possible as people usually like to walk less. The third factor to consider is the parking space environment value where the occupation of vehicles on both sides of the slot and the parking slot shape is taken in to account. The final factor to take into account is the strategy in assigning a parking slot, which is FIFO. Here does a driver gets intimated when a more feasible slot is available compared to the currently assigned one and how this scenario is being dealt with. The proposed intelligent parking management system offer convenience for drivers by considering their choices and efficient usage of space. This system save space, time and make the parking easier.

The rest of the paper is structured as follows. Section 2 presents the background of the work by explaining the driver's preferences and the concerned factors. Section 3 gives a comprehensive literature review of all the prior works on distinct parking management systems. The succeeding section provide a detailed explanation of system design and mathematical algorithms used in the proposed system. The results and discussion is given in Section 5.

I. BACKGROUND

The driver's criteria can be defined based on various factors such as Driving Distance, Walking Distance, Environmental Factors and the Other Factors.

A. *Driving Distance*

The driving distance is the shortest distance from the car park entrance to the most convenient parking slot (calculated based on fuzzy logic). The algorithm chosen here to find the shortest path is Dijkstra's algorithm since Dijkstra's algorithm expands out in all directions trying to find all possible paths and has good performance in cases where destinations are many and does not employ any heuristics (the algorithm may not produce good results if heuristic function is not good enough).

B. *Walking Distance*

The walking distance refers to the distance from the parking space to the entrance of the mall/building. Euclidean distance is used here since it calculates the length of the straight line between two points. Here we have taken the assumption that people prefer to walk shortest distance as possible.

C. *Environmental Factors*

The factors considered here are the occupancy states of both sides of a parking space and the shape of the parking space. The Figure 1 shows the various car occupancy states in a parking space. They are (a) Both sides occupation (2) One side occupation and (3) No sides occupation. According to general rules for parking, no side occupancy is the best and both side's occupancy is the worst for parking convenience.

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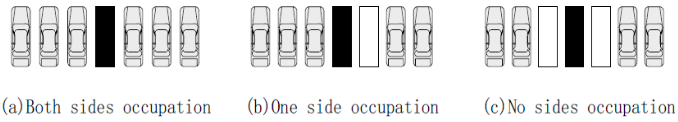
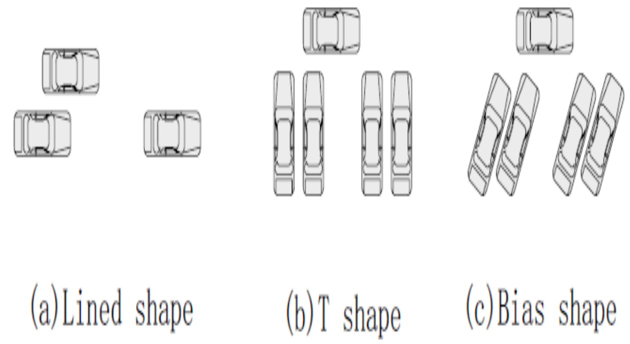


Figure 1: Car Occupancy [3]

The major three designs of car slots are given in Figure 2. They are (1) Lined shape, (2) T shape and (3) Bias shape. When considering parking shape of the parking space, line shaped parking space is the hardest to park and bias shaped parking space is the easiest to park.

Figure 2: Car Slot Shape [3]



D. *Other Factors*

Multiple entrances

Here Shortest Path using Dijkstra's Algorithm is calculated from the entrance to the assigned parking slot. Hence the shortest path varies according to the entrance. In this work, multiple entrances are considered to show this variation. Since this study does not depend on the position of the exit, a single exit alone is assumed.

Car slot assignment scheme

The proposed system has opted for the First In First Out (FIFO) scheme for users. The user who opt first for a slot will have the slot. Here there is an issue of two users accessing a slot at the same time. In such cases, the system itself deals with the scheduling as there would be at least nano seconds of difference in time. Even if there isn't, one request will be buffered while other is served which is the principle of all e-commerce websites.

II. RELATED WORK

The authors Mr Thanh Nam Pham et.al [4] introduces an algorithm that enhances the efficiency of cloud-based smart-parking system, also develops a network architecture based on Internet-of-Things technology. "They proposed a system that helps users to automatically find a free parking space at the least cost based on new performance metrics to calculate the user parking cost by considering the distance and the total number of free places in each car park. This cost will be used to offer a solution to find an available parking space upon a request by the user and a solution of suggesting a new car park, if the current car park is full. The simulation results show that the algorithm helps improve the probability of successful parking and minimizes the user's waiting time"[4]. The authors have successfully implemented the proposed system in the real world.

In the study conducted by Mr Kameswara Rao et.al [6] it was identified that the today's car parking has become a major issue in urban areas since the drivers who are searching for parking space were roaming around the city in peak hours due to lack of parking facilities and increased amount of vehicles. This causes traffic, a waste of time and money. "To solve these problems, a system is developed using sensor circuits, RFID and IoT. Here, RFID is used to detect the car details, the IR sensor is used to find the presence of the car and all the details are accessed remotely through Internet of Things (IoT)"[6]. In addition to parking, theft management is also included in the system i.e. "if a theft vehicle came for parking then the number plate is checked with the theft list in the database, if it is in theft list then a message is sent to the police. The developed system increases flexibility and security with less human interaction" [6].

A different approach by Ms Revathi G et.al [7] is based on Intelligent Decision Making System for Car Parking. "In this work, attempts were made to explore the real time concept of a smart parking system purported for Geographical Area Considered (GAC) environment. The monetary value of the commercially available smart parking

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system is eminent"[7]. The efficiency and reliability were increased considerably in the proposed work. The image-processing concept was used for identification of the number plate. In this work ZigBee protocol provides the information between the entrances and parking zone. The parking system mainly focused on allocating slots and provides slots for car parking. This could be extended by analysing the human behaviour[7].

After analysing all the above said studies, the technology used in each of them employed sensors, microcontrollers etc. which are more relevant to the field of electronics while the authors of this paper are interested in the relevance of the problem to the field of computer science. Hence an algorithmic approach was adopted. The authors Mr Liping Cheng et. al [2] proposes a system for finding the best parking slot using Hierarchical A* algorithm. Here it was argued that to find the optimal path in a large parking guidance system, only considering the shortest distance is not enough, only considering the shortest time is an ideal goal but not easy to realize, so introduced a feasible time-optimal evaluation in parking path planning. "Mathematical model R (P, C, D, V) of the parking lot network diagram was established, the all nodes in R (P, C, D, V) were divided into two layers and different evaluation functions were built. According to the improved time-optimal evaluation, the design used the improved A* algorithm to increase searching efficiency and precision. Finally, the result of running the program shows that the algorithm can quickly find out the different time-optimal path for different attribute parameter"[2]. But various drawbacks to this study was identified. Firstly, here not the distance optimal but the time optimal solution was considered which was not really necessary as the scope of congestion in a car park is minimal as high traffic is seen only occasionally. Secondly, the shortest path algorithm considered here is Hierarchical A* algorithm.

Another study by Mr Abhishek Goyal et. al [5] uses A* or Dijikstra's that A* algorithm is chosen in cases where the source and destination is already known while Dijkstra's is chosen when source but not destination is known (where there is several potential destinations). Also success of A* depends upon the Heuristic function chosen but Dijkstra's does not work on Heuristics. So here it was concluded that employing Dijkstra's instead of A* may be more feasible. Dijkstras is considered the best option if the destination is not fixed but are many to be considered [5]. Also the authors of [1] has successfully implemented the algorithm for shortest path calculation.

After critically analysing the available literature the authors are proposing a solution for choosing the best parking slot in a car park based on various factors. Since parking a vehicle depends mostly on the driver's preferences the following drivers preferences of driving distance, walking distance and environmental factors are considered in designing the proposed system.

III. SYSTEM DESIGN

The system is developed to provide the best parking slot in a car park based on various factors. The factors considered includes the driver's preferences which consist of driving distance, walking distance, environmental factors and other factors (multiple entrances and exits) as discussed in Section 2. Driving distance is the shortest path from the entrance to the parking slot and is calculated by using the Dijkstra's Shortest Path algorithm. Walking distance is the Euclidean distance between the mall entrances to the parking slot. Environmental factors considered here are vehicle occupation on both sides of a parking slot and shape of the parking slot itself. Principles of fuzzy logic are used here for decision making on which parking slot to choose. The fuzzy values are assigned to different cases of vehicle occupation based on the total area available, shape of the parking lot based on the angle of di- rection change while parking and walking distance based on the shortest Euclidean distance. The final weight is calculated by the fuzzy decision making equation.

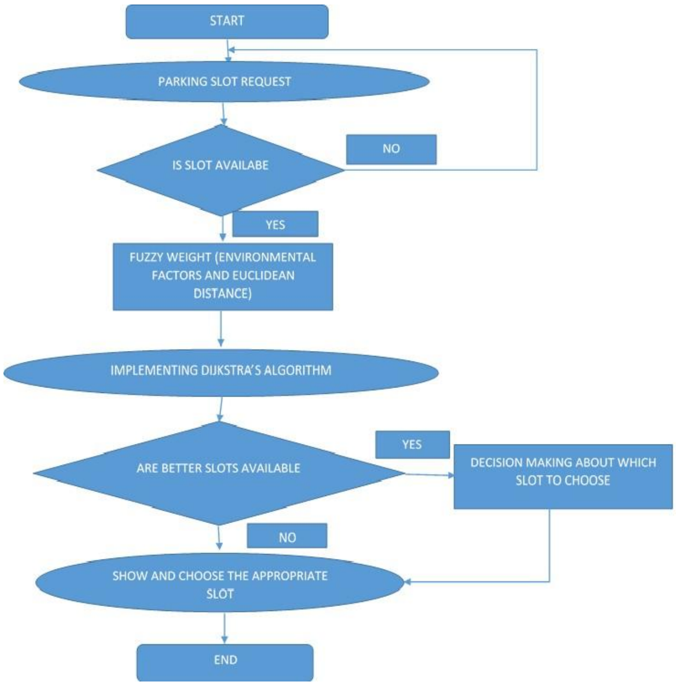

Figure 3: System Flow Chart

Fuzzy Weight = a+b-($a*$b)

where are a and b are the criteria to be selected.

Here, in total, there are three criteria namely occupation, shape and walking distance. The first two criteria are taken and the formula is applied and to the result the formula is again applied along with the third criteria to generate the final weight. This final weight is used for further decision making. The smaller the value the difficulty level is large. The higher the value the ease of parking is more. After fixing the best slot based on the weight Dijkstra's Shortest Path algorithm is applied to find the shortest path from the entrance to the best slot. The Figure 3 shows the flow chart of the developed system.

A. *Algorithm for Proposed System*

1. Check whether there is any free slot if yes go to Step 2 else go to Step 1
2. For every slot calculate the Occupancy Fuzzy Value (OFV), Shape Fuzzy Value (SFV) and Euclidean Distance Fuzzy Value (EFV)
3. Calculate Fuzzy Weight for Environmental Factor FEF using the formula FEF = OFV +SFV-($OFV*$SFV)
4. Calculate Final Fuzzy Weight FFW using the formula FFW = FEF +EFV-($FEF*$EFV)
5. Arrange the slots in decreasing order of FFW value, by applying fuzzy principle as this value decreases the difficulty in parking increases or smaller the FFW value less attractive is the parking slot
6. For n users, where n ¡=Number of free parking slots, assigned parking space for each user in the order of decreasing weights. List these as Assigned Slots (AS) against its corresponding user
7. The remaining free slots other than the Assigned Slots (AS) are shown as Remaining Available Slots (RS). This is updated whenever a new slot becomes available. The better slot options are compared to the currently assigned slots and will be appended here
8. Every user can change its AS to any of the RSs at any time. Once the user picks an RS from the list, the chosen RS becomes the new AS and the old AS gets added to the list of RSs
9. Once the slot is fixed for a user, the user's current entrance is identified and Dijkstra's algorithm is applied to find the shortest path or the route map is generated between the entrance and the slot

B. *Fuzzy Logic Application*

Calculating occupancy fuzzy value

When considering a parking slot, the occupancy states are threefold namely both sides vacant, single side vacant and both sides occupied. The criterion is to assign a fuzzy value to the available area. It is considered that when both sides (BSV) are vacant, the area available is

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maximum and when both sides are occupied (BSO), the area available is minimum and when a single side is occupied (SSO) the area available is mediocre. Therefore, the three different states are assigned to a variable named Occupancy Fuzzy Value (OFV) which contains the different fuzzy value for each state.

$$OFV = \begin{cases} .75 & \text{if both sides vacant (BSV)} \\ .50 & \text{if single side occupied (SSO)} \\ .25 & \text{if both sides occupied (BSO)} \end{cases}$$

Figure 4: Occupancy Fuzzy Value (OFV)

Calculating shape fuzzy value

When considering a Parking Slot, the shape states can be threefold namely Biased, T and Line. The angle of direction change that a car has to perform when parking in a certain shaped slot is taken as a criterion for assigning the fuzzy value. In Bias shaped, the angle of change is 45 degrees while in T shaped, it is 90 degrees and in Line shaped, it is 180 degrees. So the Shape Fuzzy Value (SFV) is assigned based on the angular measurements as follows.

$$SFV = \begin{cases} .75 & \text{For Bias Shaped. 45 Degrees Change} \\ .5 & \text{For T Shaped, 90 Degrees Change} \\ .25 & \text{For L Shaped, 180 Degrees Change} \end{cases}$$

Figure 5: Shape Fuzzy Value (SFV)

Calculating the Euclidean distance fuzzy value

To convert the Euclidean distance to a discrete fuzzy value is done using the following formula.

$$EFV = 1-(ED/MaxED)$$

Where EFV = Euclidean Distance Fuzzy Value, ED = Euclidean Distance from Mall Entrance to Slot and Max ED = Maximum Value that which ED can attain which is taken as 220 in this system.

Formula for calculating fuzzy weight

$$\text{Fuzzy Weight} = a+b-(a*b)$$

Where a = Fuzzy value of criteria1 and b = Fuzzy value of criteria2

Formula for calculating the Euclidean distance

$$\text{Euclidean Distance} = \text{sqrt}((x2-x1) * (x2-x1) + (y2-y1) * (y2-y1));$$

Where (x1, y1) and (x2, y2) are end points of a straight line path.

C. *Technology Used*

The system is designed using HTML and CSS. The server side scripting is done by using PHP which is stable and cross platform compatible. MySQL is used for backend database. These technologies help in creating user-friendly, interactive web applications that produce dynamic content [8]. They are easy to learn and understand and has been used in solving many real world problems with ease.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

A. Design of the Parking Lot

The Figure 6 shows the Design of a Parking Lot. The lot has been designed to give a pictorial representation to the users and also to make the system dynamic where car movements are shown by clicking on the car slots.

A car slot if empty consists of car number and if occupied consists of a car. If we click on the number, the slot is replaced by the car and if we click on the car, slot is replaced by the number. This method was employed to show the presence and absence of the cars which ultimately is a measure of car slot being empty or occupied (movement in the system). There are 40 parking slots in the system numbered from 1 to 40.

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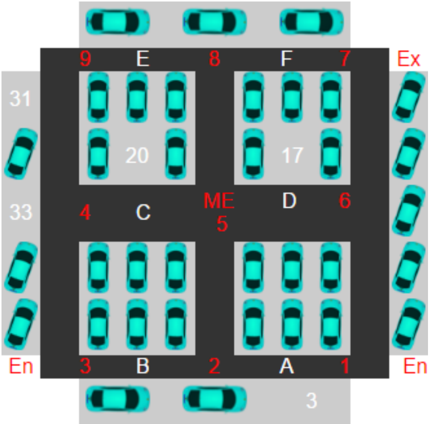

Figure 6: Car Park layout

Apart from car slots and cars there are Entrances and Exits represented by En (Entrance), Ex (Exit) and ME (Mall Entrance) in the system. The entrances act as the source node in Dijkstra's algorithm. Mall Entrance is placed in the center of the parking lot and it is to this point that the Euclidean Distance from each slot is calculated Since a parking slot is not a straight line path, adding the intermediate nodes make it a combination of straight line paths lying at 90-degree angles. Since there are different paths to be followed lying at 90-degree angle, the intermediate nodes are taken as reference on which sum of the different paths are calculated to get the total distance.

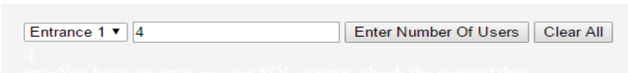

Figure 7: Criteria Value

Fuzzy Logic based Car Scheduling

Here the input received is the Entrance (Entrance 1 or Entrance 2) along with the number of users present at the car park. The number is restricted to the number of free car parking slots and is shown as default value in the text box. This is the maximum number users for whom car parking is available where one slot each for every user is available in worst case. As shown in Figure 7 and 8. There is a clear all button in the system which clears all the flags and statuses of the assigned slot which makes the system ready for the assignment of the slots next time.

Figure 8: Entrance Value

The slot assignment is shown in Figure 9.

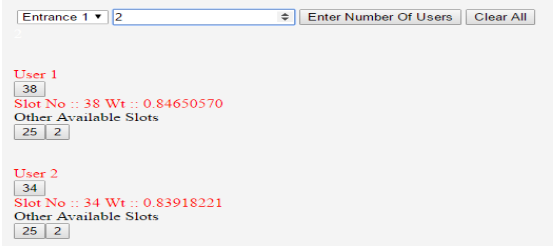

Figure 9: Slot Assignment

Here we have requested for Entrance 1 and 2 Users. In the results, we have 38 and 34 recommended as best slot option for User1 and User2 respectively. Apart from that additional slots are recommended which are 25 and 2. The additional slots are arranged in decreasing order of weights which are displayed when the mouse is hovered over it.

The slot 38 which is initially assigned was selected by User1. Once selected, the path to the node is displayed if clicked on View Path for User1. The path is displayed as 1-6. Similarly, for User2 its view path gives the shortest path to slot 34 as shown in Figure 10.

If slot 21 is chosen by User1 then 33 becomes the part of Available Slots and is appended to the list in the order of the decreasing weight as shown in Figure 11.

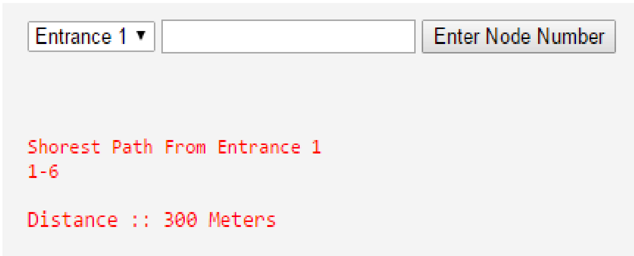

Figure 10: Shortest Path

B. FIFO Scheduling

All the free parking slots are accessible to all the users in the form of Assigned Slots (AS) and Remaining Available Slots (RS). The slot clicked by the user gets assigned to the user, this is in FIFO method. Initially when User1 clicks on an RS instead of AS, the AS of User1 becomes AS of User2 as per algorithm. This is because the AS is the best slot available. If User1 again changes his selection from the RS, the current AS gets added to the list of RSs in the decreasing order of weight. This is because AS is not the best slot available but was randomly selected by User1.

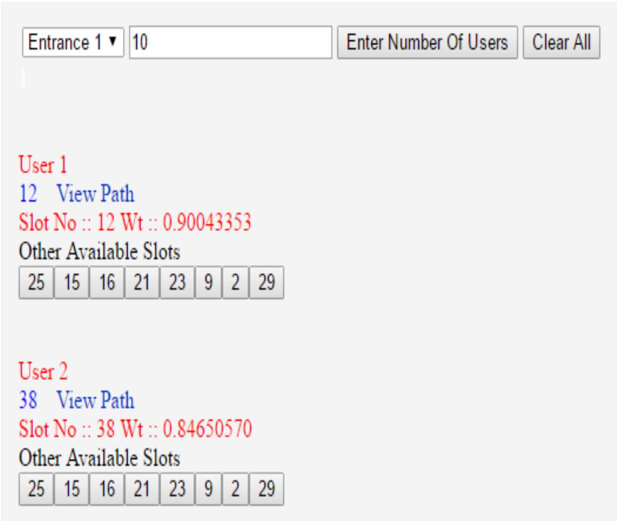

Figure 11: Slot Appending

C. Implementation of Dijkstra's Algorithm

Dijkstra's Algorithm has been implemented to find the Shortest Path between Entrance and the Slots. We can choose between Entrance 1 and Entrance 2 as shown in Figure 12 and after entering Node number the system generates Shortest path from the source to destination as displayed in Figure 13. Here shortest path is generated with intermediate nodes as reference as shown in as shown in Figure 14.

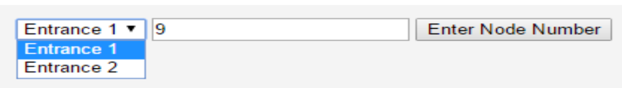

Figure 12: Dijkstra's Criteria

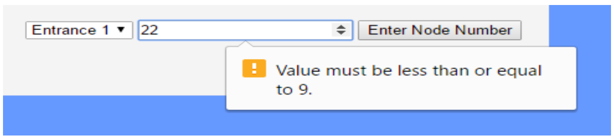

Figure 13: Dijkstra's Node Limit

The proposed system is driver friendly. The system mentioned here is not just a prototype but it has been programmed, hence this could become part of a real-time system without much change. The code in PHP has been kept simple so that it is easily understandable by people.

Figure 14: Shortest Path Entrance 1

V. CONCLUSION AND FUTURE WORK

This research is an attempt to automate the scenario of finding an appropriate parking slot based on driver's preferences. Here we have taken into consideration what all factors a driver considers while trying to park his/her car in a parking slot. We have classified these factors into Driving Distance, Walking Distance, Parking Space Environment Value and Other Factors which considers have used the Dijkstra's Shortest Path Algorithm which tries to generate optimal path distances. The system was implemented using Web Application Development Technologies where HTML and CSS were used to design the interface of the system, PHP for server-side scripting and MySQL as the database or backend of the developed system.

As future work, we could include more user preferences like the length of the shade or distance to the Exit (if closer can result in an easy exit), etc. Since nowadays most of the people use smartphones for browsing, an app implementing the above said system is worth considering, where the prior reservation of car parking is possible through logging into the app. Apart from these we can also incorporate multiple car parks in an entire city and suggesting a car park if one is full and route suggestions on how to reach these car parks

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through congestion free paths by accessing live data from Google traffic API.

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