Efficient Electronic Parking Service using Internet of Things *

Martina Pascuzzo [1], Ayush Kanaujia [2]
Reason Adhikari [3], Deep Shikha [4]
[1] School of Communication and Mass Media
[2,3,4] School of Computer Science and Information Systems
Northwest Missouri State University
Maryville, MO 64468

Abstract

Commuter students often struggle to find open parking spots on campus, leading to frustration, lateness, and potential absences from class. They typically park in parking lots far from their academic buildings because resident students tend to use most of the available open spots in mixed parking lots, causing commuters to walk a longer distance than if they would have found a parking spot in the designated academic building's parking lot. This causes commuters to illegal park in residents' or faculty's spots, receive fines, be late, or not even show up to class at all, on top of elevated levels of frustration, therefore, affecting their grades and motivation to go to class. Our approach to solving this is to create a user-based application with which commuter students can check how many parking spots are available in the parking lots around a campus building, they would navigate to the designated parking lot using Global Positioning System (GPS), and scan a unique quick response (QR) code to register that they parked in that lot, creating a record. This will keep the system updated about how many parking spaces are available in each parking lot which users can access easily.

1 Introduction

Parking a vehicle in cities, towns, big organizations, and universities is a problem because people may not find a parking slot when they visit to a parking lot. Consequently, they need to visit multiple lots to find a slot that makes the people to spend unnecessary fuel, time and energy. Therefore, different parking systems have been developed, namely quick response (QR) code based [7, 2, 1, 12], block chain and gamification based [6, 9], internet of things (IoT) based [16, 10, 15, 5], smart phone based [11], preference based [13], reservation based [14]. Although different parking systems have been developed, there is a pressing need of a parking system for teaching-level universities, where faculty and students find diffculty to get a slot in the nearest lot from their desired building. Therefore, we develop an electronic parking service system on iPhone operating system (iOS) plateform based on global positioning system (GPS) and quick response (QR) code.

Our broad goal is to implement a parking system that allows users to navigate around the campus parking lots to find the available parking space within a certain time frame and the shortest distance from their destination building on campus, in order to improve the overall user experience and satisfaction. This system will consist of an app where the user inputs their car's information and parking permit, then it will show on an interactive map how many parking spots are available at a designated parking lot once the user selects their destination building, then, it will show via an internal navigation system how to get to that parking lot. The user will then have to manually scan a QR code or select "Park", this will create a record, communicate with the server, and update the balance of that parking lot's available spots. Once the user is ready to leave the parking lot, they can just checkout through the mobile application and they will also receive a notification to checkout after an hour or so. If they select "Leave", then the server will update the balance again. It is worth to note that the parking feature through the QR code, will only be available once the device is within the campus coordinates this way, reserving a spot in advance will not be possible.

2 Related Work

Parking systems [3, 4, 8] have been gained a lot of attention due to increasing number of people in an organization, specifically in USA, where most of people use vehicle to go anywhere. Parking systems have developed for different plateform, such as Web, Android, and iPhone over time using different teachnologies, such as Angular, JavaScript, Java, and Swift. Various parking systems, such as preference based [13], reservation based [14], QR code based [7], IoT based [5] have been developed based on budget and need. Although parking systems for univeristy campuses [13] have been studied, most of them provide a way to manage the slot. However, our focus is to find the nearest lot from a user's desired building, where a slot is available. Then, the user will be navigated through a google map to the lot. Our work is similar to the cloud based smart parking system [7], where the system maitains the parking lot using wireless technology using ultrasonic sensors. However, our parking system uses QR code technology to maintain each lot based on types of users. Also, the system uses Google Map to navigate the users to their lot.

3 Motivation

Based on the previous research, this study is focusing on finding a solution to improve the overall user experience, efficiency, and value of the students' parking experience at one rural public university in the Midwest with a total enrollment of 8,872 students during the 2020-2021 academic year. While about 41% of those students are living on campus with a required resident parking pass, the remaining 59% are commuter students living off campus with a namesake parking permit. The current parking lot distribution of this rural university is as it follows: 8 parking lots for residents only, 5 parking lots for commuters only, 14 parking lots for both, and 10 parking lots for faculty/staff only. Residents have a total of 905 parking spots while commuters have a total of 324 spots. Additionally, there are 1,724 "open" spots for commuters, residents, faculty, etc. All residents, who are usually incoming first-year students, are required to have a parking permit and park on campus by their residential buildings which are about a 10min walk to all the academic buildings.

Taking this into account, residents would not need to drive around campus to go to classes, unlike commuters who would not only have to drive for a longer time to get to campus but also find an available spot among the parking lots. The reality is, however, that residents drive to their academic buildings as well, taking up most of the 1,724 "open" spots. If we assume that all residents will be driving to their classes and parking in "open" lots, then commuters would only have 1,143 available spots creating scarcity and demand for a solution to this problem.

To provide a stronger argument for the relevance of this study, an online survey was administered to 36 (n = 36) campus students at this rural institution assessing their overall satisfaction with the parking experience. The survey was constructed based on prior research regarding consumer satisfaction surveys and the assistance of a user experience professional. Besides basic demographic questions, participants were primarily asked to respond to a series of Likert-style statements and questions, using a five-level scale (1=Strongly

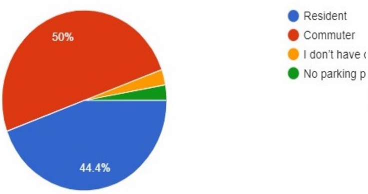

Figure 1: What type of parking permit do you have?

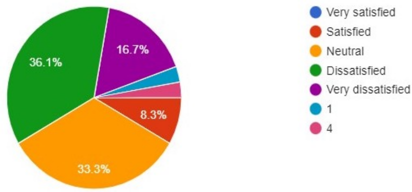

Figure 2: Overall, how satisfied/disatisfied with the parking?

Agree, 2=Agree, 3=Neutral [Undecided], 4=Disagree, and 5=Strongly Disagree) and free form responses asking for their input or opinion.

Out of 36, 50% of the participants have a commuter parking permit shown in Figure 1 and yet, only 8.3% of all respondents are satisfied with the parking experience, with a total of 52.8% of students voting in the bottom boxes of the Likert scale shown in Figure 2. Furthermore, 44.4% of respondents stated they were dissatisfied with the value they get from the parking service and 16.7% said to be very dissatisfied. The survey also showed that most respondents have considered doing one or more of the following when parking on campus: Parking in a faculty/staff/resident-only parking lot, arriving late to class due to inability to find a parking spot near their building, and feeling frustrated by not receiving what they are paying for.

These reasons provide sufficient motivation to conclude that the existing parking system at the university is inadequate to meet the demands of the users, resulting in several issues that affect their satisfaction and experience.

4 Preliminaries

Numbers and Functions. Let $\mathbb{R}$ and $\mathbb{R}_{\geq 0}$ denote the set of real numbers and the set of positive real numbers, respectively. We use $[n]$ to denote the set $\{1, 2, \ldots, n\}$. Next, given a set A, we use $|A|$ to denote the number of elements in the set A. Then, we use $f : A \to B$ to denote a function from set A to set B, where $f(x)$ denotes a value in B for $x \in A$.

2-D Points and Distance. A two dimensional point $p = (x, y)$ is represented by a pair of two real numbers, that is, $(x, y) \in \mathbb{R} \times \mathbb{R}$. Given two points $p1 = (x_1, y_1)$ and $p_2 = (x_2, y_2)$, Euclidean distance denoted by $d(p_1, p_2)$ is defined given below:

$$dist(p_1, p_2) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}.$$

Map. A map is a tuple $\mathcal{M} = (\mathcal{V}, \mathcal{V}_p, \mathcal{E}, \mathcal{W})$, where

- $\mathcal{V}$ is a set of locations;
- $\mathcal{V}_p \subseteq \mathcal{V}$ is a set of specific vertices;
- $\mathcal{E} \subseteq \mathcal{V} \times \mathcal{V}$ is a set of edges;
- $\mathcal{W} : \mathcal{E} \to \mathbb{R}_{\geq 0}$ is an edge cost function.

Paths. Given a map $\mathcal{M}$, a path $\rho = v_0, v_1, \ldots, v_n$ is a sequence of locations, where for each $i \in [n]$, $(v_{i-1}, v_i) \in \mathcal{E}$. We use $len(\rho)$ to denote the length of path ρ, that is, $len(\rho) = n$. Also, we use $\rho[i]$ to denote the i^{th} location of path ρ. Let $\mathcal{P}aths_{\mathcal{M}}$ and $\mathcal{P}aths_{\mathcal{M}}(s,t)$ denote the set of all paths of $\mathcal{M}$ and the set all paths starting from location s and ending at location t. We use $cost(\rho)$ to denote the cost of path ρ, which is defined given below:

$$cost(\rho) = \sum_{i=1}^{len(\rho)} \mathcal{W}(\rho[i-1], \rho[i]).$$

Optimal Paths. Given a map $\mathcal{M}$, a source location $s \in \mathcal{V}$, and a target location $t \in \mathcal{V}$, an optimal path from s to t is a path $\rho_{opt} \in \mathcal{P}aths_{\mathcal{M}}(s,t)$ such that $cost(\rho_{opt})$ is the minimum among all the paths in $\mathcal{P}aths_{\mathcal{M}}(s,t)$, that is,

$$\rho_{opt} = arg \min_{\rho \in \mathcal{P}aths_{\mathcal{M}}(s,t)} cost(\rho).$$

5 Problem Definition

In our parking system, we find the nearest available lot closest to a user's desired building, which is formally stated below.

Problem 1 *Given a user's desired building location l_b and a list of lots' location $\mathcal{L}$ where a slot is open, find a lot's location l_d in $\mathcal{L}$ which is the nearest from l_b.*

Upon finding the nearest lot, there may be many paths to go to the lot. Hence, we are interested in providing the shortest navigation to the user, which is formally stated below.

Problem 2 *Given a map $\mathcal{M}$, a user's current location l_u, a lot's location l_d, find an optimal path $\rho \in \mathcal{P}aths_{\mathcal{M}}(l_u, l_d)$ that starts from l_u and ends at l_d.*

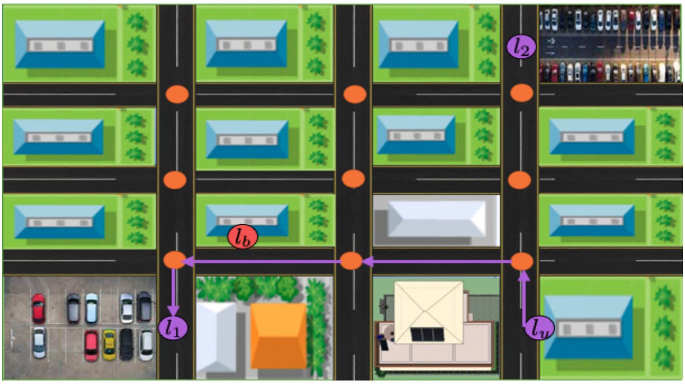

Figure 3: Campus Map

Example 1 *Consider a campus map shown in Figure 3, where l_u is the current location of a user, l_b is the desired building location, l_1 and l_2 are the lots where slots are available. In Figure 3, there are two lots located at l_1 and l_2 locations where slots are open. To solve Problem 1, we need to check which of the locations l_1 and l_2 is the nearest to the desired building location l_b. Once it is determined, our objective is to find the shortest path from the user's current location to the determined lot in order to solve Problem 2.*

6 Approach

In this section, we develop an algorithm to find the nearest available lot based on the Euclidean distance, which is explained below.

In Algorithm 1, we compute Euclidean distance from a given desired building location l_b to all the lots' location in $\mathcal{L}$, and outputs a lot' location which is closest to l_b. Upon finding the lot's location, we use Google Map navigation to solve the problem 2 that provides the shortest path for the user to go to the lot.

Example 2 *Consider the campus map shown in Figure 3. From Algorithm 1, we find the nearest lot from l_b, which is l_1. After finding the lot location, we use Google Map navigation system for the shortest path from l_u to l_1.*

Algorithm 1: Nearest Lot Search

Input: $\mathcal{L}$- a set of all lot's location, l_b - a desired building location

Output: l_d - the nearest lot from l_b

```
begin
    l_d := (0,0),    d := 0
    isFirst := true
    for l ∈ L do
        d' := dist(l_b, l)
        if isFirst then
            isFirst := false
            d := d',    l_d := l
        else
            if d' ≤ d then
                d := d',    l_d := l
    return l_d
end
```

7 Implementation

In this section, we provide the details about the implementation of our APP, which is written in Swift language. First, we provide a flow chart of our APP shown in Figure 4. Next, we explain the flow chart.

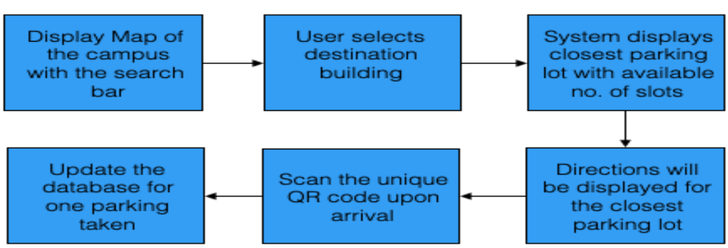

Figure 4: Flow Chart for the APP

For the APP, we first allow the user to enter their information, namely name, vehicle license plate number, and category (student/faculty/staff). Once the information is entered, we display a campus map with all the building with a location marker. Based on the user's building selection, the APP automatically will provide Google navigation to the nearest lot from the building, where a slot is open. Upon reaching the lot, the user has to scan a QR code available at the lot. Upon scanning the QR code, the number of available slots associated with the lot will automatically be decreased in the database. Similarly, when the vehicle is exited from a parking lot, the user has to scan the QR code associated with the lot. The user interface of the APP is shown in Figure 5 step by step.

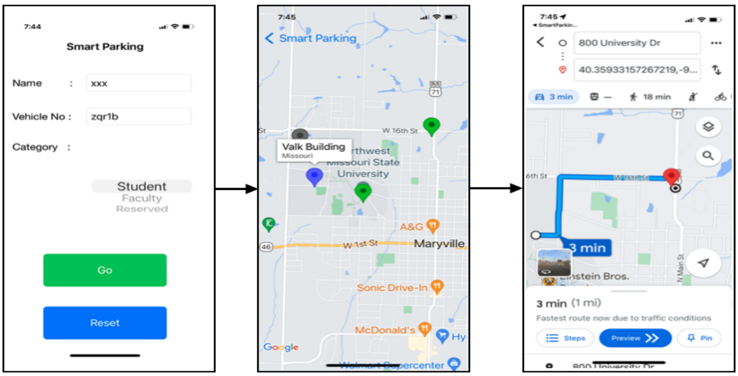

Figure 5: Smart Parking APP

8 Conclusion

In this paper, we have developed an iOS APP for assisting students, faculty and staffs to find a slot near their desired building in the campus. The APP is implemented using Swift language, where mysql database has been used for the static information, such as lots' location and admin information while cloud based database, namely firebase is used to store number of slot for each lot inorder to provide real time slot information to users. Also, we have generated unique QR code for each lot which is linked with the firebase database to update the number of slots in the backend. In the future, we plan to install a camera that will have a real time video streaming feature. Based on the video, we plan to provide local navigation to the use to park their vehicle at a specific slot.

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