A modest IoT based smart parking system with business analytics integration

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Abstract. Traditional parking systems are challenging and tedious as it is occupied at irregular intervals for various reasons. Without proper design, this could lead to loss of business revenue in commercial establishments. The objective of this study is to implement an IoT-based system to address issues faced by visitors at parking lots. The proposed system would include capabilities that can display the status of availability of the lot it is placed in and will report the status through a web service. This availability status is transmitted through WiFi, which can provide insight into the parking activities of the establishment. This provides valuable data for the use of business analytics. This study highlights the advantages a basic and low-cost IoT-based Smart Parking Lot system could present. This is visualized using custom and open-source parking datasets. These features provide the basis for discussion on future improvements and scalable parking solutions.

1. Introduction

The recent developments of the Internet of Things-based system have found great value for industrial and tertiary sector developments. More specifically, products to better customer satisfaction have been one of the main reasons for business implementations [1]. With regards to the scope of areas for customer satisfaction improvement, a simple and often overlooked issue is that of the problems customers face when they are reaching said business establishment and require to park their vehicles. In large establishments like shopping malls, smart cities, and airports with a larger number of vehicles, finding parking becomes a burden [2]. Especially due to unordered and irregular parking lot availability caused by varied arrival and departure times of customers [3]. This leads to confusion and ruins the experience for the customers and can potentially result in customers not visiting the establishment. Additionally, it affects business revenue for both shops and the additional revenue earned from parking lot charges [4]. In Parking spaces like airports, these un-organized parking systems may even lead to time being wasted by consumers and harming their travel experience [5].

These issues become compounded by other societal and environmental factors that arise as a side effect of increased purview. For example, the most recognizable large-scale implementation where these issues arise would be in the concept of smart cities. With the onset of modern transportation technologies and the increase in urbanization, space and cost constraints arise [6]. Hence, existing parking systems must be optimized to make use to the fullest advantage. These optimizations can involve shared parking systems [7], membership and reservation systems [8], data analytics based on the reason for a visit [9]. However, these improvements are based on the premise of the car being
parked in space and that instance is recorded in the database. To facilitate this, IoT systems can track these data instances through sensors and communication devices [10]. This study proposes an IoT-based Smart Parking Lot System, which if placed in individual parking lot spaces, can provide an efficient solution. This system would consist of proximity sensors that constantly check for the presence of vehicles in that particular space, and depending on the availability the indicative lights (strategically placed) allow the customer to find a parking space with ease, further the system is characterized in its capability that it can be used with a low cost of implementation and can be used with WiFi communication to ensure easy set-up. A simple web service-based interface can be used to collect the data and used for future analysis as well. The analysis could provide a commercial establishment with the necessary insight into the customer visiting patterns from the collected parking data and reasons for visit data.

2. Related Work

The ideology of solving the issues faced in the parking spaces is has been attempted by many authors and improvements can still be seen today. Recently published papers have taken different approaches to solving this problem. For example, the study by Sadhukhan [11] has addressed the problem of real-time detection of improper parking and automatic collection of parking charges. The system utilized an embedded component that they term as a “Parking meter”. The system detected real-time improper parking, vehicle parking duration, and automatically collected the parking fee over a WiFi network with local storage of data. The approach taken by Rane et al. [12] aimed to implement IoT to the parking lot and used a microcontroller to accept input from the CCTV and image processing to check employees and their number plates which were then sent to a server for verification. Cloud-based implementations to integrate into smart cities have been attempted as well, such in the case of Ji et al. [13], where the paper proposed a cloud-based smart vehicle parking system for use within for example a university compound, etc. The system included a vehicle parking locator, and information service, GIS/GPS services, a license plate checking configuration, car tracking services, etc. The system made use of the OSGi web services and connected to a mobile application.

With regards to the work of Khanna et al. [14], the proposed system used an on-site IoT module that monitored all the parking spaces individually and send a signal from the parking sensors using an internet-connected Raspberry Pi, which could be then tracked in a mobile application which allowed the user to check for availability of parking spaces. Other similar implementations of the present problem statement can be seen in the work by Mahendra et al. [15], in which the proposed work is also a mix of IoT and cloud computing. The system allowed the user to reserve a space for parking in advance using a mobile app that contained an authentication system as well. IR sensors were also integrated with a Raspberry Pi to obtain real-time data in combination with the MQTT protocol to communicate with the cloud storage. In their study, Soni proposed an automated parking system that operated wirelessly, with cloud-based data storage [16]. Additionally, RFID cards had been included aiming to prevent vehicle theft. In their study, Tu proposed a self-managed parking lot system using APP via mobile devices [17]. The implementation was aimed to hold features like free parking space detection, directional guidance to the parking space, and other information regarding duration and charges. Suresh et al. presented an Arduino and Ethernet-powered configuration that employed a car status check using a web link for airport parking scenarios [18].

Jamdani et al. implemented a parking solution that integrated features like payment services and proximity estimation with a classic parking availability calculation system [19]. Qadir et al. proposed a Zigbee powered parking space locator that combined IR sensors for real-time detection of spaces and a GSM module for SMS notification [20]. The discussed publications have all provided a variety of solutions to issues like parking space detection, location, and guidance, and included features like payment and duration calculations. Our study looks to develop this base work by implementing the analytics of the data obtained and providing it as constructive input to commercial establishments. The existing systems were focusing only on using concepts of Wireless communication and the Internet of
things to find a parking lot, whereas the current work focusses on predicting the availability of parking lots.

3. Proposed Model

Due to inhibitions caused by the COVID-19 pandemic, this study was conducted using online simulators and web services. The Tinkercad simulation software [21] and the ThingSpeak IoT Analytics software [22] were employed in this study. Furthermore, an example for the scope of business analytics was conducted using RStudio [23].

3.1. IoT Model type
The implemented system is based on a “Request-Response” IoT model type. As illustrated by Tanyingyong et al., this type of model presents one node that sends a request to a receiver node [24]. This request is communicated as a message and is replied to with a specific response. This is performed in a synchronous setting. The two Arduinos communicate over the I2C protocol in a master-slave configuration. The master Arduino sends a regular update of distance measured by the ultrasonic sensor, performing the checking of the condition, and requesting for the LED output for whether the parking lot is filled or not. The slave Arduino takes the request and responds. The slave Arduino communicates the data through the WiFi module as well.

3.2. IoT Level Template
This model is based on the “IoT Level 1” deployment template, as illustrated by a generalized example in Figure 2. With a single sensor end node and a locally hosted database, this deployment template is suitable for a low-cost system like the proposed system, with very minimal complexity [25]. The monitoring node is an Arduino. The system does not have any high computational processes. It consists of low-cost and low-complexity services. The data collected is not of great size and does not require manual collection, at discrete intervals over a cumulative period the data is shared to the cloud, but there is no further need for the node to access the data after sending it to the cloud.

![Figure 1. Flow chart of the proposed system](image)

Figure 1 illustrates the flow of the proposed system in the chart with individual stages.
3.3. Schematic and Web Service visualization
The schematic of the implemented system can be seen in Figure 3. The component specifications of the model are represented in Table 1. The master Arduino detects the distance between the vehicles and the wall or floor, depending on placement. Once the ultrasonic sensor detects proximity less than the specified threshold (in this study was considered to be 50 cm), the Arduino considers this as the “true” state. The “true” state corresponds to the presence of a vehicle, while the “false” is for absence. This state is then communicated to the slave Arduino over the I2C protocol. The slave Arduino then provides the indicative output by illuminating the respective colored LED device. A red-colored LED was chosen to represent the “true” state, and green for the “false”. These LEDs would optimally be placed on the ceiling, thus allowing the driver to search for a green light, meaning an empty available parking space.
Figure 3. Tinkercad schematic for the proposed system

Table 1. Components Required

| Sl.No. | Component          | Specification       |
|--------|--------------------|---------------------|
| 1      | Arduino Microcontroller | Arduino Uno R3      |
| 2      | WiFi module        | ESP8266             |
| 3      | LED                | Red, Green          |
| 4      | Ultrasonic Sensor  | HCSR04              |
| 5      | Resistors          | 1KΩ                 |

Our study utilizes the ThingSpeak web service, for its interactive representations and analytics of embedded IoT systems. With the sensor-powered input, the web service records the binary data of the presence of vehicles, and through a simplistic web URL-based interface the intended shop to be visited is recorded as well. The ThingSpeak integration notes all data occurring within the stipulated period and allows the user to download the data to local resources for analytics.

4. Results

Our system as a whole employs the components explained in Table I in the configuration depicted in Figure 3. The components and setup were chosen in such a way that allowance for improvement and future developments can be seamlessly integrated. The WiFi module is synced with a ThingSpeak powered channel that records the specified “true/false” data respectively as 1/0. The graphical visualization of this can be seen in Figure 4.

Figure 4. ThingSpeak graphical visualization for the parking lot status
To simulate the arrival of vehicles for a specific destination, to provide a more business-driven insight, the ThingSpeak service was used to provide an interface for customers to choose which particular shop present in the establishment they would like to visit. While this simulation is an assumption of a parking scenario, the simple premise of visiting a shopping establishment and parking vehicles in the provided lots were taken as a base. In addition to this simulation, the scope of analytics on parking status was demonstrated with the help of an open-source parking dataset in the following section. For the collected data, to provide a simple example, it was considered that there were only 2 shops present in the establishment. The user would simply have to click and internet search the link with the necessary choice and the data would be recorded, as seen in Figures 5 and 6.

![Figure 5](image1.png)  
**Figure 5.** ThingSpeak graphical visualization for the parking lot status

![Figure 6](image2.png)  
**Figure 6.** ThingSpeak graphical visualization for the parking lot status

Using the gathered data on customer choice a simple regression-based predictive model was implemented in RStudio, to compute the probability that a customer visited a particular shop in the shopping mall. This could provide insight as to which shop is performing better. Figure 7 provides a screenshot of the Excel sheet obtained from the ThingSpeak service containing data for the parking lot status and choice of the customer.

To demonstrate the business potential of parking space data used in association with data analytics, we employ an open-source dataset to delineate this. The Parking Birmingham dataset was utilized, with certain pre-processing for this task [26]. To provide an instance for a shopping establishment, the parking data for one such factor was chosen from the 4th of October, 2016 to the 19th of December, 2016. The maximum occupancy per day was calculated as used as the target variable. The respective day of the week was used as the explanatory variable for a linear regression model. Figure 7 illustrates
the data set used. A linear regression model was fit on this dataset. This model predicts the occupancy values of the parking space based on the day of the week. Figure 8 presents the results obtained from the model. As noticed from figure 7, the occupancy rates are comparatively lower on weekends than weekdays.

| Dates        | MaxofCapacity | MaxofOccupancy | Day | DayofWeek |
|--------------|---------------|----------------|-----|-----------|
| 04-10-2016   | 1920          | 1460           | 3   | Tuesday   |
| 05-10-2016   | 1920          | 1446           | 4   | Wednesday |
| 06-10-2016   | 1920          | 1422           | 5   | Thursday  |
| 07-10-2016   | 1920          | 1267           | 6   | Friday    |
| 08-10-2016   | 1920          | 954            | 7   | Saturday  |
| 09-10-2016   | 1920          | 497            | 1   | Sunday    |
| 10-10-2016   | 1920          | 1335           | 2   | Monday    |
| 11-10-2016   | 1920          | 1431           | 3   | Tuesday   |
| 12-10-2016   | 1920          | 1407           | 4   | Wednesday |
| 13-10-2016   | 1920          | 1428           | 5   | Thursday  |
| 14-10-2016   | 1920          | 1240           | 6   | Friday    |
| 15-10-2016   | 1920          | 905            | 7   | Saturday  |
| 16-10-2016   | 1920          | 968            | 1   | Sunday    |
| 17-10-2016   | 1920          | 1292           | 2   | Monday    |

**Figure 7.** Pre-processed dataset employed in this study.

This is reflected in figure 8 as well. The results provided an R-squared value of 0.7399 and an F-score statistic of 33.9 on 6 and 66 degrees of freedom. These results are representative of the business potential of predictive analytics. Based on the examined trends, the establishment could expect a maximum occupancy value in advance. This could allow these establishments to prepare in advance, and offer insights into the results of any current offers and seasonal trends and their effect on customer visits.

| DayofWeek   | MaxofOccupancy |
|-------------|----------------|
| Sunday      | 776.400        |
| Monday      | 1443.091       |
| Tuesday     | 1479.818       |
| Wednesday   | 1473.182       |
| Thursday    | 1464.700       |
| Friday      | 1343.800       |
| Saturday    | 1036.600       |

**Figure 8.** Predicted values for the maximum occupancy per day of the week.

5. Conclusion

The low-cost system implemented in this study has proven to possess high potential in commercial business analytics and can be an effective solution to everyday parking problems people face. Without bells and whistles and a fundamental approach, our system is robust to network and maintenance issues that other complex solutions are prone to. Larger scale implementations of our system
integrated with cloud-based computational analytics are much in the scope of a product/service type of growth in the field of business and sales analytics. This proposed system provides a time-efficient and accurate prediction in the parking space. This system integrates the Internet of Things by deploying sensors and aggregating the field data. Also, this system integrates the Machine learning algorithm by which based on the aggregated data the system predicts the availability of parking space and also helps in predicting whether customers visit which shops in the shopping mall. However, there are a few limitations here. The system can predict the availability of parking based on the free space available. Further, if the system can be integrated with weather and other social events for enhancing the prediction of parking space requirements.

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