

Smart Parking Management System Using IoT

Bshayer S. Alsafar¹, Dhay M. Alzaher², Raghad W. ALshwukh³, Afnan M. Darwish⁴,
Thowiba E. Ahmed⁵, Eyma A. Alyahyan⁶, Dabiah Alboaneen⁷, and
Enas E. El-Sharawy^{8*}

¹Computer Science Department, College of Science and Humanities, Imam Abdulrahman Bin
Faisal University, Jubail, Saudi Arabia. 2190003715@iau.edu.sa,
<https://orcid.org/0009-0001-8918-4699>

²Computer Science Department, College of Science and Humanities, Imam Abdulrahman Bin
Faisal University, Jubail, Saudi Arabia. 2190001584@iau.edu.sa,
<https://orcid.org/0009-0005-7517-1095>

³Computer Science Department, College of Science and Humanities, Imam Abdulrahman Bin
Faisal University, Jubail, Saudi Arabia. 2190000881@iau.edu.sa,
<https://orcid.org/0009-0009-8960-8955>

⁴Computer Science Department, College of Science and Humanities, Imam Abdulrahman Bin
Faisal University, Jubail, Saudi Arabia. 2190004168@iau.edu.sa,
<https://orcid.org/0009-0002-2086-2487>

⁵Computer Science Department, College of Science and Humanities, Imam Abdulrahman Bin
Faisal University, Jubail, Saudi Arabia. teahmed@iau.edu.sa,
<https://orcid.org/0000-0002-3738-6731>

⁶Computer Science Department, College of Science and Humanities, Imam Abdulrahman Bin
Faisal University, Jubail, Saudi Arabia. eaalyahyan@iau.edu.sa,
<https://orcid.org/0000-0002-9272-6129>

⁷Computer Science Department, College of Science and Humanities, Imam Abdulrahman Bin
Faisal University, Jubail, Saudi Arabia. dabuainain@iau.edu.sa,
<https://orcid.org/0000-0003-2215-9963>

^{8*}Computer Science Department, College of Science and Humanities, Imam Abdulrahman Bin
Faisal University, Jubail, Saudi Arabia. eeelsharawy@iau.edu.sa,
<https://orcid.org/0000-0002-9826-2900>

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Abstract

Considering the continuous growth of urban populations and the expansion of cities, alongside an increase in the number of vehicles, the organization and availability of car parks have emerged as critical aspects of urban planning. This development is indicative of a society's cultural depth and level of urbanization. Most parking facilities experience a range of issues, including overcrowding, which leads to traffic congestion, significant delays, and missed appointments. Furthermore, the scarcity of shaded parking spots often results in vehicles being exposed to direct sunlight, rain, and

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*Corresponding author: Computer Science Department, College of Science and Humanities, Imam Abdulrahman Bin Faisal University, Jubail, Saudi Arabia.

dust, potentially causing long-term damage. This paper proposes the development of a smart parking management system utilizing Internet of Things (IoT) techniques to address these challenges. The system includes a display that provides a map of the parking area and indicates the nearest available spot via a button adjacent to the screen. Infrared sensors are employed to detect vehicle presence, updating the database in real-time. Additionally, a real-time database has been designed using the Firebase platform to monitor the status of parking spots. The anticipated outcome of the proposed system is a substantial reduction in the time and effort required to locate an optimal parking space, thereby mitigating traffic and air pollution associated with increased vehicle numbers.

Keywords: Smart Parking, Sensors, Automatic Umbrella, IoT.

1 Introduction

In alignment with global changes and the pursuit of visions emphasizing societal vitality, economic prosperity, and national ambition, numerous initiatives are undertaken to enhance citizens' quality of life. Among these, granting equal rights—such as the universal right to drive—stands out as a significant milestone on the path to progress. Countries worldwide are now leveraging technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and high-performance computing to evolve and develop smart cities (Badii et al., 2013; Trivedi et al., 2023). For example, Saudi Arabia has initiated the construction of Neom, a smart city projected to include a zero-carbon emission linear city in the future (NEOM, 2022, Juma et al., 2023, Abdullah., 2020).

However, challenges persist, particularly with the recent population surges and the increasing number of vehicles in densely populated urban areas. These issues manifest as significant difficulties in locating parking spaces quickly and conveniently in frequently visited places such as workplaces, markets, and other public areas, exacerbating global warming and environmental degradation. Additionally, the escalating costs of acquiring parking facilities are a complex issue, with insufficient foresight regarding future needs and capacity demands.

The implementation of computer and communication systems technology as smart technology, when interconnected, allows for the seamless exchange of information and collaboration. These smart technologies could enhance energy efficiency, improve timeliness, and increase impact if properly synchronized or distributed. The IoT encapsulates the network of intelligent devices and the capabilities they offer (Thanga et al., 2023).

Smart parking systems exemplify how IoT can address issues like traffic congestion and road blockages in urban settings. From this perspective, we propose to develop a smart parking system for urban areas, integrating IoT technology. Our system will incorporate various sensors, a microcontroller, and Liquid Crystal Display (LCD) screens, all working in unison to provide an effective and efficient solution to aid drivers in finding parking spots. Additionally, automatic umbrellas will be included to protect vehicles from heat, particularly pertinent in countries with high temperatures.

The remainder of this paper is arranged as follows. Section 2 presents the related work about smart parking management systems. Section 3 explains the proposed model. The results and conclusion are discussed in Sections 4 and 5, respectively.

2 Related Work

In this research, the authors address traffic congestion in parking lots by integrating a hierarchical organizational structure into the proposed parking system. They employed a hybrid solution combining Vehicle Routing Problem (VRP) and Multiple Depot Vehicle Routing Problem (MDVRP) to distribute

parking areas according to various visitor priorities. The hardware implementation included a Raspberry Pi, Pi camera, Ultrasonic sensor, and GPS to achieve their objectives. A comparative analysis validated the Capacitated VRP, which was found suitable for organizations with hierarchical or humanitarian priorities (Marouane, et al., 2022). Additionally, Nagowah, et al., (2019) tackle parking issues at the University of Mauritius, such as students parking in staff-designated slots and the inefficient search for available spaces. They revisited and adapted existing ontologies like Wise-IoT, SSN, and FOAF to develop a new smart parking ontology tailored to the campus's needs, incorporating sensors, a mobile application, and an electronic verification methodology to facilitate a smart parking system. Furthermore, at King Fahad University for Petroleum and Minerals, significant time is wasted searching for parking spaces. To address this, an internal, preference-based parking system was developed. This system, using a smart card, guides registered users to one of their top five preferred parking spots or the nearest available spot to their selected building exit. Preferences are retrieved and updated in a central database. If the top choices are full, the system directs the user to the nearest available spot to their chosen exit. The effectiveness of detecting open parking spaces was tested using both sensor-based and camera-based methods across various scenarios, demonstrating accuracies of 100% and 98%, respectively (Mohandes et al., 2019; Priyanka et al., 2023).

The authors (Kadhim, 2018) and (Elsonbaty & Shams, 2020) presented a smart system developed using Arduino components and a mobile application, to solve the shortage of parking spaces due to the increased number of cars and traffic jams. The mobile application could be used to find an available spot in the nearest parking area. Ultrasonic sensors might be used above each car park to check the availability of the park. The system can be implemented in both public and private places. Some of the benefits of the system include reducing air pollution, the updated state of the parking could make drivers satisfied and minimize waiting time and the result was an effective application designed for Android mobile phones capable of discovering a parking space by IoT.

The authors here are interested in solving the issue of parking. In their system, they used the Arduino Mega microcontroller and LDR sensor module. A prototype they made of their system has an LED indicator that helps the user search experience by displaying the available parking spot for a specific type of car. The system can perform well in dark environments due to the implementation of smart streetlights in the parking area. The system is also efficient, reduces time, and saves the environment by reducing fuel consumption (Wai & Zainal, 2021) and (Nandyal & Anjum, 2017).

The authors attempted to solve the problem of the difficulty of finding a parking area due to the lack of a full or empty parking lot. They thought it might lead to traffic jams, pollution, and fuel inefficiency. They used a microcontroller-based smart parking system to overcome the issue (based on the Internet of Things). They employ a Near-Field Communication (NFC) microprocessor, an Arduino ATmega 2560, and an Arduino Uno. The application was created by the authors using a MySQL database and PHP. With this approach, they anticipate that parking will be managed more effectively, saving time and fuel, and giving car owners the confidence to leave their vehicles in the designated spots (Ramsari & Utomo, 2020).

A real-time system was presented to eliminate the reliance on the Internet is based on Arduino Uno which is a microcontroller that serves as the brain of the system it was used as the only way to communicate, Radio Frequency Identification (RFID) to check whether the driver belongs to a specific organization, a GPS sensor was used to provide the driver the exact location of the parking, Ultrasonic sensor was used for distance calculations, LCD. The system is easy to implement and cost-effective, it also can offer a long-term solution to parking problems once it is implemented. The testing for the proposed design was conducted through Proteus Simulation software and the authors concluded that the

technology aids the driver and shields him from collisions and mayhem brought on by a lack of location awareness (Mittal, et al., 2021) and (Allbadi, et al., 2021).

Moreover, (Susilo, et al., 2021) and (Olufajo & Mustapha, 2021) are invested in solving the problems people face during their process of finding the closest available slot to their destination like wasting time, fuel, and money which leads to traffic congestion and pollution. They used an application so the user could search for the closest possible available parking spot by entering the destination and the entry gate. The system helps the user navigate the parking spot by displaying a recommended route to follow. The proposed system, mobile application, ultrasonic sensors, and light indicators to guide the driver on parking properly. The system helps in reducing carbon emissions and time and also prevents cars from blocking the entryway to the parking areas.

The authors of this paper's goal are to make a prototype of a car parking sensor and test it, to make it easy for drivers to park their cars. The control system method was used which is based on the user's needs and the "Blackbox" testing method. The prototype was tested using an imitation of a parking area and a toy car. Several sensors were used such as Arduino and Raspberry Pi, as well as a few wireless sensor networks. The design of this parking system can carry out instructions through the voice issued by the speaker to make it easier to park the car (Soni, 2018) and (Ahmed, et al., 2019; Steephen et al., 2022).

Further, the authors (Sri-Venkateshwara, 2017) and (IEEE, 2019) want to reduce the time a driver might take during the allocation of a nearby available parking. They proposed a system that will help the drivers allocate nearby free parking spaces to navigate through the area and book parking using a mobile application. They used in their model IR sensors, an Ultrasonic sensor to check the availability of the parking slot, and Raspberry Pi. An experiment was done to evaluate the system which resulted in a 98% accuracy rate in license plate detection. Their system can reduce wasting time by 50% which can help in reducing traffic congestion in urban areas.

Based on the reviewed studies, android mobile and LED light indicators have been used in the smart parking system to lead drivers into the empty parking spot. Also, the studies applied the mobile application to reach the target group to make it easier to know the available spot in the parking, and it will be reserved before arriving at the parking area to save time. In this research, a smart screen will be used and placed near the parking area entrance as an alternative to the mobile application that can only be applied in some operating systems, which can be a burden to download for some.

3 Methodology

The Main Methods Used in the Implementation

- LCD smart screen is used to install the system.
- The button is used, and it will be near the screen to display the nearest parking to the driver before entering the parking area.
- Infrared sensor used in the parking spot to detect car presence and absence.
- A real-time database (Firebase) used to store the availability of parking.
- HTML page to display the availability of parking spots by displaying a map of the parking area.
- WeMo microcontroller to connect the sensors, screen, and button to the database. The microcontroller is programmed in C programming language.
- Automatic umbrellas are added to protect the car, the umbrella will open once there is a car in the parking spot.

- A survey is conducted, and several questions will be asked about the prototype of the smart parking system.

The Analytical Vision of the Proposed System

The proposed system is a smart system consisting of an LCD screen near the entrance as shown in Figure 1. It will display a web page with a map of the parking lot showing the status of each parking space and a counter to show the number of available parking spaces. The HTML web page is connected to the database by JavaScript. Near the screen, there will be a button when pressed it will change the color of the nearest parking space to blue and make it blink on the screen. The parking space status will then be unavailable for a short time. Each parking spot will have an IR sensor that will monitor the status of each spot, so if the driver parks the car in the parking spot and the sensor detects the car, the status will continue to be unavailable. In addition, the umbrella will open, but if the driver changes his mind and chooses to leave the parking area, the status will change to available once again when the brief time ends.

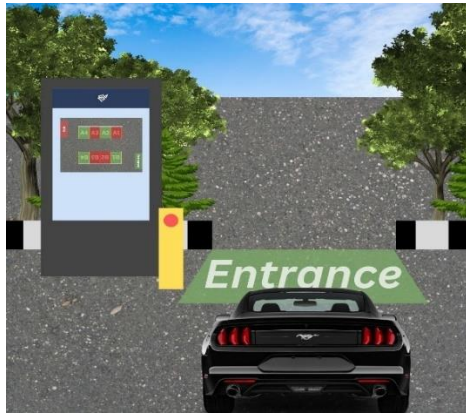


Figure 1: The Proposed System



Figure 2: The Proposed Automatic Umbrella

In Figure 2, automatic umbrellas will be assigned for each parking spot to protect the cars. The umbrella will open only when a car enters the parking spot; that is when an IR sensor senses the presence of a car.

Workflow and Implementation

Database Workflow and Implementation

The real-time database initialized Firebase platform by Google is shown in Figure 3. An account was created for each team member to set up a clear development for working together. First, create a database containing the three parking spaces that work in the prototype and one push button shown In Figure 4, which relates to a C language code to let the system always be in update mode. Additionally, Firebase was linked to an HTML page using JavaScript to display the results on the entrance screen. The interaction with the screen will be by using the button to be guided to the nearest free parking to the entrance.

In Figure 5 since there is no car in parking A1 the status of the parking in the database is available. Figure 6 shows that when the sensor senses the car and the database is updated so that parking A1 status

is unavailable, in addition, the umbrella will open automatically. In Figure 7 and Figure 8 the status of parking B2 and B3 respectively, are set to unavailable in the database because there is a car.

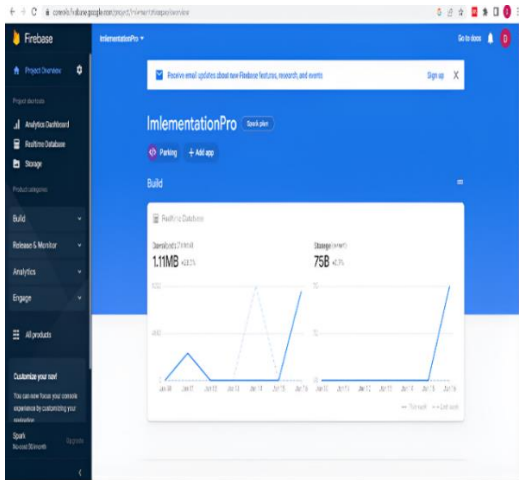


Figure 3: Firebase Project Console

<https://imlementationpro-default-rtdd.firebaseio.com/>



Figure 4: Real-time Database Initialized in Firebase



Figure 5 (A): Available Parking

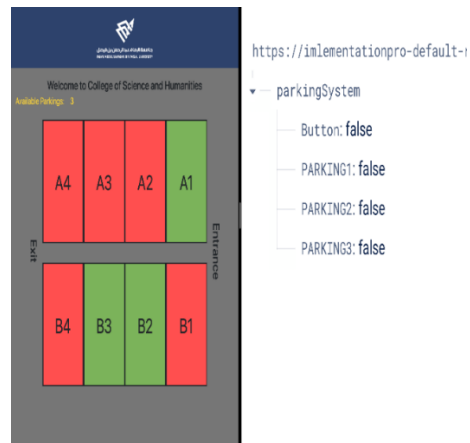


Figure 5 (B): Database Values When Parking Is Available

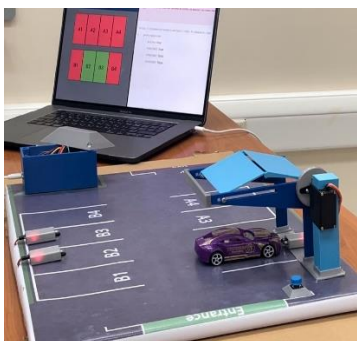


Figure 6 (A): Opened Umbrella

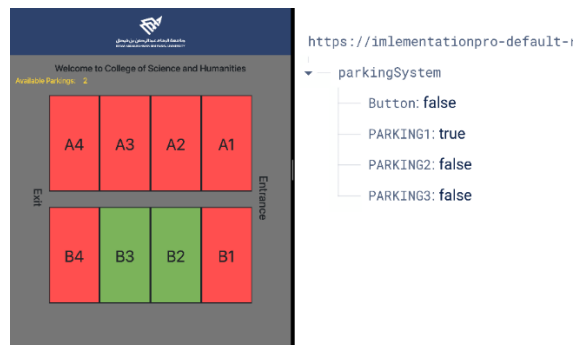


Figure 6 (B): Database Values when Parking A1 is not Available



Figure 7 (A): Parking B2 is not Available

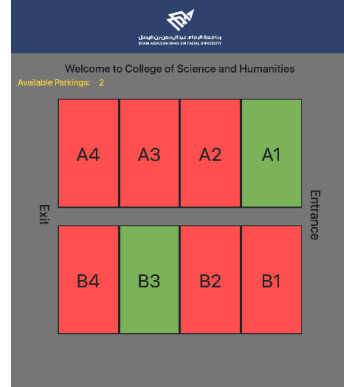


Figure 7 (B): Database Values when Parking B2 is not Available

```

https://implementationpro-default-
└─ parkingSystem
  └─ Button: false
  └─ PARKING1: false
  └─ PARKING2: false
  └─ PARKING3: true
    
```



Figure 8 (A): Parking B3 Not Available

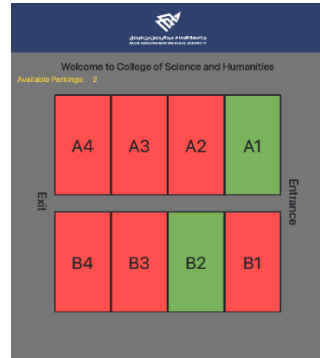


Figure 8 (B): Database Values when Parking B3 is not Available

```

https://implementationpro-default-
└─ parkingSystem
  └─ Button: false
  └─ PARKING1: false
  └─ PARKING2: true
  └─ PARKING3: false
    
```

Website Workflow and Implementation

The designing of the website was done using “HTML”, “CSS” and “JavaScript”. The interface included the organization logo, a parking area map, and a counter showing the total available parking. Each car park has three states in which it changes. In the first case, the color of the parking spot is green, which means that the parking spot is available, as shown in Figure 9. In the second case, when the button is pressed, the nearest available parking will be provided to the driver by making it blink and changing the background color to blue as shown in Figure 10. After that, the background color will change to red to reserve the parking for a brief time. If the driver parks in the area, the background will remain red, but the background color will return to green if the driver doesn’t park in it. In the last case, the color of the parking spot changes to red, as shown in Figure 11, which is an indication of the car’s presence, which means that the parking is not available. The webpage is connected to the database to store and retrieve the status of the parking.



Figure 9: Parking A1 Is Available

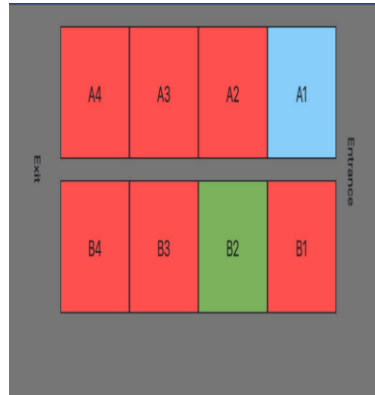


Figure 10: A1 is the Nearest Available Parking



Figure 11: Parking A1 is Unavailable

Prototype Workflow and Implementation

In constructing the prototype for the project, the proposed design was done using one WeMo that have been programmed using the C language to connect the other devices. One servo motor to open the umbrella and the motor is placed at the top of the pole, the umbrella is designed and implemented by 3D printing. Three IR sensors to detect the car's presence, one push button (with four pins) so the user can click on it to get the nearest parking displayed on the screen, one micro-USB female plug, one soldering board (glass fiber, 1.6mm thickness) to weld all the components together, a firebase database to host the real-time database. Figure 12 shows the prototype that was worked on to demonstrate the proposed system.

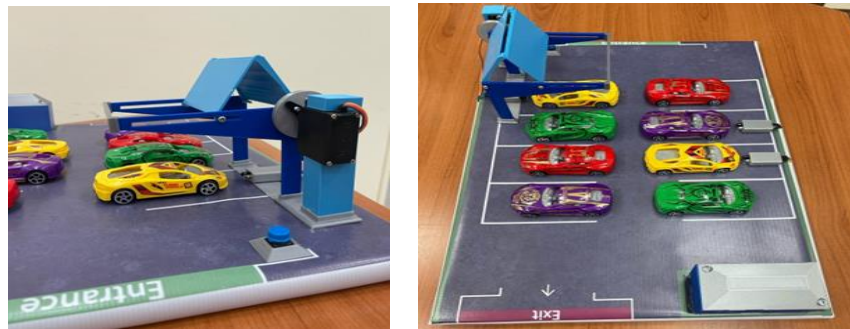


Figure 12: Implemented Prototype

Tool Used

WeMo Microcontroller

The microcontroller shown in Figure 13 was used to build interactive objects. Downloading the suggested system's mechanism onto WeMo and programming it using the C programming language. Which is utilized to make other devices communicate with it. Also, WeMo provides a network with an active internet connection within it.

IR Sensor

A sensor that measures and recognizes infrared radiation in its environment. The IR sensor shown in Figure 14 has been installed in every parking lot, and the sensor will sense the car's presence if it is parked in the parking lot; then, it will send a signal to the database to change the parking status on the screen from available to unavailable.

Servo 180

This tool shown in Figure 15 is a motor that turns the things connected to it. It is used to operate the umbrella automatically (Barela, 2022).

Soldering Board

Metal pieces are joined using the soldering technique shown in Figure 16 to create a mechanical or electrical link. In most cases, a low melting point metal alloy (solder) is used, which is heated and applied to the metal pieces that need to be joined. When the solder solidifies, it joins to the metal parts and creates a connection (UTS, 2023).

Micro USB Female Connector

It is on hubs, computers, and other devices that accept the plug-in attachment. Extender cables with a male-A connector on one end and a female-A connector on the other end are also available. A laptop's side-mounted female USB-A connectors. Products with a 5V Micro USB adapter as the power source can be used (SFUPTOWNMAKER, 2023) as shown in Figure 17.

Wires

The wires shown in Figure 18 were used to connect the WeMo with the sensors, the button, and the rest of the tools used on the board.

Power Bank

In Figure 19, a portable charger was created to recharge any electronic device anywhere, at any time with a capacity of 1000mAh (Petan, 2023).

Push Button

A button is essential hardware to trigger actions specified in the system implementation. As for this system, when the button in Figure 20 is pushed, it will provoke the screen to show the driver the nearest available parking spot to the entrance displayed on the screen. The screen and the button will be placed right before the access (USB, 2023).



Figure 13: WeMo Microcontroller



Figure 14: IR Sensor



Figure 15: Servo 180

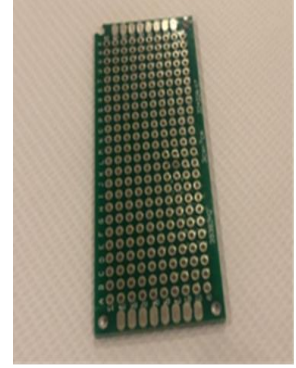


Figure 16: Soldering board

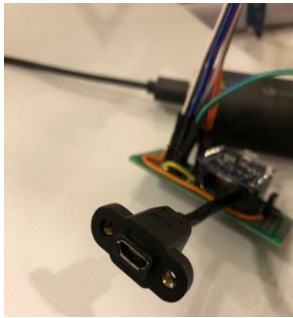


Figure 17: Micro-USB Female Connector

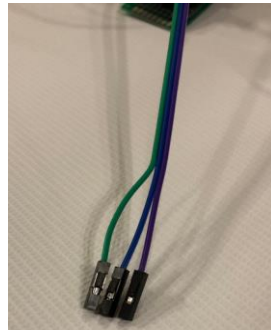


Figure 18: Wires



Figure 19: Power Bank



Figure 20: Push Button

4 Results and Discussion

A smart parking management system using IoT was created. The suggested technique assisted in resolving issues with difficulty in finding available parking in general, particularly in the shade due to the unkempt area and lack of umbrellas. The following aims help achieve these objectives:

HTML and JavaScript were used to develop a mock screen interface to display the scenarios' states. The Firebase platform built a database that links sensors and monitors.

A prototype was made to mimic the proposed smart parking management system. According to the discussion, the system has accomplished all the targeted objectives. The prototype was presented to some of the employees and visitors of the organization, they showed their satisfaction with the system. In addition, there were some suggestions given to us that will increase the efficiency of the system and help in marketing it, and they were mentioned in the future work section.

By contrasting the proposed system with other systems that we have reviewed and discussed in the literature review section, we can see that the proposed system is comparable to other systems in that it offers the benefit of using an infrared sensor to confirm vehicle presence and a screen to display the number of parking spaces available. Yet, the proposed system differs in several ways, making it special, useful, and effective. Besides using screens with a reservation application in most studies, the system used a screen with a button to display available and unavailable parking spaces for the customer with an indication of the nearest parking space. According to the studies, sensors are also used in other systems, but they simply confirm the vehicle's existence as a whole system. The suggested system differs from other systems researched because sensors were utilized to determine if a car was present or absent in the

parking lot and combined with the smart umbrella. This novel feature had not been employed in other studies. On the other hand, the system's presence will make parking management easier, making drivers satisfied with the system.

5 Conclusion

In this research, a smart parking management system was proposed to implement in any organization studies on smart parking management using sensors and the Internet of Things were compiled. In addition, a survey was presented to employees and visitors of the organization. The results showed that most of the respondents prefer automatic umbrellas over traditional ones and prefer smart parking management systems that use a screen and a button near the parking lots. A prototype of the proposed system was made to test all the functions, and it was shown to many employees, and they showed their satisfaction with the system. When the proposed system is implemented, the time and effort spent searching for a suitable parking space will be reduced.

The system provides a feature of locating the nearest available location using a button. To obtain this feature if there is more than one parking entrance, there must be a button at each entrance so that when pressed by the driver it shows the closest parking to the driver based on the entrance which they are in. If the system is implemented in large parking lots, the use of GPS technologies can be added to locate the car, by placing a barcode that appears on the website.

The use of AI algorithms on vehicles that are parked in more than one parking lot can be investigated in the future. In addition, using RFID technology allows digital data to be coded into the RFID tags. The tags will be placed on every worker's vehicle, to automatically identify whether the driver is a worker in the organization or not.

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Authors Biography



Bshayer Alsafar, a dedicated computer science graduate with a bachelor's degree from Imam Abdulrahman Bin Faisal University (IAU). Born in 2000 in Saudi Arabia, she possesses a profound interest in utilizing technology to address common challenges. Her recent research project methodology to solve daily struggles on finding the best parking spot as fast as possible entails the implementation of Internet of Things (IoT) technology, reflecting her commitment to innovation and the practical use of her computer science expertise to real-world problems. Bshayer is poised to continue her path in exploring the convergence of technology and daily life, striving to make a significant difference through her work.



Dhay Alzahr, born in Saudi Arabia in the year of 2000, a computer scientist, graduated with a bachelor's degree in science from Imam Abdulrahman Bin Faisal University (IAU). She is keen to learn about technology and captivated by it. Her most recent endeavor used Internet of Things (IoT) technology to create a parking management system, which aims to lessen the daily struggle of finding the closest parking spot as quickly as possible. This demonstrates her dedication and her aptitude for using her computer science expertise to solve a practical problem, that also indicates her passion to learn more about the field of computer science to help solve real-life problems.



Raghad Alshuwkh, a bachelor's degree graduate in Computer Science at Imam Abdulrahman bin Faisal University (IAU). Born in Saudi Arabia in 1999, Raghad is fascinated by technology and eager to learn all about it. Her latest project was a parking management system including internet of things technology (IoT), to solve the struggle of searching for a parking everyday. She believes that computer science is challenging, and she likes to be challenged, and She will always be enthusiast to pursue her passion in computer science.

Afnan Darwish, Date of birth 2000 AD-Kingdom of Saudi Arabia, holds a bachelor's degree in computer science from Imam Abdulrahman bin Faisal University (IAU). Possess the skill of problem solving and critical thinking, produced many projects in various fields, such as software and networks, in order to apply the theoretical knowledge that been studied. Aspires to learn more in the field of artificial intelligence in an effort to keep pace with technological development.



Thowiba E. Ahmed, joined Imam Abdulrahman Bin Faisal University - College of Science and Humanities – KSA (2013 - til now), as an assistant professor in the computer science department, and a Head of the computer science department (2016 -2019). She received her B.S. (2004) in computer science and statistics from El-Neelain University-Sudan, M.Sc. (2007) and Ph.D. (2012) in Information Technology from El-Neelain University, Sudan. In (2004) she joined the National Highway Authority- Sudan - as a programmer and after that as the information network supervisor. In (2004) joined El-Neelain University as a collaborative teaching assistant and collaborative assistant professor in 2012, and in 2012 she joined Emirates College of Science and Technology- Sudan - as an assistant professor and head of the information technology department. Her research interests include Data Science, Expert systems, HCI, Systems and algorithms analysis and design, Web applications, and E-learning.

Eyman Alyahyan, is a Ph.D. student in the School of Computing Science at the University of Glasgow, UK. Her research interests include Data Mining, Data Analytics, Machine Learning, Text Mining. Alongside her Ph.D. studies, she is a lecturer in Computer Science at Imam Abdulrahman Bin Faisal University. Eyman earned her B.S. and M.S. in Computer Science from Imam Abdulrahman Bin Faisal University, Saudi Arabia, in 2008 and 2020, respectively. Eyman has contributed to several significant publications in Computer science field.

Dabiah Alboaneen, received the M.Sc. degree (Hons.) in advanced computer networking and the Ph.D. degree in cloud computing and artificial intelligence from Glasgow Caledonian University, in 2013 and 2019, respectively. Currently, she is an Assistant Professor at the College of Science and Humanities in Jubail, University of Imam Abdulrahman Bin Faisal. She was awarded a lot of prizes, such as the Best Master Project in Networking and Wireless Communication Prize of the Glasgow Caledonian University, in 2013, and 11 distinction awards from the Saudi Cultural Bureau in London, since 2013. Her current research interests include machine learning, AI governance, and RegTech.



Enas E. El-Sharawy, earned her bachelor's degree in Mathematics and Computer Science, followed by a M.Sc. and a Ph.D. in Computer Science (Software Engineering) from the Faculty of Science at Al-Azhar University, Egypt, in 2006, 2011, and 2014, respectively. She worked as a faculty staff member at Al-Azhar University from 2009 to 2018. Currently from 2019 till now, she works as an Assistant Professor in Computer Science Department at the College of Science and Humanities, Imam Abdulrahman Bin Faisal University (IAU), Jubail, Saudi Arabia. E. El-Sharawy has worked at various accredited universities and has a prolific record of publications in recognized international journals and conferences. With extensive teaching experience, she has made notable research contributions and served as a reviewer for numerous reputable international journals. Her research interests include Formal Methods, the Rodin platform, and other fields of Software Engineering.