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IoT-Enabled Smart Car Parking Management: Revolutionizing Urban Traffic Flow

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A B S T R A C T

The IoT-based smart auto parking management system is a breakthrough solution that addresses the increasing issues of urban parking congestion. The present urban environment is marked by a growing population, fast urbanization, and inadequate parking facilities, resulting in persistent traffic congestion and driver dissatisfaction. Traditional parking management systems are inadequate in this situation as they do not offer immediate access to information about parking availability and do not have fast paying procedures.

In order to tackle these urgent problems, our cutting-edge system utilizes ESP32 and Wi-Fi technology in combination with IR sensors to provide a holistic solution. By utilizing a specialized smartphone application, customers may instantly receive information regarding available parking spaces, which greatly simplifies and improves the parking process. Moreover, the incorporation of billing capabilities directly into the application streamlines payment procedures and improves user comfort.

Our system maximizes resource use and reduces traffic congestion by using condition-based controls, such as keeping the input gate closed when there are no empty slots. This comprehensive strategy not only addresses the existing difficulties experienced by city residents but also establishes the groundwork for sustainable urban transportation solutions. The IoT-based smart auto parking management system improves urban living standards and transportation infrastructure by seamlessly integrating technology and user-centric design.

Keywords: ESP32, Wi-Fi technology, IR sensors, PCB Design.

1. INTRODUCTION

As a result of urbanization and economic expansion in Bangladesh, there has been an increase in the number of vehicles on the road, which has made the deficiencies in the current parking infrastructure even more severe. Drivers are finding it increasingly difficult to secure parking spots on roadways as the number of vehicles on the road continues to increase. This has resulted in wasted time, increased congestion, and increased pollution of the environment. In addition, the lack of real-time parking information makes the difficulties that motorists experience even more difficult, particularly during peak hours and during the holiday season. Within the scope of this study article, the multifaceted problems that are affecting parking management in Bangladesh's metropolitan areas are investigated. It investigates the effects of high vehicle density on urban roadways and the challenges that drivers face as a result of this density when attempting to secure parking places. This study highlights the urgency for creative solutions by assessing the inadequacies of standard parking systems and the exacerbation of congestion and pollution due to inefficient parking practices. Overall, the paper emphasizes the need for innovative solutions.

As an additional point of interest, the article investigates the potential for Internet of Things-based parking management systems to revolutionize urban parking paradigms. using the utilization of sensors, data analytics, and cloud-based services, the Internet of Things (IoT) makes it possible to effectively monitor the availability of parking spaces in real time and to make reservations for parking spaces using mobile applications in a smooth manner. Additionally, the incorporation of automatic gate-opening technologies improves the convenience of the user experience while simultaneously reducing the amount of pollutants and congestion in the environment.

The purpose of this research is to provide insights into the effectiveness of Internet of Things (IoT)-based parking management systems in minimizing parking difficulties in metropolitan Bangladesh. These insights will be provided through extensive analysis and case studies. Through the presentation of a transformational approach to parking management, this paper advocates for the implementation of Internet of Things technologies in order to build urban settings that are more intelligent, more efficient, and more environmentally friendly.

2. LITERATURE REVIEW

In recent years, significant changes have been observed in urban landscapes due to population growth and increased vehicular traffic, leading to notable challenges such as parking space shortages. This issue is associated with traffic congestion, environmental degradation, and time wastage for drivers. In response, innovative solutions leveraging the Internet of Things (IoT) have been developed, aiming to transform parking management in urban areas.

This review seeks to explore the evolving landscape of IoT-based parking systems, examining various concepts, research findings, and real-world implementations. By delving into existing studies, an understanding of the operational mechanisms, efficacy, and potential challenges associated with these technological advancements is sought.

Novel algorithms for real-time parking management have been proposed in several studies. For instance, an algorithmic approach to transform the online problem of parking scheduling into an offline framework was introduced by **(Geng & Cassandras, 2011, 2013; Zhao et al., n.d.)**. By formulating the problem as a linear model, an efficient algorithm to optimize parking allocation was devised. While promising results were demonstrated in experimental simulations, critical aspects such as resource reservation mechanisms, system assessment, and handling of service denials were overlooked.

In another study by (Mainetti et al., 2014), an IoT-based Smart Parking System (SPS) was proposed, integrating UHF frequency, RFID, and IEEE 802.15.4 wireless sensor networks. This system enables real-time monitoring of parking space occupancy and guides drivers to available spots via a software application. Despite its practical implementation, mathematical modeling of the system architecture and performance evaluation on a large scale were lacking.

Furthermore, (Hsu et al., 2012) introduced an innovative parking guidance system incorporating smartphone reservation and inertial navigation technology. Through wireless transmission and DSRC protocol, parking spaces can be reserved remotely, and navigation assistance is provided upon arrival. While the system demonstrates accuracy in inertial navigation within indoor environments, the study falls short in evaluating parking service performance and providing mathematical models for system analysis.

In another paper (Alsafery et al., n.d.) proposes a new smart car parking system that utilizes IoT technology to address challenges in urban parking management. Existing cloud-based solutions are expensive due to high data transmission costs. This system focuses on reducing data transmission by processing raw sensor data locally before sending it to the cloud for further analysis with machine learning. The system offers additional functionalities beyond just finding parking spaces, including traffic congestion information.

(Anusha et al., 2019) Propose an IoT-based smart parking system using Arduino components and a mobile application to address parking issues in crowded cities. This system utilizes on-site slot modules to detect parking space availability and a mobile app for users to find and book spots. They claim smart parking can improve urban economies by reducing fuel consumption and pollution.

(Chinrungrueng et al., 2007) Propose adapting their existing optical wireless sensor network (WSN) technology for parking management in garages. Their WSN system informs drivers of available parking spaces, reducing driver frustration and congestion caused by searching for spots. The paper discusses challenges encountered when applying their original WSN design to parking garages and proposes solutions.

In summary, the transformative potential of IoT in revolutionizing urban parking management is underscored by these studies collectively. However, comprehensive evaluations encompassing system performance, scalability, and user experience are needed. Future research endeavors should focus on addressing these gaps to realize the full benefits of IoT-driven parking solutions, paving the way towards more sustainable and efficient urban living.

3. Methodology

3.1 Block Diagram

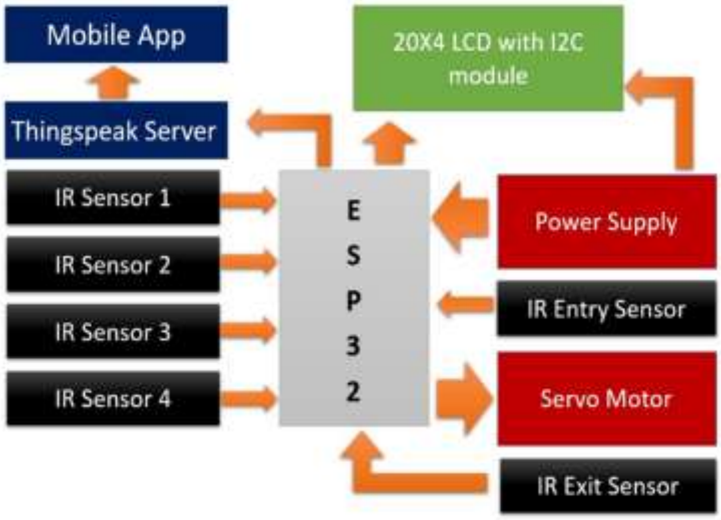

Fig 1 Block Diagram of Proposed System

The organized flow of power and data within the system is visually represented in the block diagram (Fig 1), illustrating the collaborative dynamics shaping its operation. The process commences with a two-pin power adapter, establishing a connection to a DC Buck Module (LM2596) responsible for regulating voltage within the range of 3-5 V. This regulated power then flows into the ESP32 microcontroller, serving as the central control hub. From the ESP32, connections extend to pivotal components. A servo motor facilitates controlled motion, while an I2C module establishes communication between the ESP32 and a 20x4 LCD screen, enabling data exchange and providing visual feedback. Augmented by six IR sensors, the system gains environmental awareness, continuously relaying real-time data to the ESP32 for informed decision-making. The block diagram encapsulates the intricate interplay of power distribution, control mechanisms, interactive interfaces, and intelligent processing. It highlights how these components collaboratively contribute to realizing the system's objectives, emphasizing the cohesive functioning of the system as a whole.

3.2 Schematic Diagram

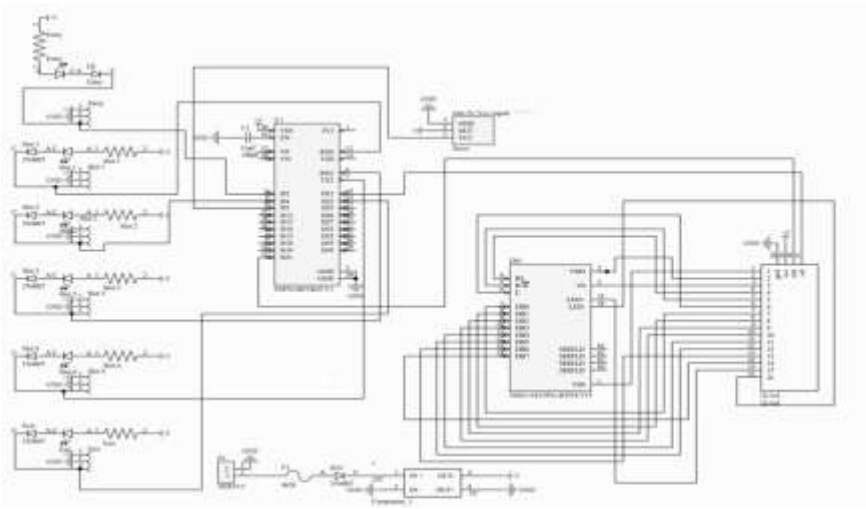

Fig 2 Circuit Diagram of the system

The focal point of our project is a precisely crafted schematic diagram, which serves as the foundation for its functionality. The central component of this diagram is a two-pin power adaptor, which serves as the starting point of connection to the AC main power line. The main power source connects to a DC Buck Module, namely the LM2596, which is well-known for its capacity to control and provide voltage in the range of 3 to 5 volts. The DC Buck Module plays a crucial role as an intermediate, ensuring a stable and suitable voltage supply. The microcontroller board assumes a prominent role following the power regulation unit. The ESP32 microcontroller exercises control over the entire array of equipment, establishing dominance in the control hierarchy. The microcontroller relies on several interconnected components to function well. A servo motor, a very reliable component used for motion control, is an exemplary example of such an element. The connection enables accurate manipulation of mechanical components based on the instructions provided by the ESP32. In addition, a liquid crystal display (LCD) is connected to the microcontroller using an I2C module, allowing for smooth communication. This interactive display offers visual feedback and presents information, significantly improving user engagement and system clarity. The project's intelligence and adaptability are emphasized by the inclusion of six strategically integrated IR sensors in the concept. These sensors function as sensory organs, transmitting live data to the ESP32. This input enhances the microcontroller's ability to perceive and understand its surroundings, allowing it to make well-informed judgments and adaptations. This well designed schematic diagram provides a clear representation of the various links and operations of our project. Our project successfully integrates several components, including a regulated power supply, intelligent microcontroller, motor control, display interaction, and sensor feedback, to perform its intended function with accuracy and efficiency.

3.3 Required Components:

- PCB
- ESP32
- Power Adapter
- 2004 LCD Display
- LCD I2C module
- IR Sensor x6
- Servo Motor(sg90)
- DC Buck Module
- Diodes
- Mini LED Lights

3.4 PCB Board Design

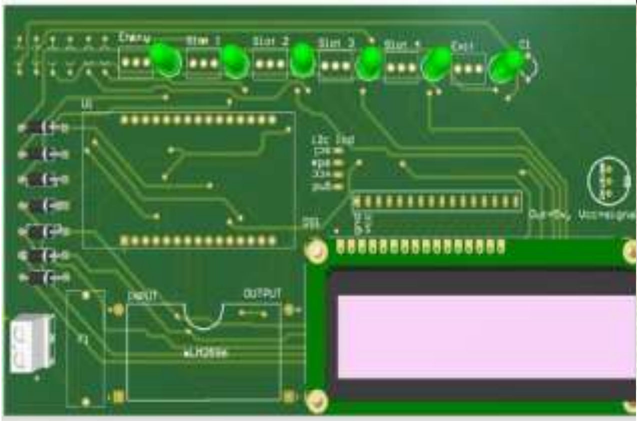

Fig 3 Primary PCB Design

Fig4 Final PCB Board

In order to enhance the performance of the design that was proposed, a printed circuit board (PCB) layout was developed for a system that includes four parking slots with Wi-Fi connectivity. The procedure began with the creation of an early PCB design stage (Figure 3). After thorough assessment and fine-tuning, the ultimate PCB board was manufactured (Figure 4). The PCB layout was carefully designed to guarantee the most effective arrangement and routing of components, reducing any disturbances and maximizing the integrity of the signal. The utilization of superior materials and meticulous production procedures significantly augmented the dependability and efficiency of the system. The PCB design underwent thorough testing and validation to ensure that it matched the strict requirements of the intended application. The ultimate PCB board embodies meticulous planning, design, and implementation, offering a sturdy and effective base for the system's functioning.

3.5 Designed Android Application for the system

The suggested solution was accompanied by the development of an Android application that was designed to assist the collecting and viewing of data. After the data from the ESP32 was sent to the Thingspeak server, the application collected it and displayed it on the mobile device that the user was using. The application's design and functionality were both accomplished through the utilization of Kodular, which is a visual development platform. Users would be able to determine whether parking spots were available or occupied using this platform, and they would also be able to receive an invoice as they were checking out, which would streamline the parking process. One example of the application's user interface is shown in Figure 5.

Fig 5 Interface of our designed application

3.6 Final Look of the demo system

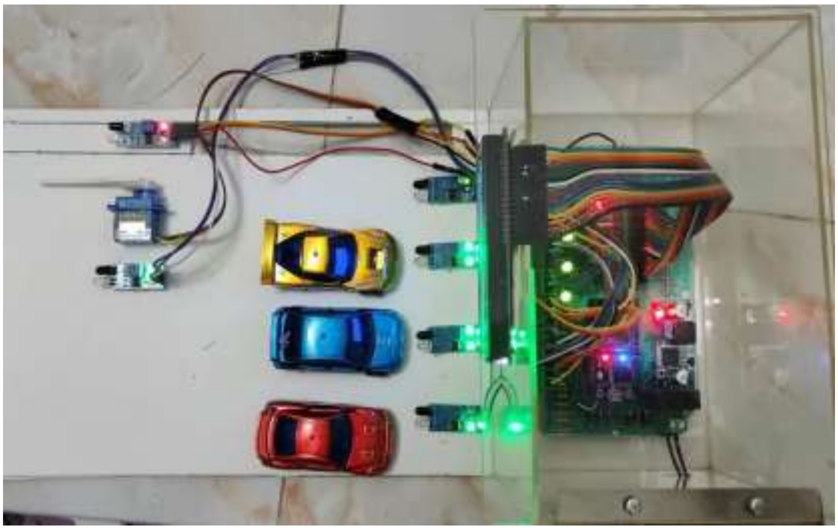

Fig 6: Final Design of The Hardware

Result & Data Analysis

This chapter will analyze the results of our systems from two different viewpoints. Firstly, the detection system will be evaluated for its capacity to accurately ascertain the status of an item as either empty or full. Secondly, the billing system will be rated based on its performance subsequent to the completion of a purchase.

4.1 Car Detection Accuracy:

Table 1: Car Detection Accuracy

Car Detection	**Sensor-1**	**sensor-2**	**Sensor-3**	**Sensor-4**
Detected	19	19	20	18
Delayed	1	1	0	2

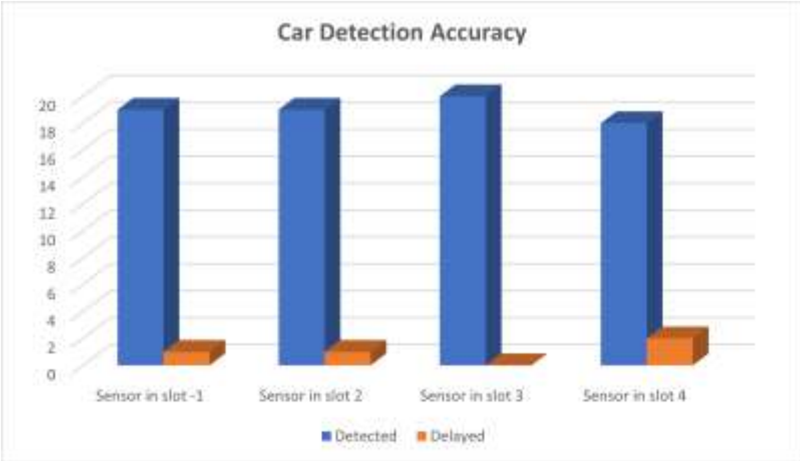

Fig 7 Graphical View of Car Detection Accuracy

The graphic demonstrates four sensors' automobile detection accuracy. Sensors are on the x-axis and accuracy on the y. Blue bars show car detection, and orange bars show car delay. The first sensor has the best accuracy, followed by the second, third, and fourth. First sensor has lowest latency, followed by second, fourth, and third. The first sensor performs best, followed by the second, fourth, and third.

4.2 Parking Cost Accuracy:

Table 2: Parking Cost Accuracy

Parking Cost Accuracy	**Sensor-1**	**sensor-2**	**Sensor-3**	**Sensor-4**
Accurate	18	18	20	19
Slightly Low or High	2	2	0	1

Fig 8 Graphical View of Parking Cost Accuracy

The figure depicts the precision of parking cost measurements from four sensors. The horizontal axis of the graph corresponds to the sensor number, while the vertical axis reflects the accuracy. The green bars depict the proportion of precise measurements, whilst the blue bars illustrate the proportion of slightly over or underestimations. The accuracy of all the sensors is consistently above 95%. Sensor 3 achieves the highest accuracy, with a rate of 99%, followed by sensor 4 with a rate of 98%. The accuracy of sensor 2 is 97%, whereas sensor 1 has the lowest accuracy at 96%. The overall efficiency of the system is 97.5%.

Conclusion

In conclusion, the study's objective is to propose a Smart Car Parking System (SCPS) that makes use of Internet of Things (IoT) technology in order to ease the growing parking scarcity in developed cities. This is the purpose of the study. The system offers a solution that is both cost-effective and makes use of real-time data in conjunction with mobile applications that are simple to operate. This is done with the intention of simplifying the parking experience. It is possible that cities will not only anticipate an increase in parking efficiency as a result of the installation of SCPS, but they may also anticipate a reduction in traffic congestion, an improvement in air quality, and overall cost savings for drivers. Two upcoming enhancements that will further improve user convenience and resource management are the integration of a mobile booking system with automatic payments and the optimization of sensor consumption based on the presence of a car. Both of these enhancements will be implemented in combination with one another.

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