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A Comprehensive and Inclusive Key Design for Smart Parking Solution Using the Three Validation Real Time Method

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Abstrak. *Penelitian ini mengagas inovasi perancangan teknologi sistem parkir SM- Park yang menggunakan metode three Validation real – time (3VR) untuk memastikan keakuratan dan efesiensi pada pemantauan lahan parkir. System ini mengintegrasikan beberapa teknologi sensor termasuk ultrasonic dan sensor passive infrared (PIR) , bersamaan dengan computer vision utuk mendeteksi dan memvalidasi ketersediaan slot parkir secara real time. Melalui perpaduan teknologi Internet of things (IoT) dan Artificial Intelligence (AI), SM – Park memungkinkan pengguna mendapatkan informasi ketersedian slot parkir kosong secara cepat dan tepat melalui system informasi berbasis web sehingga meminimalisir waktu menunggu dan meningkatkan efisiensi dalam sistem parkir. Sistem ini telah dirancang melalui beberapa tahapan diantara lain studi literatur, perancangan purwarupa, dan integrasi teknologi. System ini mampu berfungi tanpa menggunakan perangkat eksternal seperti RFID atau Aplikasi mobile sehingga mampu menjadi Solusi parkir yang lebih inklusif. Makalah ini menguraikan desain dan arsitektur sistem SM Park, komponen teknisnya, serta potensi sistem ini dalam mengatasi tantangan utama dalam manajemen parkir perkotaan, seperti kemacetan, emisi karbon, dan pemanfaatan ruang yang tidak efisien.*

Abstract. *This study presents an innovative smart parking system known as SM Park, which utilizes the Three Validation Real-Time (3VR) method to provide accurate and efficient parking space monitoring. The system integrates multiple sensor technologies, including ultrasonic and Passive Infrared (PIR) sensors, along with computer vision, to detect the availability of parking slots in real-time. By leveraging the Internet of Things (IoT) and Artificial Intelligence (AI), SM Park enables users to reserve parking spaces in advance via its website, thus minimizing wait times and improving the overall efficiency of parking. The development process followed a prototype methodology, which allowed for rapid prototyping, feedback collection, and iterative design enhancements. The system's performance was evaluated through various stages, including literature review, system design, prototype development, and sensor integration. The system design eliminates the need for external devices such as RFID tags or mobile applications, creating a more inclusive parking solution. This paper outlines the design and architecture of the SM Park system, its technical components, and its potential for addressing key challenges in urban parking management, such as congestion, carbon emissions, and inefficient space utilization.*

1. INTRODUCTION

Transportation is a crucial sector that supports the activities of modern society. However, the number of motor vehicles in Indonesia continues to grow rapidly every year. According to data from the Central Bureau of Statistics [1], the total number of vehicles, particularly passenger cars and

motorcycles, shows a consistent upward trend. In 2022, the number of passenger cars reached 17,168,862 units, while motorcycles reached 125,305,332 units[2]. This increase in the number of vehicles directly impacts the demand for supporting facilities, such as parking spaces, which often become a major issue in various locations like shopping centers and campuses [3]

The lack of data on available or vacant parking spaces forces drivers, especially apartment owners, to circle the parking area in search of a vacant spot, resulting in long parking times [4]. Common problems include difficulties in finding an empty parking space and long queues, leading to delays and wasted time. This situation is further exacerbated by the high level of carbon emissions produced by vehicles while searching for parking spaces. Additionally, a study conducted in Seattle, USA, revealed that 60% of traffic congestion was caused by drivers circulating in search of parking spaces in the area[5] .

While parking management technology in Indonesia has advanced, there are still few systems that provide real-time information about available parking slots, especially in buildings like shopping malls and hospitals[6]. As a solution, we propose an innovative smart parking system based on the Internet of Things (IoT) called SM Park (System Monitoring Parking) [3]. This system integrates camera-based technology with an Artificial Intelligence (AI) model, as well as ultrasonic and Passive Infrared (PIR) sensors, to detect parking slot availability in real-time. By utilizing this technology, SM Park ensures high data accuracy and allows users to reserve parking spots in advance via the website, reducing waiting times and improving parking efficiency. Based on the background research, here is a potential research question:

"How can the integration of Internet of Things (IoT) and Artificial Intelligence (AI) in smart parking systems improve parking space availability, reduce traffic congestion, and minimize carbon emissions in commercial areas, and what are the key design considerations for an effective monitoring parking system ?"

2. METHODS

In this research on the smart parking system, the development model that will be used is the prototype method. The goal of this prototype is to develop and test an initial model, which will then be developed into the final system. The prototype method is used to provide users with a preview of how the application will be built by first creating a system prototype [7]. This allows users to provide feedback. The evaluation of this prototype application can then serve as a reference for building the final product of this research. Here are the stages involved in the prototype development method:

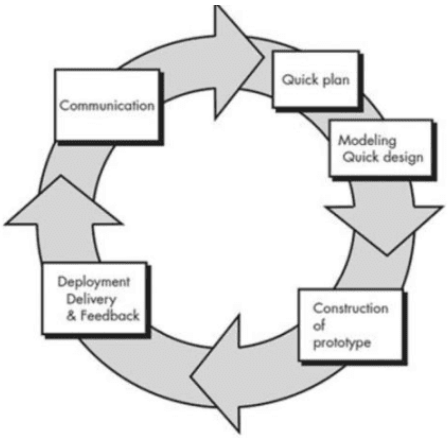


Figure 1. Construction Deisgn Cycle
Source : Primary data

1. Communication: This stage involves identifying the problem and the interaction between developers and stakeholders to understand the system development goals, gather requirements, and establish system constraints.
2. Rapid Planning: In this stage, rapid modeling is conducted based on the requirements gathered during the communication stage.
3. Rapid Design: This stage involves designing the system in a way that
4. Users can understand, such as designing the user interface, based on the planning conducted earlier.
5. Prototype Construction: In this stage, the prototype is built with the aim of providing users with a preview of the identified and designed requirements. This prototype is then evaluated to gather feedback.

6. Implementation, Delivery, and Feedback: The built prototype is evaluated by stakeholders, who provide feedback that will be used to obtain additional requirements. In this process, iterations may occur to better meet the needs

3. RESULTS AND DICUSSION

To address these issues, we propose an innovative smart parking system based on the Internet of Things (IoT) called SM Park (Parking Monitoring System). This system integrates camera-based technology with an Artificial Intelligence (AI) model, along with ultrasonic and Passive Infrared (PIR) sensors to detect parking slot availability in real-time. By using this technology, SM Park can provide high data accuracy and allow users to reserve parking spaces in advance through a website, thus reducing waiting times and improving parking efficiency. The development of this system involves several main stages as follows:

3.1 Literature Review

The first stage involves conducting a literature review to understand the current state of existing parking management systems and to identify the most suitable technologies to be integrated into an IoT and AI-based parking monitoring system. The table 1. summarizes key research studies focused on parking detection technologies, exploring various methods for detecting vacant parking spaces and counting vehicles.

These studies highlight the strengths, limitations, and potential improvements in current parking detection systems [11], from the analysis of the studies, a clear gap in the current research emerges: the validation of parking monitoring systems can still be improved by combining multiple methods and designing more efficient systems. Each individual method—whether it be ultrasonic, PIR, or computer vision—faces inherent limitations that can be mitigated by integrating multiple detection technologies.

For instance, combining sensor-based systems like ultrasonic sensors or PIR with advanced computer vision techniques such as YOLO could improve the accuracy of detection, particularly in challenging environments with obstructed views or complex parking configurations.

Table 1. Research studies on parking detection

Reference	Method	Limitations	Result
(Wibawa et al., 2022 [8])	IoT with ultrasonic sensors to detect empty parking spaces and send this informatio n via a bot	The ultrasonic sensor has a minimum reading distance of 2 cm,	If the angle exceeds 20°, the sensor cannot read properly, leading to higher error percentages.
(Fasha, 2020 [9])	PIR (Passive Infrared) Sensor AM 312	Capable of detecting the heat signals from objects such as vehicles recently parked.	Adding an extra validation layer to the system may lead to detection errors caused by non-vehicle objects.
(Rizkata ma et al., 2021 [10])	Intelligent Car Counting System using Python programmi ng and YOLO v4 algorithm	The system's accuracy rate reached 72.8%.	The system faces issues with detecting vehicles obstructed by other objects.

Furthermore, creating more efficient system designs that optimize data processing and reduce false positives could enhance overall performance. he reviewed studies offer valuable insights into the development of intelligent parking systems. However, to improve real-world applications, it is crucial to address the limitations identified in each study. Combining different sensing technologies (e.g., integrating ultrasonic sensors with computer vision or using multi-sensor fusion) could help mitigate individual system weaknesses. Additionally, incorporating machine learning algorithms to handle environmental variations, such as occlusion or false heat sources, could significantly enhance the reliability and accuracy of parking detection systems.

Future research should focus on overcoming these limitations and bridging the existing gaps by combining methods and creating more robust, adaptive systems capable of functioning effectively in diverse and dynamic environments.

3.2 System Design:

SM Park introduces a unique parking system that uses the 3VR method, which combines two sensors and computer vision to validate parking space availability in real-time. Unlike many systems that rely on a single sensor, such as ultrasonic sensors used in [12], SM Park also creates a more inclusive system by eliminating the need for additional devices like applications or RFID tags, which are common in systems like Parkmobile and EasyPark. Furthermore, SM Park offers the ability for users to book parking spaces through its website This makes SM Park a more effective and user-friendly solution for parking.

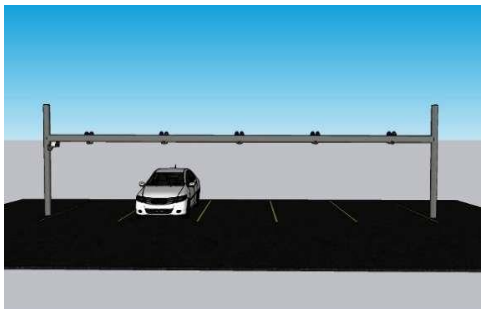


Figure 2. System Design using 3VR Method

The sensor support structure for SM Park is designed in the form of a pillar made of hollow steel with a cubic structure. Hollow steel is chosen because it is lightweight yet strong, and it is commonly used in construction for support frameworks. This pillar has dimensions of 2.5 meters in width and 13.5 meters in length, with the capacity to accommodate 5 parking slots.

3.3 Prototype Development:

The system prototype is developed (figure 2), including the hardware setup for ultrasonic (a) and PIR sensors(), computer vision camera (figure 3), and the development of a user interface for the website that allows users to reserve parking spots.

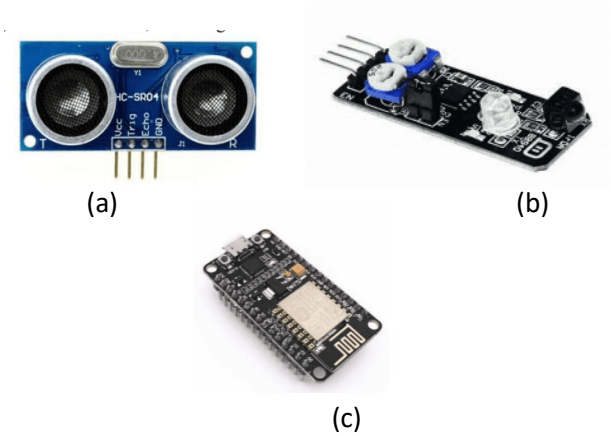


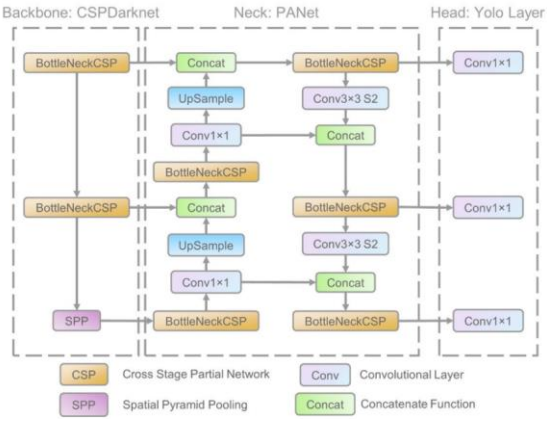
Figure 3. IoT sensors used in the design : (a) Ulta Sonic Sensor HC-SR04 (b) Infrared Sensor KY-032 (c) ESP8266

Figure 4. PS5268 Computer Vision Camera

In this design, the system is developed using the KY-032 infrared sensor to monitor parking areas. The data collected by the sensor is sent to the MQTT broker via an internet connection and can be processed by the subscriber, allowing real-time monitoring of the parking area. The KY-032 infrared sensor operates at a voltage of 3.3 volts and has a sensitivity range of approximately 2 cm, and it is connected to the ESP8266. Additionally, the two servo motors operate at 5 volts, the LCD display uses 5 volts, and the HC-SR04 sensor operates at 3.3 volts, all connected to the ESP8266.

3.4 Machine Learning Model Training

An essential aspect of this system is the AI model, which is trained using the machine learning framework (YOLO V5 for image recognition). This model processes camera feed to detect available parking slots, improving the real-time accuracy of parking availability information [12].



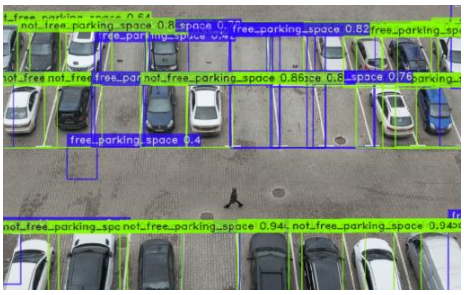


Figure 5. Computer vision to detect available parking slots
Source : YOLO V5 Guide reference

3.5 Sensor Architecture and IoT Integration

The architecture for the sensors is designed according to the specific needs of the parking environment [13]. Ultrasonic sensors are used to detect the presence of vehicles in parking slots, while PIR sensors help detect temperature changes, indicating that a vehicle has been recently parked. These sensors are integrated into the IoT system to enable real-time communication and data collection.

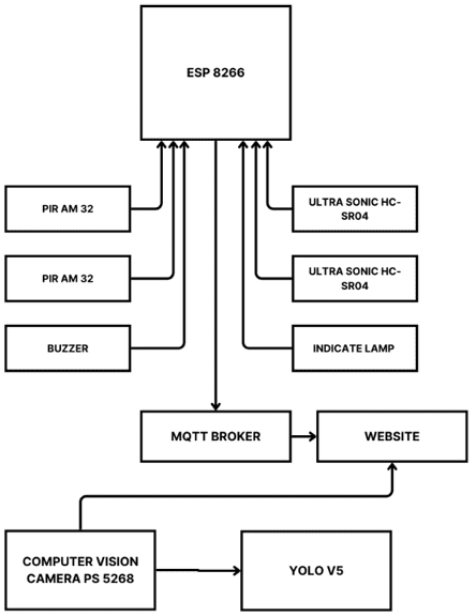


Figure 6. Flowchart of Architecture sensors are integrated into the IoT system

3.6 Platform Website Design

The SM Park website is designed to provide a more efficient and modern parking experience for its users. By utilizing web-based technology, users can easily access information about parking slot availability in real-time and make reservations for parking spaces before arriving at the location. This aims to reduce the time spent searching for parking, optimize the use of parking space, and enhance user convenience. Additionally, the website is developed with a simple user interface, making it easy to use for various parties, both through computers and mobile devices (figure 7).

The SM Park website is designed with two main functionalities: (1) View Parking Slots. This feature allows users to monitor the availability of parking slots in real-time without the need to log in. This information can be easily accessed through the website's homepage. (2) Book Parking Slot.

To reserve a parking slot, users are required to log in to their accounts. This login feature ensures the validity of user data and facilitates the management of reservations within the backend system.

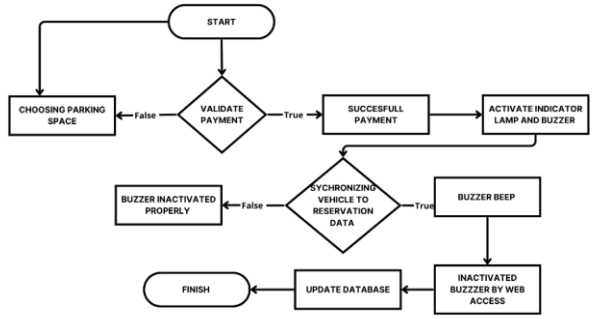


Figure 7. Flowchart of a SM Park website system

Figure 8. Interface websiten design of SM park

4. CONCLUSIONS

SM Park uses the 3VR (Three Validation Real Time) method, which relies on two different sensors and computer vision technology to validate parking slot availability in real-time. This differs from systems that typically use only a single sensor, as found in research by Priyanto et al. (2021), which uses a single ultrasonic sensor to monitor parking space availability.Second, SM Park creates a more inclusive environment by avoiding the use of apps or RFID (Radio Frequency Identification) on vehicles, which are often required in other parking systems such as Parkmobile and EasyPark, which rely on additional devices to function.

Third, SM Park allows users to book parking slots through the website, a feature not found in many other parking systems, such as those in the research by [14][15], which focus on automatic parking systems based on sensors that only monitor slot availability without offering reservation capabilities. With these features, SM Park provides a more effective, inclusive, and practical parking solution.

Authors Note

The authors declare that there is no conflict of interest regarding the publication of this article. Furthermore, the authors confirm that the paper is free of plagiarism and has been prepared with the highest standards of academic integrity.

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