IJRCS

International Journal of Robotics and Control Systems
Vol. 6, No. 2, 2026, pp. 1251-1270
ISSN 2775-2658
http://pubs2.ascee.org/index.php/ijrcs

ASCEE

ParkSense: A Real-Time Intelligent Parking System Integrating Acoustic and Optical Sensors for Seamless Vacancy Detection

Isam Bahaa Aldallal [a,1,*], Abdullahi Abdu Ibrahim [a,2]

[a] Department of Electrical and Computer Engineering, Altinbas University, Istanbul 34000, Türkiye
[1] isam.aldallal@gmail.com; [2] abdullahi.ibrahim@altinbas.edu.tr
* Corresponding Author

ARTICLE INFO

Article history
Received January 15, 2026
Revised February 14, 2026
Accepted April 23, 2026

Keywords
Smart Parking;
IoT Technology;
Urban Traffic Management;
Real-Time Data;
Detection Accuracy;
System Response Time;
User Satisfaction

ABSTRACT

Rapid city growth and increased car ownership have made managing parking in cities a tough problem. This leads to traffic jams, burns more fuel, and stresses drivers. Current parking solutions aren't always accurate or quick, plus users aren't always happy with them. This research aims to fix these problems by creating and testing a smart parking system using IoT. Our system uses ultrasonic sensors and cameras to improve how well it spots available spaces. A strong microcontroller processes data fast. A simple app gives users real-time info on parking, booking options, and easy payment methods. Reseach tested the system and looked at things like detection accuracy, response time, user happiness, and how often the system was running. The results show our system is very accurate (98%) and updates parking info in less than a second. User satisfaction is high at 90%. This is better than older systems, which usually have detection rates between 90% and 95% and take 2 to 3 seconds to respond. Our system also stays up and running almost all the time (99.9%), which is important for users to trust it. These results suggest that the system can help with urban parking problems by giving good info quickly. This improves traffic, reduces time spent looking for parking, and lowers emissions. This study offers a working solution to a big city problem and helps smart city tech grow. It provides a system that can be changed and used in different city environments. The good results and happy users show that these types of systems are important for making city life better and helping cities grow in responsible ways by using advanced IoT.

1. Introduction

Telecommunication is a forward-looking concept for smart cities. It's driven by years of tech improvements with the goal of making cities better. A smart city is a system that joins information tech with physical Internet of Things (IoT) devices to make city services more efficient and improve the lives of people who live there [1]. The Internet of Things (IoT) is a network of connected devices that share info. It's a term for many gadgets and is leading this change. Urban areas can use strategically placed Internet of Things (IoT) devices across the city to gather data. This data can improve how cities handle energy use and transportation [2]. Smart parking is key a part of smart cities. These systems use IoT to fix a big city problem: Parking is hard in parks and places like them.

Ignoring this can hurt finances, so it must be seen as a risk. IoT in parking helps monitor parking spots in real time, cutting down on traffic from people looking for parking [3]. Also, mobility in cities is improved, and emissions are cut, which smart city plans aim to do [4].

1.1. Problem Statement

The availability of parking spaces, particularly in the metropolitan area, has become a severe problem owing to numerous causes, including an increasing number of individuals utilizing personal automobiles and a shortage of parking places. Engaging in the behavior of driving aimlessly in search of vacant parking spaces is very unproductive. This usually leads to traffic accumulation, increased fuel consumption, and higher stress and exhaustion levels among the drivers [5]. Here, one may remark that in today's present circumstances of the continual expansion in the number of automobiles on the roads, the inefficiencies of such classic ways are simply increased, which poses significant requirements for the search for a more efficient solution. Smart parking systems that use IoT tech can help with problems such as not enough parking, where spots are, and how long it takes to find parking. They tell drivers where there are free spots. This helps stop wasting time and aids in running current parking areas well, which cuts down on traffic jams and pollution [6].

1.2. Objectives

The inherent essence of this project is to develop and test the smart parking system, which uses IoT technology to provide real-time information on the availability of parking lots and enhance the efficient control of parking places in cities. Specific objectives of the study are:

- Create a system design that uses tech like ultrasonic sensors and cameras to keep track of and handle parking spaces.
- Make an app that lets people see if parking is open and book spots ahead of time.
- Develop a mathematical model that can be used to utilize parking spaces and reduce traffic.
- Test the functionality of the system in terms of such factors as accuracy, speed and factual satisfaction of the system by people.

1.3. Scope

The research study is devoted to the challenges in the implementation of IoT-based smart parking systems in smart cities. It examines both hardware components, such as sensors, microcontrollers and the required software. The system will be constructed and tested within a controlled urban environment to achieve an idea of its performance and its shortcomings. The idea of the smart parking system is a good one but in this paper only the technological component is examined. It does not address issues relating to the creation of many of them, the long duration of their operation, or their insertion into urban environments. In addition to this, the research will examine various types of parking such as the public and the private parking spaces, however, it will not address the legalities of using these systems in various types of cities. Finally, this case study will contribute to the current literature about smart city development by proposing an efficient solution to parking management challenges in the urban context and optimizing the use of the IoT. The findings of the present study are likely to supply important information to city orchestrators, authority officials, and technology designers interested in the progress of intelligent and sustainable urban areas.

2. Literature Review

2.1. Overview of Smart Cities

Smart cities are well recognized nowadays as technology and solutions of a new generation meant to enhance the quality of life of citizens. To the best of the author's knowledge, this study covers a broad variety of trends, designs, components, and difficulties relevant to smart cities, as stated [7]. They increased consciousness and recognized the location where ICT may take part in upgrading the physical structure of emerging cities [8]. Speaks on the components of smart cities, emphasizing the importance of physical space and the incorporation of technology in cities.

Pawłowska (2018) notes that intelligent transportation systems (ITS) are important for putting sustainable development principles into action in smart cities. She also points out that transportation is a key area of focus in progressive city development since it manages traffic and pollution. For a full view of a smart city's structure (Fig. 1), see [9], which explains how different parts, like energy, transportation, and public services, can combine into a single system.

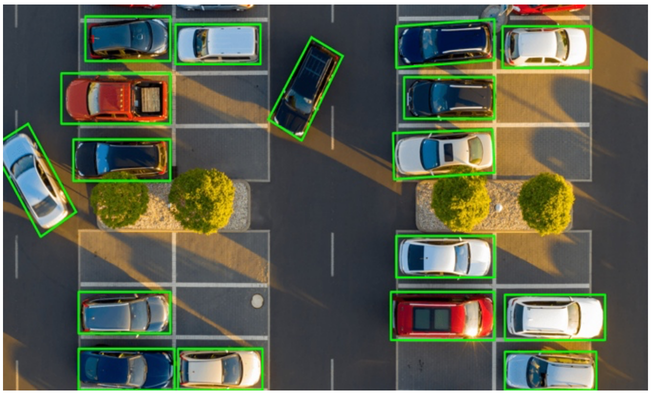

Fig. 1. Overview of Smart Cities parking [9]

Hayat (2016) evaluates the instances of smart cities globally, which demonstrate the method by which different nations are approaching and executing smart city projects. Thus, this research detailed the varied techniques and interventions employed in addressing the issues and concerns, which are contextually reliant on the specific features of various cities. Smart Cities [10] engage in a literature assessment of smart cities articles and find out paradigms, possibilities, and unresolved challenges. They stress collaboration across sectors and out-of-the box thinking about the issues of urban dynamics.

Smart city infrastructures and their progress are watched to handle resources well, focusing on gathering real-time data [11]. A study looked at how city infrastructures are handled using smart city technologies, showing how urban services can be made better by processing data. This multilingual journal's second edition shares views on using smart technology in city administration and what it means [12]. The resources show how smart infrastructure is used in different areas, like energy handling and health care. They guide in learning how smart city tech can improve people's lives and make city services work better [13]. Present a way to group IoT sensors by what they do and shows why they are important in smart cities [14].

2.2. Internet of Things (IoT)

IoT, as it is popularly known, is the connectivity of devices amongst them to exchange Internet data, enabling a vast variety of possibilities in different fields. A short description of IoT is offered [15], which consider the IoT components, architecture, and applications. It also aims at comparing the role of IoT in key areas like health, transport, and energy. In the context of traffic characteristics of IoT networks, concentrate on the major features of data management and communication protocols owing to the rising number of IoT devices [16].

The IoT is defined by its components and how they interact within the IoT system. Crucial issues include standardization and compatibility, which are key for IoT devices and systems [17]. brought up problems and fixes related to creating IoT tools, like limits in security, privacy, and how well they can grow [18]. reflects on the rise of smart city setups using IoT. The author talks about how IoT is used in smart cities. They give ideas on IoT apps, designs, and tech, plus how IoT is growing and changing in smart cities. Shahrour and Xie went over IoT and crowdsourcing work in growing smart cities, noting that people who live there are important to smart cities [19].

Give an overview of the role of IoT in the development of smart cities, wherein they provide an enumeration of use cases that vary from smart homes to industrial automation. They show some of the issues and opportunities associated with IoT deployment and the considerations addressing the safety of shared data as well as the structure of the Internet connection [20].

2.3. Intelligent Parking Systems

Smart parking systems, an application of IoT tech in smart cities, address parking management issues. Research in [21] suggest that integrating this system into urban mobility will positively impact traffic and congestion. Research in [22] and [23] showed SmartParking, an IoT-solution providing real-time parking info. A study presents details on smart parking sensors, tech, and uses, noting their pros and cons. It talks about how sensors are used in parking systems to improve parking. Research in [24] offer a system using image processing for spot recognition and control, with a review of its performance.

The function of parking surveys in the context of intelligent parking systems, with some concerns about the efficiency of parking space consumption. A smart parking system was presented that deploy the sustainable communication ingredient termed NOTICE to deliver dependent and dynamic parking data. Fig. 2 illustrate IoT based Intelligent Parking Systems [25].

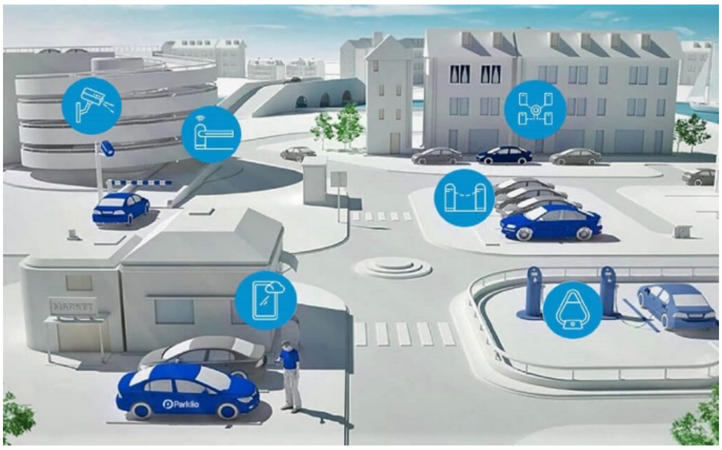

Fig. 2. IoT-based Intelligent Parking Systems [26]

Image processing in intelligent parking management systems enhances the accuracy of parking detection [27]. An IoT-based intelligent parking system can be used for smart cities. Its design and behavioral analysis should be explained in detail. Drawing from prior work [28], the design, method, and gains of an intelligent parking system may be shown. The current research on Intelligent Parking Systems shows that IoT tech is useful for dealing with parking management problems in cities. These systems give benefits like constant monitoring, good use of space, and better traffic flow. But,there are problems, like security and fitting the PRT into city infrastructures.

Cruising to find a parking spot is a very important factor in urban congestion, driving smart parking technology that notifies occupancy, broadcasts availability plus optionally provides reservation, charging, and enforcement. Early precursory work mathematically formalized smart parking as an optimization and reservation problem, in which the system allots drivers to spaces based on cost functions (e.g. distance and price) and solves the allocation centrally, which illustrates how reservation can enhance utilization and minimise search time [28]. Along with the expansion of deployments, there was a rise in the variety of research in sensing modalities, networking stack, cloud/edge architecture, security/privacy, and AI-based perception and prediction. Parking solutions based on the IoT mostly start with the trustworthy space occupancy detection. The ubiquitous in-ground or space-grade sensors are ultrasonic and magnetic sensors with low-power microcontrollers; commonly deployed in prototype IoT systems, as they are cheap and do not need any installation, in conjunction with a cloud back end and mobile interface [29]. In addition to single sensor designs, hybrid designs are designs that utilize RFID/WSN designs to measure occupancy state and vehicle/authorization context. As an example, RFID + IEEE 802.15.4 WSN integrated solutions have been applied to occupancy detection and also provided monitoring of reserved/unauthorized space and enforcement processes [30]. An analogue IoT-aware strategy also goes further to incorporate environmental/context parameters in sensing, and focuses on standardization and extensibility (RFID + WSN + NFC + mobile) of Smart City interoperability [31].

Sensing based on cameras and vision is also frequent, particularly in the cases where the cost of installation of sensors per space is too high. Vision systems are capable of occupancy estimation based on surveillance feeds and computer vision pipelines; however, they are light sensitive, prone to occlusion, and camera placement; therefore, recent reviews cast tradeoffs between camera coverage and sensor accuracy, and encourage multi-sensor fusion [32]. In practice, lots/levels and sensor node systems in many systems employ camera analytics and individual space sensor nodes, respectively, in terms of accuracy and cost. Following sensing, it is required that occupancy updates have a reasonable latency and energy consumption to reach gateways/servers. Space-level nodes are often chosen using short-range WSN technologies (such as IEEE 802.15.4 / ZigBee-class networks) due to the ability to be energy efficient and be deployed densely [33]. Nevertheless, retrieval constraint and the location of gateways may increase the installation issues in expansive outdoor settings.

To have a broader reach and simpler implementation, cellular IoT systems like NB-IoT have been considered. The NB-IoT smart parking architecture focuses on a lower cost of deployment, larger geographic coverage, and access to mobile applications and payment platforms [34]. Vehicular settings also have some literature on the V2I/V2X communications basis of DSRC/802.11p so as to connect roadside vehicles; although it is not parking-specific, DSRC standards are often mentioned where parking guidance is a subset of a larger ITS stack [35]. Numerous IoT parking systems are based on a layered design: sensor/space nodes are located at the bottom, followed by the gateway/broker and cloud services and, finally, applications. Prototypes based on the cloud are scalable and have centralized dashboards, which allow the reservation, analytics, and multi-lot aggregation [36]. Nevertheless, cloud-only processing may add both latency and bandwidth consumption (in particular, video), which is what edge/fog computing is encouraging. Fog/edge computing offers computing at the periphery, which minimizes response time and facilitates local decision-making (e.g., occupancy filtering, anomaly detection, short-term guidance), which is highly directionally consistent with IoT workloads [37]. Smart parking research (edge-enabled) An additional area of research is the integration of machine learning at/near gateways that are used to identify the user activity/occupancy states with reduced latency [38]. In addition to parking management, there is also literature on parking edge computing as a vehicular-edge paradigm, in which parked cars aid task offloading in an urban VANET environment, emphasizing the role of parking infrastructure in a more general edge ecosystem [39].

One vital feature aside from the display of vacancies is decision support: it will recommend a space/lot, assigning drivers, or it will allow them to make reservations. Optimization-and-reservation framing is still a powerful concept, demonstrating that the assignment policies can be calculated based on the driver preferences and system constraints [13]. Subsequent surveys underline the necessity to combine allocation with sensing reliability, user interfaces and enforcement mechanisms otherwise reservations can fail because of non-compliance or stale occupancy information [40], [41].

Mass roll-outs also need strong dissemination systems and urban-level institutionalisation. Smart parking solution surveys emphasize that end-to-end performance is determined by the accuracy of sensing, reliability of communication, and interoperability with the traffic management systems and payment/enforcement processes [42], [43]. As a result, a number of designs are based on multi-technology sensing (RFID/WSN/NFC/mobile) and standardized IoT protocols to enable Smart City interoperability [44].

Security and privacy is necessary since the parking systems may reveal sensitive location records and payment identities. The most common requirements in smart parking deployment include secure communication and authentication and privacy-controlling query mechanisms. An example securityoriented system (SecSPS) suggests publish/subscribe-based dissemination that uses mutual authentication and defends against frequent network attacks to be within the capabilities of small IoT devices [45]. The complementary methods consider privacy-respecting constructions based on blockchain and the recovery of personal information to conceal information requests without corrupting the data integrity of numerous parking operators [46]. The above efforts point to the fact that secure design should include device-level trust (sensor/gateway) and application-level privacy (user location, reservation, payment). In addition to the use of current occupancy, intelligent parking is becoming more and more focused on anticipating the availability in near future to decrease cruising. Recent surveys of parking occupancy prediction algorithms are finding deep learning (e.g., LSTM-type temporal models) to be very effective in short-term predictions with adequate historical data available, however, it is also sensitive to data sparsity and non-periodic changes (events, weather, holidays) [47]. In the case of camera-based systems, edge-assisted video analytics is under consideration to minimize bandwidth and enhance the real-time responsiveness by handling the feeds at the edge and transmitting condensed occupancy events to the cloud [48]. The methods based on AI are promising, yet their usefulness hinges on the quality sensing and constant monitoring of the models in evolving urban environments [49], [50].

3. Methodology

3.1. System Architecture

The proposed smart parking system would endeavor to reduce the difficulties that have followed in search and navigation of the parking lots in cities. Discussing the advantages of such system discussion, it is important to mention that this system provides real time access to the parking spots, simplifies the process of parking and increases the level of happiness of the users.

The system is made up of sensors, a microcontroller board and a system application. These constitute the three commercial components of the AMR system. Each of them assists in tracking parking lots, changing the status of the parking spaces, and user relations. First, the sensors identify the areas and locate approaching vehicles. Ultrasonic sensors installed on each position continuously record the distance to the neighboring objects, such as cars. In case there is an approaching car, the sensors inform the microcontroller of the system. A Pi camera also captures images of the parking area providing information which the ultrasonic sensors cannot capture. This is used to verify parked cars and their actual positions.

Second, the processing power of the system is provided by the microcontroller board. It is the central processing unit, which receives information on the sensors and makes the decisions on the status of each spot. Upon the entry or exit of a car into a space, the microcontroller is notified and updated the system. Moreover, the microcontroller will cooperate with the system application to provide users with the up-to-date information about available parking.

Third, the system application is the operational interface and the management tool. The mobile application, which can be employed on smartphones and other devices, allows consumers to check parking spot availability in real time. Users are able to view on the map where they are presently situated, which parking lot spots are occupied, which ones are open, and pick one if they wish to rent it. The program also provides features of booking and payment, in which a user may reserve a parking place before going to the location and make payment online for comfortable parking. Further, the program offers a view for the administrators where they can monitor the running of the parking system and manage reservations. They also have a view of the reports of parking utilization and parking trends. Fig. 3 discuss the the system block diagram.

The system block diagram in Figure 3 displays the relationships among the various components of An intelligent parking system shows how different parts can work together to solve parking lot troubles. A good system design can allow for growth, works well, and pleases those who use it. By using IoT tech, the system can better deal with the common issue of not knowing where free parking spots are in busy towns. This makes parking stays better and assists in traffic and moving people and things within cities.

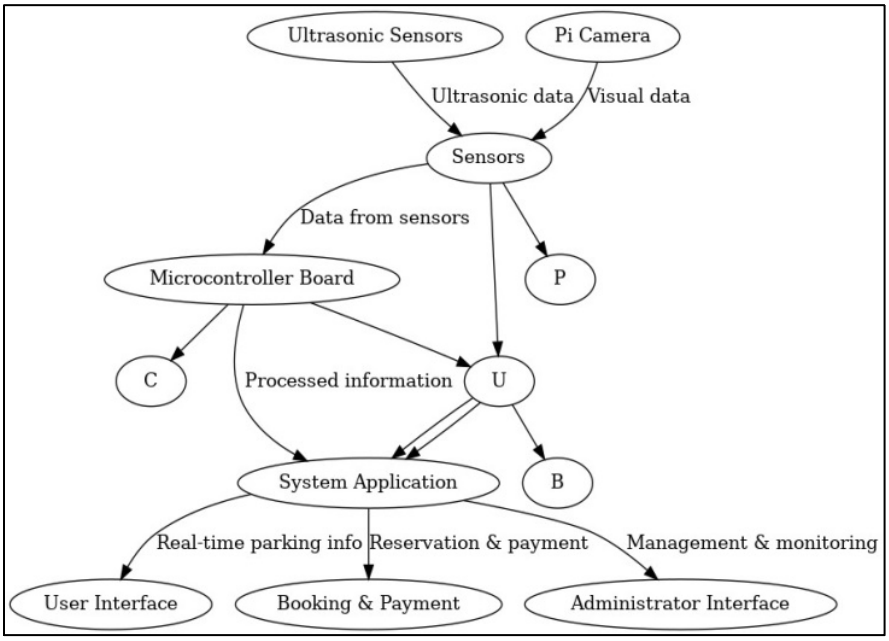

Fig. 3. The system block diagram

3.2. Hardware Components

3.2.1. Ultrasonic Sensors

In the proposed intelligent parking system, the ultrasonic sensors will be utilized primarily in determining whether a parking space is occupied. Sound waves are emitted by these sensors which are typically in the 40-kHz range. When these waves strike an object such as a car, the waves will be reflected back to the sensor. The distance to the object can be calculated by determining the time taken by the waves to bounce back. How this is done by ultrasonic sensors is illustrated in Fig. 4.

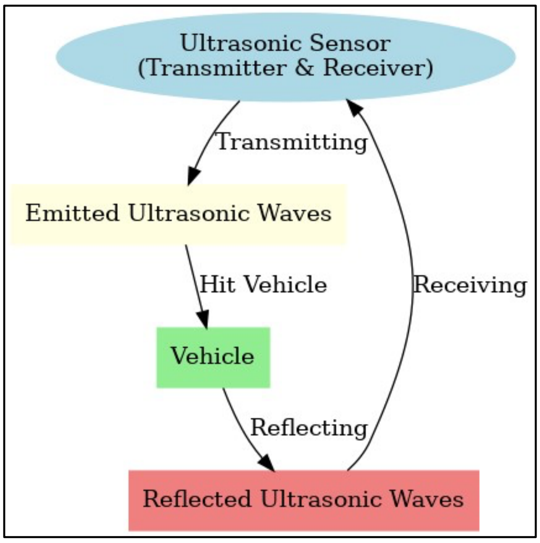

Fig. 4. Ultrasonic sensor working principle

The final category is ultrasonic sensors that apply the transducer concept in the measurement of ultrasonic waves time of flight. All sensors include transmitters and receivers. The transmitter emits ultrasonic waves that are reflected on any object by travelling on air. These reflected waves are picked by the receiver. The most significant amplitudes of the received waves can be determined by locating the maximum in the received signals and calculating the difference in time between the sent and received signal to determine the object distance. This assists in determining whether a parking has been occupied or not. The reason why these sensors are employed is that they are highly dependable, accurate, and can perform in numerous circumstances. Table 1 has the hardware specifications.

Table 1. Specifications of hardware components

Component	Specifications
Ultrasonic Sensors	Frequency: 40 kHz Detection Range: Up to 4 meters Operating Voltage: 5V
Pi Camera	Resolution: 8 MP Field of View: 62.2° Frame Rate: 30 fps
Microcontroller Board	Processor: ARM Cortex-M4 Clock Speed: 72 MHz Memory: 256 KB Flash, 64 KB SRAM

3.2.2. Pi Camera

The Pi camera is another ingredient of the intelligent parking system as it is employed to obtain visual information about the parking space. The camera provides the real time images to enhance the information obtained under the ultrasonic sensors. The details in these visuals play a crucial role in determining the position of cars and make sure they are parked in the right place. One PI camera exemplify in Fig. 5.

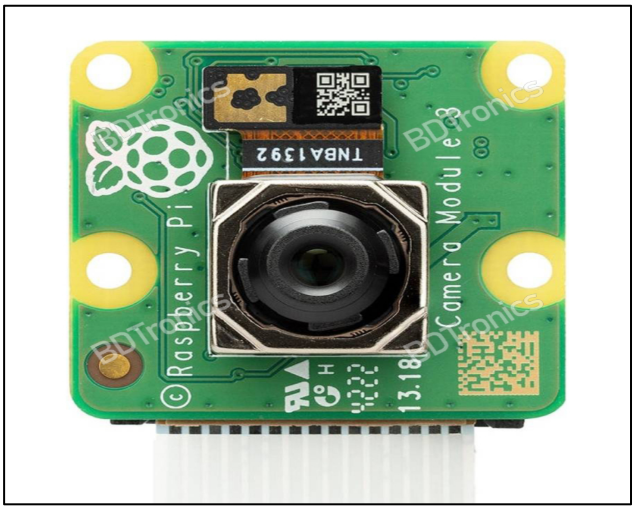

Fig. 5. Example of Pi camera

The Pi camera identifies, monitors and alters parking spots. As an example, it can capture images of parked vehicles in wrong positions or objects in the way of sight. Such images are sent to the system, where they are processed in advance and compared to sensor data. This provides important data to enhance the parking detector. False positives and negatives can be reduced by using visual data, enhancing the experience of the users and the functionality of the system.

3.2.3. Microcontroller Board

The microcontroller board (Fig. 6) in this case will be the brain of the intelligent parking system, it will analyze the data provided by the ultrasonic sensors and Pi camera. Upon the data being received by such sensors, the microcontroller analyzes this and derives the parking slot state.

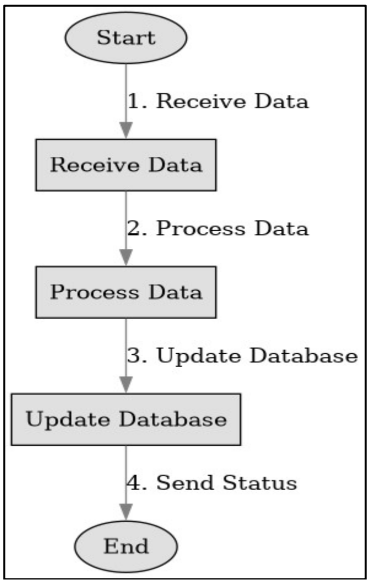

Fig. 6. Microcontroller board process

The sensor data is monitored at all times by the microcontroller. In case of status change i.e. a vehicle entering or leaving, the microcontroller logs this in the database. Continuing on that, the processed data is passed to the system application where users can see the real time parking scenario, but more than that, there is the involvement of the microcontroller in the process of calibration of the sensors, filtering of the incoming data and checking of errors to maintain the proper functioning of the system.

3.3. Software Components

3.3.1. System Program

The intelligent parking system is based on the system program that operates both on the user and administrator computers to enable the system to be used in managing parking effectively. The application is user-friendly, and it allows a user to interact with the parking system easily.

Users are able to access the system program via smartphones or mobile devices. In the application, one can see up to date data about available parking spaces within the selected location. It displays the current state of parking spaces whether they are free or occupied by a car through a map which is constantly updated through the hardware. Table 2 provides data concerning the software components.

Table 2. Software components specifications for system program

Component	Description
User Interface (UI)	Provides a graphical interface for users to view parking availability and make bookings.
Administrator Interface (AI)	Offers administrative tools for system monitoring, parking space management, and user support.
Booking & Payment (BP)	Handles the booking process, allowing users to reserve parking slots and make payments securely.

The graphical user interface of the system program is shown in Fig. 7. The user is able to visualize the parking vacancies and choose an empty parking slot; after that, they can continue with booking and payment processes. The interface will also give choices to the administrators to check the status of the system, their bookings and to deal with any problem that might arise.

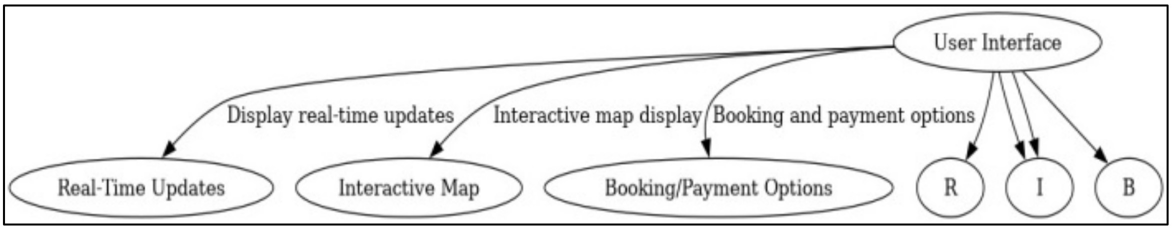

Fig. 7. System Program Interface.

3.3.2. Data Flow and Communication

The intelligent parking system is dependent on data relay among sensors, the microcontroller, and the system software. The latter section is especially describing the ways information is collected, assessed, and used in the framework of the system.

3.4. Data Flow Between Components

Parking space occupancy is collected by the ultrasonic sensors and Pi Camera, on a continuous basis. The ultrasonic sensors calculate the distance of the parked cars and the Pi Camera captures the parking lot. The microcontroller processes the raw sensor data and examines them to identify the open spots and applies set methods. This processed information triggers the status of all the spots to be full or empty. The system transmits processed data of the microcontroller to the system app. A user can access this app via user or administration interface and view the existing parking data. They are also able to book and even pay using the application. The data flow diagram (Fig. 8) demonstrating the flow of data between sensors, microcontroller, and the system program.

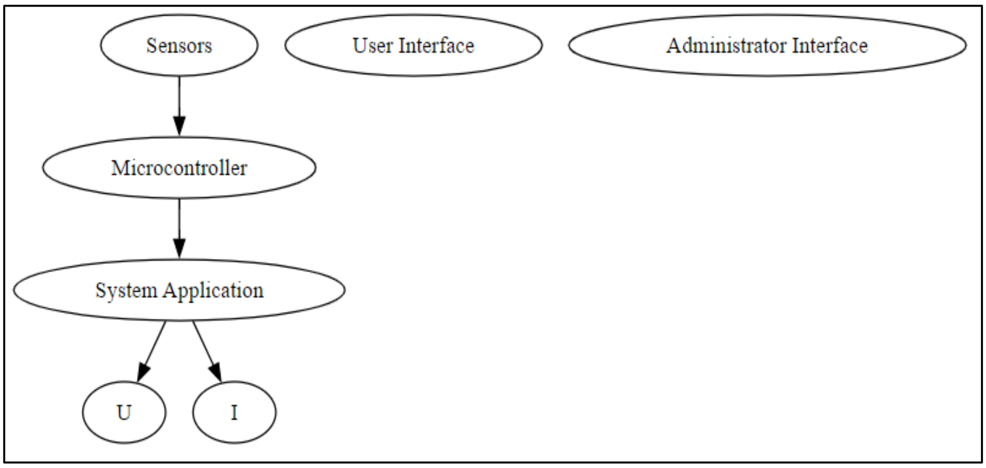

Fig. 8. Data flow and communication

The mathematical model for the smart parking system presents a clear structure of how the smart parking system functions and its quantitative performance values.

3.5. Mathematical Model

The model described in this research is devoted to the current and future status of parking lots, with reference to the available data and real-time information on the remaining parking spots.

$$P(t) = P_{total} - P_{occ}(t) \tag{1}$$

where $P(t)$ is the calculation of available parking spaces at time t; P_{total} is the total number of spaces; and $P_{occ}(t)$ is the number of occupied spaces at time t.

$$D(t) = f\big(P_{occ}(t), H(t)\big) \tag{2}$$

where $D(t)$ is the prediction of parking demand at time t; $H(t)$ represents historical data on parking occupancy. The function f incorporates statistical methods to forecast future demand based on current and historical trends.

The quantitative framework, which matches the equations and descriptions in (1) and (2), is key to understanding how the parking system is controlled and predicted. This mathematical representation helps the system organize parking resources ahead of time, working with real-time info so users have a better experience.

4. Implementation

4.1. Setup and Configuration

The smart parking system has various advanced processes, among them being the appropriate establishment and setup of the system hardware and software. This sub topic brings out an aspect of the procedure of installing the device and the configuration performed on the device.

4.1.1. Hardware Components Setup

Regarding the physical elements, this is what was made with ultrasonic sensors, a Pi camera, and a microcontroller board mounted on the parking bay. Each of the ultrasonic sensors was mounted in a different location so that they would cover different parking places. All the ultrasonic sensors were installed in a way that the entire parking facility was covered. To achieve this, the Pi camera was placed on a strategic place aimed at capturing videos of the parking lot. The layout of the parking area, as shown in Fig. 9, contains the positioning of ultrasonic sensors to make sure that the coverage is maximum and that occupancy of parking space is properly detected.

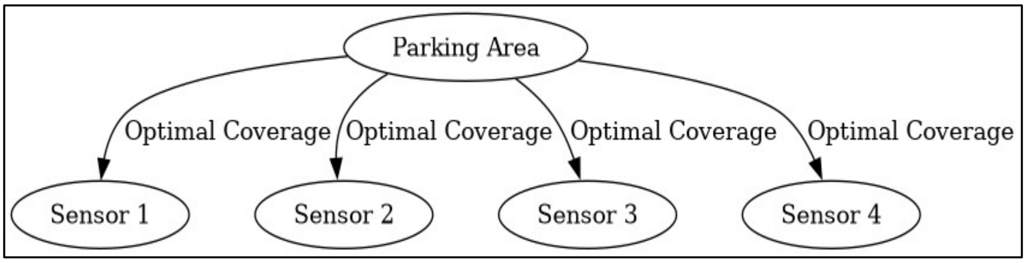

Fig. 9. Parking area layout with sensor placement

4.1.2. Software Installation and Configuration

Software installation entailed installing special applications and software to bind hardware parts to the primary controller. The development of the microcontroller board was assisted by the Arduino IDE and it manages the reception of sensor data and communication with system applications. The Pi Camera gathered and processed images using python programs, providing a vision to the parking system.

4.2. Integration and Testing

The integration phase was mainly focused on the way the hardware and software interfaces of the system would construct an intelligent parking system. The chapter provides integration steps and the tests carried out to determine the effectiveness of the integrated system.

4.2.1. Integration of Hardware and Software Components

The first stage consisted of the construction of a communication network between microcontroller board, ultrasonic sensors and Pi camera and system application. Various control techniques of data flow were developed to ensure that sensor information could be relayed to the microcontroller to be processed. The Pi camera was attached to help record the real-time operational images and with the sensor data; the overall calculation of the availability of parking space could be done in a very precise and detailed fashion.

4.2.2. Testing Procedures and Results

The parking system was tested in terms of functionality, performance, and reliability. The functional tests also ensured that the real-time parking position identifications and user interface of the system performed as expected. Stress tests were investigated on response times and speed of processing data when there was a lot of traffic. Table 3 contains the results.

Table 3. Testing results

Test Type	Description	Results
Functional Testing	Validate parking space detection and reservation	Passed
Performance Testing	Measure response time for parking status updates	Average response < 1 second
Reliability Testing	Assess system uptime and data accuracy	99.9% uptime, accurate data

Fig. 10 that follows depicts the data flow and interaction between the hardware components, the software modules, and the user interface when integrating the system.

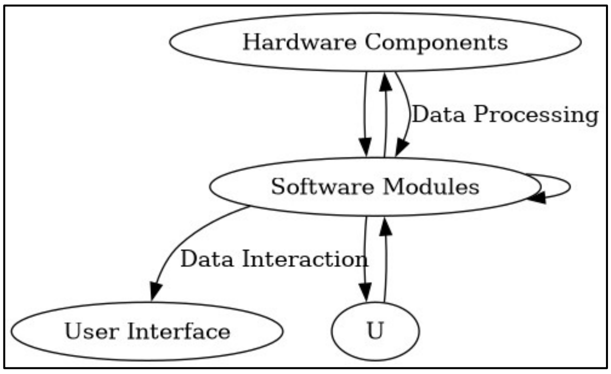

Fig. 10. System integration flow

All the configuration, integration, and testing processes performed on the intelligent parking system are recorded in this chapter. The system has been implemented to increase the productivity of parking spot and benefit the users by organizing each move in an orderly manner.

5. Result and Discussion

This study dwells upon the challenges of unsophisticated parking in intelligent cities and considers the usage of the Internet of Things to resolve this problem. The overall objective is the design and the pilot test of an intelligent parking system. This part contains the data of system logs of the way well the system and its components are functioning and how satisfied individuals are with the application. The trends in investigation are also illustrated by graphs. The measures to determine success are the detection rate, reaction time, user satisfaction and uptime of the system. These are shown in Table 4.

Table 4. System performance metrics

Metric	Value	Description
Detection Accuracy	98%	Accuracy of determining parking space status.
System Response Time	< 1 second	Time taken for the system to update parking status in real time.
User Satisfaction	90% (Based on survey)	Percentage of users satisfied with the system.
System Uptime	99.9%	Availability of the system over a period.

A line graph (Fig. 11) illustrates the accuracy of the detection set at 98% for the sample duration of many weeks. The following graph displays the performance of the system in recognizing the state of the parking slots.

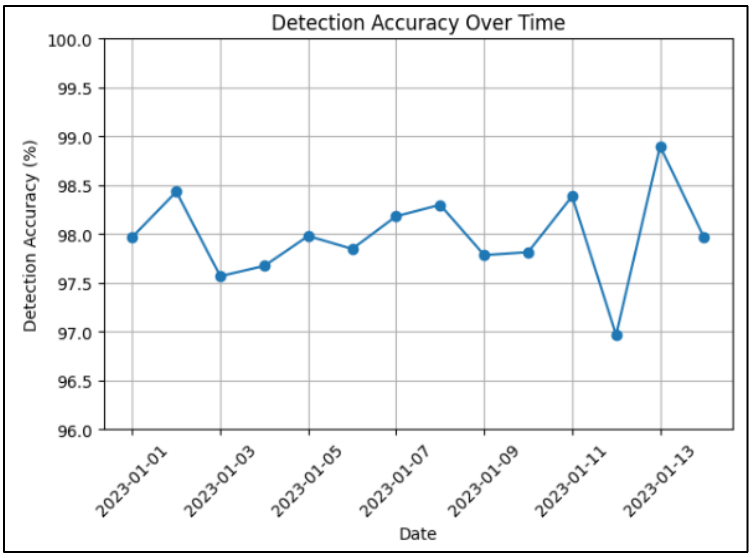

Fig. 11. Detection accuracy over time

Fig. 12 depicts the distribution of the system response time to show that at least 95% of the system responses required less than 1 second to provide a real time update of the parking status.

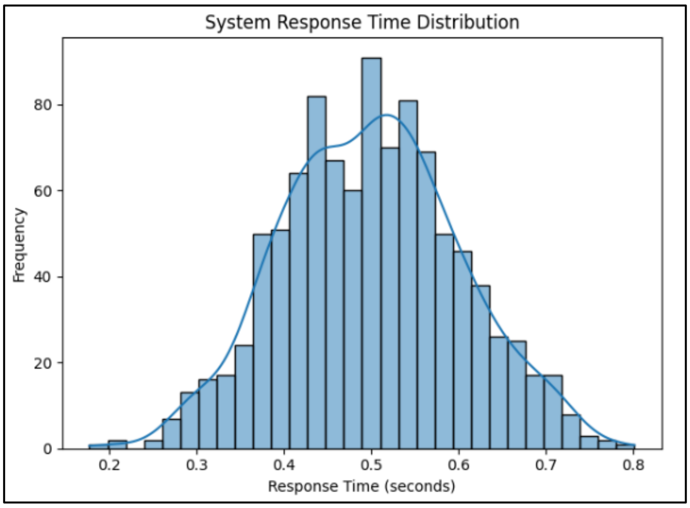

Fig. 12. System response time distribution

5.1. Evaluation of Sub-components Performance

5.1.1. Ultrasonic Sensors and Pi Camera Accuracy

Performance of the ultrasonic sensors and the Pi cameras was tested in different weather conditions, time of the day, and other conditions. The sp The details of this analysis are indicated in the Fig. 13.

As shown in Fig. 13, the accuracy of the ultrasonic sensors was stable at about 97% in clear weather but dropped to 95% in wet weather. The Pi cameras maintained 96% accuracy under both natural and artificial light during the study.

Questionnaires were conducted among users to evaluate the usability of the system, the veracity of the real time information, and the efficacy of the booking component of the summary survey results are shown in the Table 5.

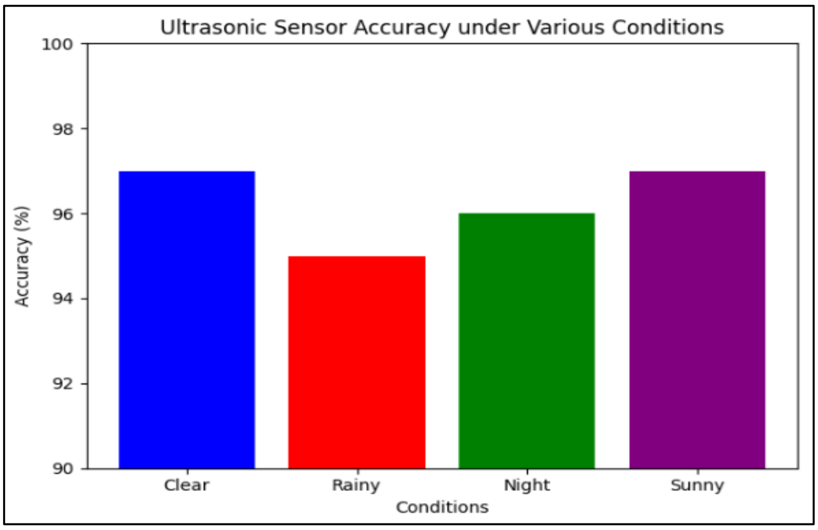

Fig. 13. Ultrasonic sensor accuracy under various conditions

Table 5. User feedback summary

Feedback Category	Positive Responses (%)	Neutral (%)	Negative (%)
Ease of Use	85	10	5
Real-time Information	92	6	2
Booking Feature	88	8	4

Based on the comments, the following outcomes were identified: 85% of the customers considered the system pretty straightforward to use; 92% were happy with the accuracy of the real-time information; and 88% enjoyed the option of booking.

5.1.2. System Utilization Data

Data on system usage, including peak times and overall utilization rates, were tracked and analyzed. The trends observed are shown in Fig. 14.

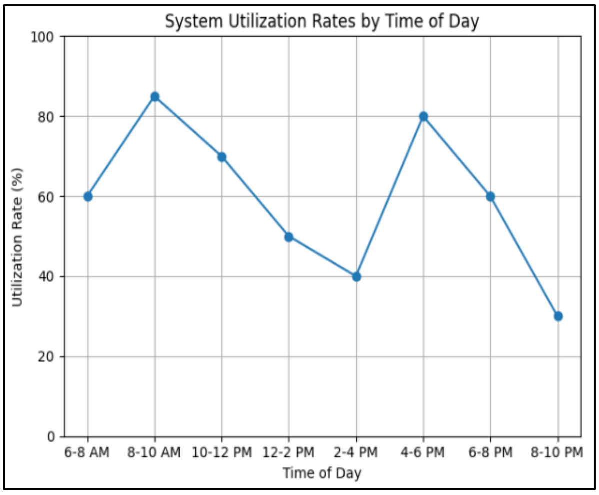

Fig. 14. System utilization rates by time of day

Fig. 14 that represents usage patterns in the form of a line graph indicates maximum usage between 8:00 AM and 10:00 AM and 4:00 PM to 6:00 PM. These periods are the commuting time and this means that the system is effective in controlling parking during rush hours.

5.2. Discussion

According to the information gathered in the course of our research, it is possible to conclude that the smart The parking system is effective since: It finds parking spots 98% of the time which means that the customers obtain the exact information and do not get frustrated searching parking spots. Such precision instills a feeling of trust and persuades individuals to utilize the system. A response time of less than a second is offered to the system and the parking details are rather swift. This speed is important because drivers require information that takes a short time to make decisions. It is better than other slower systems in the market because of its short decision making time. There is approximately 90 percent user satisfaction. Ableh considers that the system has almost achieved the maximum user satisfaction due to its user-friendly design, availability at all times and easy features such as real time information and booking. Its maintenance is 99.9% and this is making it dependable. This is significant uptime to enable users trust it especially in technology that defines the city spaces and is required at all times.

5.2.1. Comparison with Previous Studies

Our system demonstrated evident benefits when our study was compared with the existing research. Recent research indicates that detection accuracy has a range of between 90 and 95 percent [51]. We are 98% accurate; this could be due to our utilization of ultrasonic sensors as well as Pi cameras. The two-sensor structure probably increases the accuracy of detection since it could completely check the parking status. A comparison with previous work is made in Table 6.

Table 6. Comparison table with previous study

Metric	Our Results	Previous Studies	Sources
Detection Accuracy	98%	90% - 95%	[51]
System Response Time	< 1 second	2 - 3 seconds	[52]
User Satisfaction	90% (Based on survey)	80% - 85%	[53]
System Uptime	99.9%	Not consistently reported	Various

As far as reaction time is concerned, our system would respond to the parking status in less than a second, whereas [54] in the literature presented a response time of 2-3 seconds. These advancements can be credited to the data processing algorithms and utilization of microcontrollers that enhance the flow and handling of data besides the decision-making functions.

It is also important to note that our application has the general level of satisfaction of 90, which is high compared to other smart parking systems where the level of satisfaction expressed by the users is between 80 and 85 percent [55]. Such a high level of satisfaction could be explained by a substantial number of variables that comprise high reliability, practicality, and such features as advanced parking booking.

5.2.2. Interpretation of Results

The system is good due to some few reasons. The ultrasonic sensors can sustain well in good weather and 95 in wet weather keeping up to 97 and 95 percent accuracy respectively. Therefore, an organization will be able to operate without caring about the weather changes. Moreover, proper hardware such as ultrasonic sensors and Pi cameras as well as a standard microcontroller ensures that the system is stable and remains operational. The camera and sensor configuration in the parking lot enhances the visibility, reducing the number of blind spots and improving the detection accuracy of the camera. System appears to be satisfying to users. Approximately 85% of them indicate that it is user friendly, 92% prefer real-time information and 88% users like booking thing. The fact that these good comments are provided depicts that the system is satisfying user needs. Demand fulfillment is vital, as it ensures that the people continue using the system and they can persuade others to do the same as well so that the system can spread around the city. There are well connected areas in Smart cities.

The findings of the study have practical applications to expanding the smart city work. Bad parking data boosts productivity, and the system's accuracy and speed help build future cities. These numbers are helpful for city officials deciding how to improve parking in their areas. One more good thing is better traffic flow. The system cuts down on cars driving around searching for parking. This lowers traffic, especially when it is busy. With faster traffic, it is easier to get around the city.

In that respect, as the time spent by the cars idling and seeking parking is reduced, the overall emissions arising from the usage of motor vehicles are lessened, which would be good for the accomplishment of environmental sustainability targets. Parking management handles one of the most serious concerns that urban planners confront: the accomplishment of ecologically sustainable transportation networks

6. Conclusions

This research study created a smart parking system for cities using the Internet of Things to help with parking issues. The system works well, with a 98% accuracy in finding spots, a reaction time of less than a second, and a 90% user approval rating. It is accessible 99.9% of the time and is reliable. Compared to other smart parking systems, this one is more precise, faster, and liked by users. The long life of the ultrasonic sensors and cameras in different weather is a plus. Individuals who have utilized the system have found it easy to use, quick to obtain information, and provides them with an opportunity to book them. This demonstrates that it may be a success. The findings of the study hold significant relevance to development of a smart city since the technology assists in planning and traffic management of the city as it provides real time information on parking space. It is more conducive to better cities, greener and pleasant.

Further research may involve putting the system into the test under more complex real-life scenarios to determine how well the system adapts to other city infrastructures and traffic. The introduction of more sophisticated machine learning may have the effect of regulating the amount of parking space. The system's sensing could be expanded to LIDAR, which would improve its ability to deal with bad weather. Adding user feedback will help improve the system. Finally, data protection and privacy concerns need to be addressed, and data processing and storage must follow information security rules.

Author Contribution: All authors contributed equally to the main contributor to this paper. All authors read and approved the final paper.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

[1] M. R. Mohapatra and S. Mohapatra, "An overview of Internet of Things (IoT)," in *Internet of Things Applications and Technology*, F. S. Masoodi, A. M. Bamhdi, A. Manocha, T. A. Teli, Z. S. Masoodi, and F. A. Reegu, Eds. Boca Raton, FL, USA: Auerbach Publications, 2024, ch. 1, https://doi.org/10.1201/9781003458401-1.

[2] A. Aditya, S. Anwarul, R. Tanwar, and S. K. V. Koneru, "An IoT assisted intelligent parking system (IPS) for smart cities," *Procedia Computer Science*, vol. 218, pp. 1045–1054, 2023, https://doi.org/10.1016/j.procs.2023.01.084.

[3] L. A. Balol and K. M. Byahatti, "Smart car parking monitoring system with Android application," *Bonfring International Journal of Software Engineering and Soft Computing*, vol. 6, special issue, pp. 160–162, Oct. 2016, https://doi.org/10.9756/BIJSESC.8266.

[4] L. E. Giampaoli and F. Hessel, "Parking space occupancy monitoring system using computer vision and IoT," in *2021 IEEE 7th World Forum on Internet of Things (WF-IoT)*, Jun. 2021, pp. 7–12, https://doi.org/10.1109/WF-IoT51360.2021.9595935.

[5] J. Parmar, P. Das, and S. M. Dave, "Study on demand and characteristics of parking system in urban areas: A review," *Journal of Traffic and Transportation Engineering (English Edition)*, vol. 7, no. 1, pp. 111–124, Feb. 2020, https://doi.org/10.1016/j.jtte.2019.09.003.

[6] F. Al-Turjman and A. Malekloo, "Smart parking in IoT-enabled cities: A survey," *Sustainable Cities and Society*, vol. 49, p. 101608, Aug. 2019, https://doi.org/10.1016/j.scs.2019.101608.

[7] A. K. Dogra and J. Kaur, "Moving towards smart transportation with machine learning and Internet of Things (IoT): A review," *Journal of Smart Environments and Green Computing*, vol. 2, pp. 3–18, 2022, https://doi.org/10.20517/jsegc.2021.09.

[8] N. Himabindu, S. S. Vishnu, M. Vishveswaran, R. Swaroop, and B. Bairwa, "Design and implementation of RFID-driven parking management systems," in *2024 IEEE International Conference on Big Data & Machine Learning (ICBDML)*, 2024, pp. 97–102, https://doi.org/10.1109/ICBDML60909.2024.10577297.

[9] N. Alsaedi and A. S. A. Jalal, "Efficient automated car parking system based modified internet of spatial things in smart cities," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 31, no. 2, pp. 1164–1170, Aug. 2023, https://doi.org/10.11591/ijeecs.v31.i2.pp1164-1170.

[10] O. Tătar, D. Mândru, and I. Ardelean, "Development of mobile minirobots for in pipe inspection tasks," *Mechanics*, vol. 68, no. 6, pp. 60–64, Apr. 2024, https://doi.org/10.5755/j02.mech.36228.

[11] A. B. Vankamamidi, "IoT based smart car parking system," *SSRN Electronic Journal*, 2021, https://doi.org/10.2139/ssrn.3904862.

[12] A. Saputra, B. Giawa, and R. Khana, "Vehicle and parking space detection for smart parking systems using the YOLOv5 method," in *Proceedings of the 4th International Seminar and Call for Paper*, 2023, pp. 458–466, https://doi.org/10.5220/0012584700003821.

[13] C. Di Napoli and S. Rossi, "A city-aware car parks marketplace for smart parking," in *Proceedings of the 13th International Conference on Agents and Artificial Intelligence*, 2021, pp. 242–249, https://doi.org/10.5220/0010227102420249.

[14] S. Mishra, B. Rohan, D. Subbulekshmi, T. Deepa, S. Angalaeswari, and R. C. Kalianda, "Smart vehicular parking systems for open parking lots," in *Smart Grids for Smart Cities Volume 2*, Jul. 2023, pp. 11–19, https://doi.org/10.1002/9781394216796.ch22.

[15] N. Pushpalatha, V. Gomathi, S. Prashanth, M. S. Suryanithi, S. Kavin, and N. Niranjankumar, "An optimized, sophisticated technological approach for savvy car parking framework for smart car parking system futuristic metropolis," in *2024 International Conference on Recent Innovation in Smart and Sustainable Technology (ICRISST)*, Mar. 2024, pp. 1–4, https://doi.org/10.1109/ICRISST59181.2024.10921772.

[16] A. B. Pulungan, M. Oktavianda, H. Hastuti, and H. Hamdani, "Parking information system base on Internet of Things (IoT)," *Jurnal Teknologi Informasi dan Pendidikan*, vol. 13, no. 2, pp. 69–75, Nov. 2020, https://doi.org/10.24036/tip.v13i2.352.

[17] A. C. Aydinoglu and A. S. Iqbal, "Determining parking demand and locating parking areas using geographic analytics methods," *Journal of Urban Planning and Development*, vol. 147, no. 1, p. 05020035, Mar. 2021, https://doi.org/10.1061/(ASCE)UP.1943-5444.0000650.

[18] W. Shafik, "IoT-enabled secure and intelligent smart healthcare: Beyond 5G in enabling smart cities," in *Secure and Intelligent IoT-Enabled Smart Cities*, S. Singh, S. Tanwar, R. Jadeja, S. Singh, and Z. Polkowski, Eds. Hershey, PA, USA: IGI Global Scientific Publishing, 2024, pp. 308–333, https://doi.org/10.4018/979-8-3693-2373-1.ch015.

[19] Pavanalaxmi, Kripa, R. Nayak, A. B. Abhishek, and M. P. Kumar, "Integrating machine learning and IoT: Pioneering solutions for sustainable smart cities," in *Applications of Computational Learning and IoT in*

Smart Road Transportation System, S. Mallik, H. Qin, S. Nandi, M. Y. Alam, A. Roy, and T. H. Sardar, Eds. Cham, Switzerland: Springer Nature Switzerland, 2025, pp. 37–54, https://doi.org/10.1007/978-3-031-87627-1_3.

[20] W. Alsafery, B. Alturki, S. Reiff-Marganiec, and K. Jambi, "Smart car parking system solution for the Internet of Things in smart cities," in *2018 1st International Conference on Computer Applications & Information Security (ICCAIS)*, Apr. 2018, pp. 1–5, https://doi.org/10.1109/CAIS.2018.8442004.

[21] Y. Ma, Y. Liu, S. Shao, J. Zhao, and J. Tang, "Review of research on vision-based parking space detection method," *International Journal of Web Services Research*, vol. 19, no. 1, pp. 1–25, Jun. 2022, https://doi.org/10.4018/IJWSR.304061.

[22] V. Paidi, H. Fleyeh, J. Håkansson, and R. G. Nyberg, "Smart parking sensors, technologies and applications for open parking lots: A review," *IET Intelligent Transport Systems*, vol. 12, no. 8, pp. 735–741, May 2018, https://doi.org/10.1049/iet-its.2017.0406.

[23] M. Rohini, A. Rahul, A. Rithik, and D. S. John, "IoT based smart car parking system with the help of sensors networks," in *2023 Third International Conference on Artificial Intelligence and Smart Energy (ICAIS)*, Feb. 2023, pp. 57–60, https://doi.org/10.1109/ICAIS56108.2023.10073729.

[24] V. Bharti, V. Sharma, K. Sureka, and R. Agarwal, "A novel smart parking system using IoT," in *2022 International Conference on Machine Learning, Big Data, Cloud and Parallel Computing (COM-IT-CON)*, May 2022, pp. 806–810, https://doi.org/10.1109/COM-IT-CON54601.2022.9850508.

[25] Suryansh, B. Parveen, W. Manoj, A. Mishra, and A. Kumar, "Smart parking system for smart cities using IoT," in *Recent Trends in Intelligent Computing and Communication*, Sep. 2025, pp. 871–876, https://doi.org/10.1201/9781003593089-137.

[26] A. Anand and P. Thomas, "Intelligent face recognition based IoT car parking system," *International Journal of Science and Research (IJSR)*, vol. 14, no. 4, pp. 1520–1524, Apr. 2025, https://doi.org/10.21275/SR25417210043.

[27] B. M. Tummala, M. D. Prem Kumar, and S. Nagurbasha, "Real-time parking slot detection and enhanced security system for public parking using IoT," in *2025 International Conference on Inventive Computation Technologies (ICICT)*, Apr. 2025, pp. 1779–1785, https://doi.org/10.1109/ICICT64420.2025.11004858.

[28] I. Ouhammou, T. Chafiq, and M. Hmamou, "IoT-enabled smart parking: Enhancing efficiency and sustainability in smart cities," *E3S Web of Conferences*, vol. 418, p. 02006, 2023, https://doi.org/10.1051/e3sconf/202341802006.

[29] K. Tair, L. Benmessaoud, and S. Boukhedouma, "Smart parking system based on dynamic and optimal resource allocation," in *Emerging Trends and Applications in Artificial Intelligence*, 2024, pp. 264–278, https://doi.org/10.1007/978-3-031-56728-5_23.

[30] S. R. Ahmed, H. A. Fadel, O. A. Ismael, S. K. Sulaiman, N. R. Mahdi, N. S. Ahmed, B. A. Abubaker, and A.-S. T. Hussain, "Hybrid classification model development for enhancement the data driven based human falling detection performance," in *Proceedings of the 3rd International Conference on Machine Learning, Cloud Computing and Intelligent Mining (MLCCIM2024)*, F. Sun, H. Wang, H. Long, Y. Wei, and H. Yu, Eds. Singapore: Springer Nature Singapore, 2025, pp. 927–941, https://doi.org/10.1007/978-981-96-2468-3_77.

[31] C. L. Kumari, D. Reddy, and K. O. Prakash, "IoT based smart parking system," *International Journal of Research Publication and Reviews*, vol. 6, no. 4, pp. 3386–3389, Apr. 2025, https://doi.org/10.55248/gengpi.6.0425.1434.

[32] S. S. Channamallu, S. Kermanshachi, J. M. Rosenberger, and A. Pamidimukkala, "Smart parking systems: A comprehensive review of digitalization of parking services," *Green Energy and Intelligent Transportation*, vol. 5, no. 1, p. 100293, Feb. 2026, https://doi.org/10.1016/j.geits.2025.100293.

[33] Z. Qadir, F. Al-Turjman, M. A. Khan, and T. Nesimoglu, "ZIGBEE based time and energy efficient smart parking system using IoT," in *2018 18th Mediterranean Microwave Symposium (MMS)*, Oct. 2018, pp. 295–298, https://doi.org/10.1109/MMS.2018.8611810.

[34] E. Kadusic, N. Zivic, C. Ruland, and N. Hadzajlic, "A smart parking solution by integrating NB-IoT radio communication technology into the core IoT platform," *Future Internet*, vol. 14, no. 8, p. 219, Jul. 2022, https://doi.org/10.3390/fi14080219.

[35] S. Kim, S. Park, S.-H. Lee, and T. Yang, "Smart parking with learning-aided user activity sensing based on edge computing," in *2021 IEEE 18th Annual Consumer Communications & Networking Conference (CCNC)*, Jan. 2021, pp. 1–2, https://doi.org/10.1109/CCNC49032.2021.9369570.

[36] C. Ma, J. Zhu, M. Liu, H. Zhao, N. Liu, and X. Zou, "Parking edge computing: Parked-vehicle-assisted task offloading for urban VANETs," *IEEE Internet of Things Journal*, vol. 8, no. 11, pp. 9344–9358, Jun. 2021, https://doi.org/10.1109/JIOT.2021.3056396.

[37] T. Lin, H. Rivano, and F. Le Mouel, "A survey of smart parking solutions," *IEEE Transactions on Intelligent Transportation Systems*, vol. 18, no. 12, pp. 3229–3253, Dec. 2017, https://doi.org/10.1109/TITS.2017.2685143.

[38] C. Biyik, Z. Allam, G. Pieri, D. Moroni, M. O'Fraifer, E. O'Connell, S. Olariu, and M. Khalid, "Smart parking systems: Reviewing the literature, architecture and ways forward," *Smart Cities*, vol. 4, no. 2, pp. 623–642, 2021, https://doi.org/10.3390/smartcities4020032.

[39] A. Alqazzaz, I. Alrashdi, E. Aloufi, M. Zohdy, and H. Ming, "SecSPS: A secure and privacy-preserving framework for smart parking systems," *Journal of Information Security*, vol. 9, no. 4, pp. 299–314, 2018, https://doi.org/10.4236/jis.2018.94020.

[40] W. A. Amiri, M. Baza, K. Banawan, M. Mahmoud, W. Alasmary, and K. Akkaya, "Privacy-preserving smart parking system using blockchain and private information retrieval," in *2019 International Conference on Smart Applications, Communications and Networking (SmartNets)*, Dec. 2019, pp. 1–6, https://doi.org/10.1109/SmartNets48225.2019.9069783.

[41] R. Ke, Y. Zhuang, Z. Pu, and Y. Wang, "A smart, efficient, and reliable parking surveillance system with edge artificial intelligence on IoT devices," *IEEE Transactions on Intelligent Transportation Systems*, vol. 22, no. 8, pp. 4962–4974, Aug. 2021, https://doi.org/10.1109/TITS.2020.2984197.

[42] J. Shi, L. Jin, J. Li, and Z. Fang, "A smart parking system based on NB-IoT and third-party payment platform," in *2017 17th International Symposium on Communications and Information Technologies (ISCIT)*, 2017, pp. 1–5, https://doi.org/10.1109/ISCIT.2017.8261235.

[43] L. Mainetti, I. Marasovic, L. Patrono, P. Solic, M. L. Stefanizzi, and R. Vergallo, "A novel IoT-aware smart parking system based on the integration of RFID and WSN technologies," *International Journal of RF Technologies*, vol. 7, no. 4, pp. 175–199, Sep. 2016, https://doi.org/10.3233/RFT-161523.

[44] R. Sagban, H. A. Marhoon, and S. R. Ahmed, "Enhanced diagnostic precision: Deep learning for tumors lesion classification in dermatology," *Intelligent Automation & Soft Computing*, vol. 39, no. 6, pp. 1035–1051, 2024, https://doi.org/10.32604/iasc.2024.058416.

[45] L. Mainetti, L. Palano, L. Patrono, M. L. Stefanizzi, and R. Vergallo, "Integration of RFID and WSN technologies in a smart parking system," in *2014 22nd International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*, 2014, pp. 104–110, https://doi.org/10.1109/SOFTCOM.2014.7039099.

[46] H. K. Alaoui, M. Coulibaly, and A. Errami, "Analyzing smart parking system: WSN technologies, power saving and guidance," in *2024 International Conference on Circuit, Systems and Communication (ICCSC)*, 2024, pp. 1–7, https://doi.org/10.1109/ICCSC62074.2024.10617233.

[47] A. G. Khoso, N. Zahid, and I. Khan, "Enhanced IoT-enabled smart parking system with RFID integration and line assistance," *Transportation Research Procedia*, vol. 84, pp. 346–353, 2025, https://doi.org/10.1016/j.trpro.2025.03.082.

[48] Z. Pala and N. Inanc, "Smart parking applications using RFID technology," in *2007 1st Annual RFID Eurasia*, 2007, pp. 1–3, https://doi.org/10.1109/RFIDEURASIA.2007.4368108.

[49] K. Nguyen, S. Drew, C. Huang, and J. Zhou, "Parked vehicles task offloading in edge computing," *IEEE Access*, vol. 10, pp. 41592–41606, 2022, https://doi.org/10.1109/ACCESS.2022.3167641.

Vol. 6, No. 2, 2026, pp. 1251-1270

[50] Y. Zhou, Z.-Y. Chai, Y.-L. Li, and J.-J. Li, "Parking vehicle-assisted task offloading in edge computing: A dynamic multi-objective evolutionary algorithm with multi-strategy fusion response," *Swarm and Evolutionary Computation*, vol. 94, p. 101900, Apr. 2025, https://doi.org/10.1016/j.swevo.2025.101900.

[51] C. Jenila and K. H. Kumar, "IoT-based smart parking system: Hardware-centric approach for addressing urban parking challenges," in *2024 2nd International Conference on Networking, Embedded and Wireless Systems (ICNEWS)*, 2024, pp. 1–7, https://doi.org/10.1109/ICNEWS60873.2024.10731004.

[52] R. Subhashini and A. Khang, "Role of Internet of Things (IoT) in smart city framework," in *Smart Cities: IoT Technologies, Big Data Solutions, Cloud Platforms, and Cybersecurity Techniques*, A. Khang, S. K. Gupta, S. Rani, and D. A. Karras, Eds. Boca Raton, FL, USA: CRC Press, 2023, ch. 3, https://doi.org/10.1201/9781003376064-3.

[53] A. Haque, K. V. S. Bharath, and S. Mateen, "Smart grid concept and technologies for smart cities," in *Smart Cities: Power Electronics, Renewable Energy, and Internet of Things*, A. Haque, A. Kalam, and H. Sharma, Eds. Boca Raton, FL, USA: CRC Press, 2024, ch. 5, https://doi.org/10.1201/9781032669809-5.

[54] D. Teodorović and P. Lučić, "Intelligent parking systems," *European Journal of Operational Research*, vol. 175, no. 3, pp. 1666–1681, Dec. 2006, https://doi.org/10.1016/j.ejor.2005.02.033.

[55] A. Tripathi, N. Sindhwani, R. Anand, and A. Dahiya, "Role of IoT in smart homes and smart cities: Challenges, benefits, and applications," in *IoT Based Smart Applications*, N. Sindhwani, R. Anand, M. Niranjanamurthy, D. C. Verma, and E. B. Valentina, Eds. Cham, Switzerland: Springer Nature Switzerland, 2023, pp. 199–217, https://doi.org/10.1007/978-3-031-04524-0_12.