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Effective smart rotary parking management in urban areas

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Abstract
With urbanization on the rise, coupled with the burgeoning intensity of traffic in cities, parking management is becoming an increasingly insurmountable problem. This paper concentrates on the design and development of an intelligent rotary parking, with an appropriable lending function for eight vehicles within a mini urban encroachment. The system combines sensors, servomotors, and an Arduino controller to an automated parking system that saves space by parking vehicles vertically one above another. The proposed solution consists of sensors with an automatic barrier system to allow and control access to vacant parking spaces. To provide more ground parking space with better reliability and lower impact on the environment, the evaluation shows that for

urban areas, the system might improve the traffic flow, reduce emissions, and offer a sustainable way of solving problems about parking.

Keywords: Separated. Rotary parking system. Arduino controller. intensity of traffic (IoT). Intelligent Per.

1. Introduction

Automatic rotating parking systems were developed to present a solution to acute urban problems, primarily space management, traffic congestion, and improvement in the quality of life in over-populated urban areas. The continuous expansion and growth of urban spaces and increased vehicle ownership lead to a deficit in available parking spaces. As a result, driving time is prolonged, air pollution is on the rise, drivers are frustrated, and urban mobility problems continue to be aggravated. Smart city technologies are solutions to address these issues, with intelligent parking systems successfully addressing the challenges of locating time-consuming parking spaces. IoT and AI technologies joined the non-contact intelligent parking field sense (Hanzl, 2020). In contrast to traditional parking systems, whether manual or multi-level slow-moving pavements, both parking spaces require more space and substantial pre-installation investments (Dogaroglu *et al*., 2021; Shah *et al*., 2021). On the other hand, rotating parking systems are well-suited to compactness as they stack several vehicles in a narrow space, allowing more space to be used. The multi-story slow-moving pavements automatically address over-population parking issues with an effective mechanism (Miranda *et al*., 2023). Developing countries, such as India, use more than 300 million square meters of road area for parking, accounting for more than 40 percent of the country's available road space. Sometimes parkers and traffic suffer delays (Jog *et al*., 2015). The increased interest in intelligent parking solutions is due to the increase in urbanization and vehicle ownership (Juwita *et al*., 2020). The use of sensors and related technology by rotating parking systems has facilitated the road to the future of the intelligent parking system through the effective management of parking spaces as well as efficiency and accuracy with significant cost savings. Sensing technology will reduce the human intervention required, improving parking efficiency in an environmentally friendly way while also reducing the disruption caused by driver and vehicle emissions. An intelligent parking system is one that the market is looking forward to, with products integrating high technology and high-new concepts to create an efficient, effective virtual and physical parking space.

Moreover, the smart parking systems that use AI and IoT are transforming the current dynamics of parking management through live notifications, prediction of parking availability, and an optimized user experience (Diayasa *et al*., 2020; Fahim *et al.*, 2021; Laaouafy *et al*., 2024). For example, in Indonesia, the IoT-based systems provide real-time notifications to parking users, which minimizes time spent to seek parking and reduces traffic congestion (Diayasa *et al.*, 2020). In addition, research proves that such technologies are useful for enhancing operational efficiency and revenue generation for parking operators (Channamallu *et al*., 2023).

While smart parking systems do serve in favor of sustainability and thus cause a significant reduction in emissions, they also help in addressing larger urban mobility challenges. Intelligent systems embedded in parking infrastructures permit cities to better manage traffic flow and vehicle guidance while severely reducing the time in search of parking space, thus ensuring good urban mobility (Channamallu *et al.*, 2023; Hanzl, 2020; Skrzyniowski *et al.*, 2018).

Arduino is an open-source electronics platform, incorporating easy-to-use hardware and software for the creation of interactive projects and for controlling/automating systems with sensors and actuators. Some examples of Arduino boards used in various applications include robotics, environmental monitoring, and home automation. The versatility alongside simplicity makes it famous among hobbyists, students, and professionals alike (Bagua, 2023; Khoury Junior *et al*., 2020; Valle *et al*., 2021).

The present project deals with the design and actualization of the functional model of an automated rotary parking system, one which would manage upland parking of up to eight vehicles in urban spaces where parking areas are limited. By utilizing advanced technologies such as sensors, servomotors, and Arduino controllers, the study attempts to establish an integral solution for efficient space utilization and parking management efforts in places with high traffic density.

This system ensures automated parking by stacking vehicles vertically. It occupies less ground space compared to conventional methods of parking. Sensors would detect vehicle presence, and the system would automatically control the parking and retrieval processes, allowing for easy, smooth, and efficient operation without human intervention. The Arduino controller shall enable the user to specify just how the cars are set in motion and how they will be assigned various parking slots, hence a user-friendly and effective system.

In addition, this work tries to assess the integrated performance of the stable system in terms of efficiency, reliability, and impact on the environment. With shorter parking times, diminished vehicle emissions, and reduced urban traffic congestion, the system proposes a sustainable solution to parking demands in growing cities. It looks to achieve better urban mobility and enhanced spatial efficiency.

2. Materiel and methods

Figures may be colored or not and must be inserted in the main body of the manuscript as close as possible to the point where they are cited in the text. They must be centralized and should not exceed the margins defined for the page. The automated control of the prototype of an intelligent rotating parking system has been planned and designed using the relevant control plan for the selected parking system. The control plan was developed, which was based on specific conditions of the control. Figure 1 illustrates the proposed system subsistence of a vertical rotating parking system RPS as a parking vehicle system in vertically stacked cages with a vertical displacement system. There are a controlled barrier and RPS in the parking system. An application of the prototype of the practical mechanical structure was obtained in the form of a smart rotating parking system by making use of electric motors and appropriate sensors which will be automated and controlled by an Arduino UNO microcontroller system.

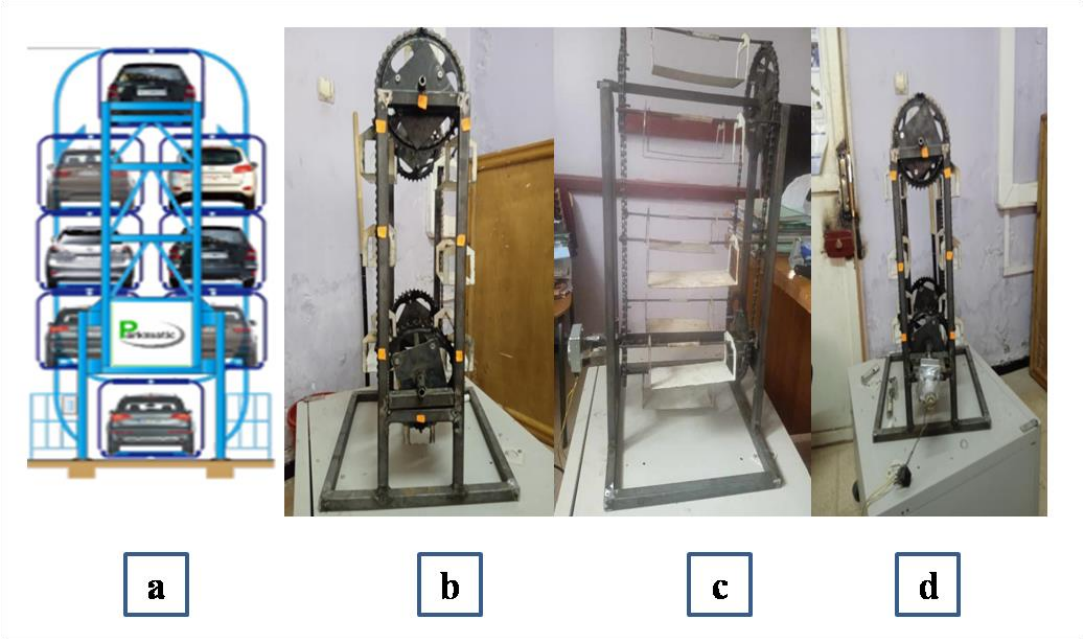

Figure 1 - Presentations: a) 8 cars model, b) c) d) different faces of the realized prototype of vertical rotary parking.

2. 1. The Automated Barrier Parking System

As illustrated in Figures 2 and 3, the automated barrier parking system operated using Arduino is designed to provide an efficient way of administering parking space. The system employs infrared sensors to identify the presence of vehicles, a servo motor to raise and lower the parking barrier, and an LCD for updating the user about the free parking status. The system aims to bring optimization to the parking process by providing real-time information to users about free parking space and automatic barrier lift operations based on sensor inputs.

Once the IR1 sensor, detects the entry of a vehicle, the system checks for a free slot. If the slots are free, it opens the barrier via the servo motor, and the number of available slots is reduced by one. If there are no slots available, a "Parking Full" message is displayed on the LCD. The system will, on the detection of the vehicle by IR2, increment the slot count and open the barrier via the servo motor for the exit. The barrier opens when all entry and exit conditions are satisfied, and after a while, it resets the flags and closes the barrier.

It is user-friendly because the information is fed into the LCD continuously. It is an intelligent LCD module, embedded. The controller is used that convert alphabet and numeric data into ASCII code to be displayed. The LCD shows the number of cars currently present in the parking lot, how many spaces are open, and the time (the screen displays real-time information).

In modern times, the Internet of Things is becoming more and more indispensable to embedded systems, such as parking control and monitoring. The integration of IoT technology into parking management systems shows originality in looking into parking challenges. For example, the system packs a WiFi module that transmits data to the internet for real-time parking availability monitoring ensures precise evaluation of available parking spaces, and provides accurate real-time updates (Suhermanto *et al*., 2024).

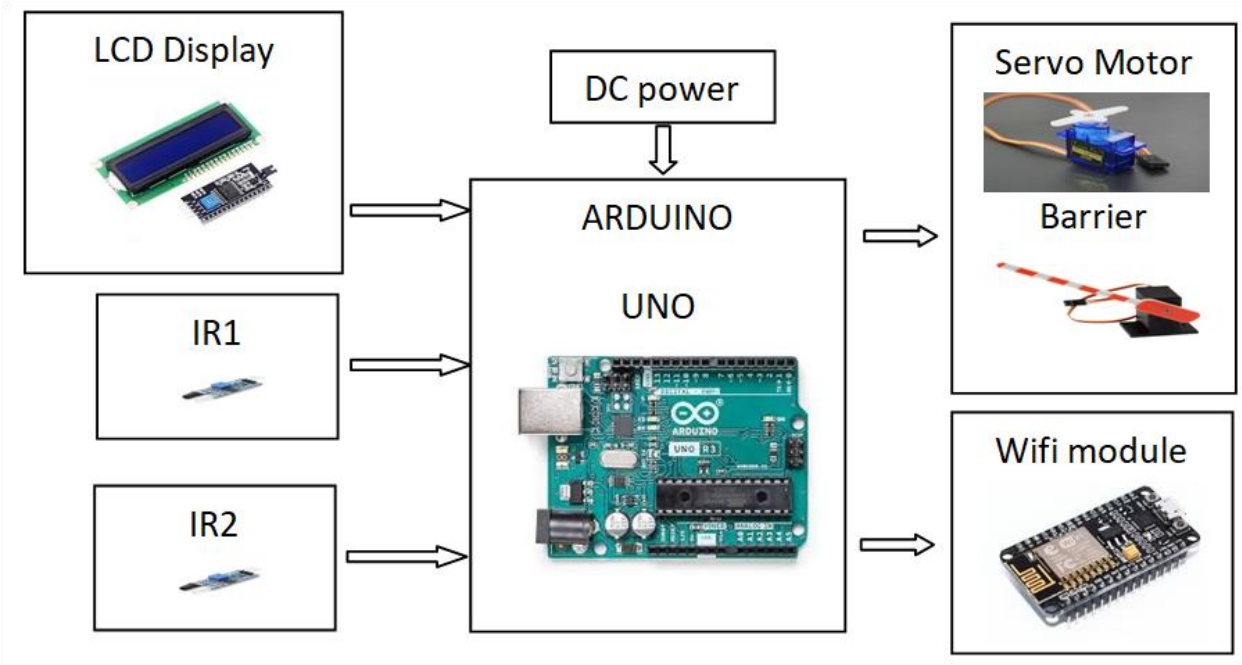

Figure 2 - Proposed barrier Control System.

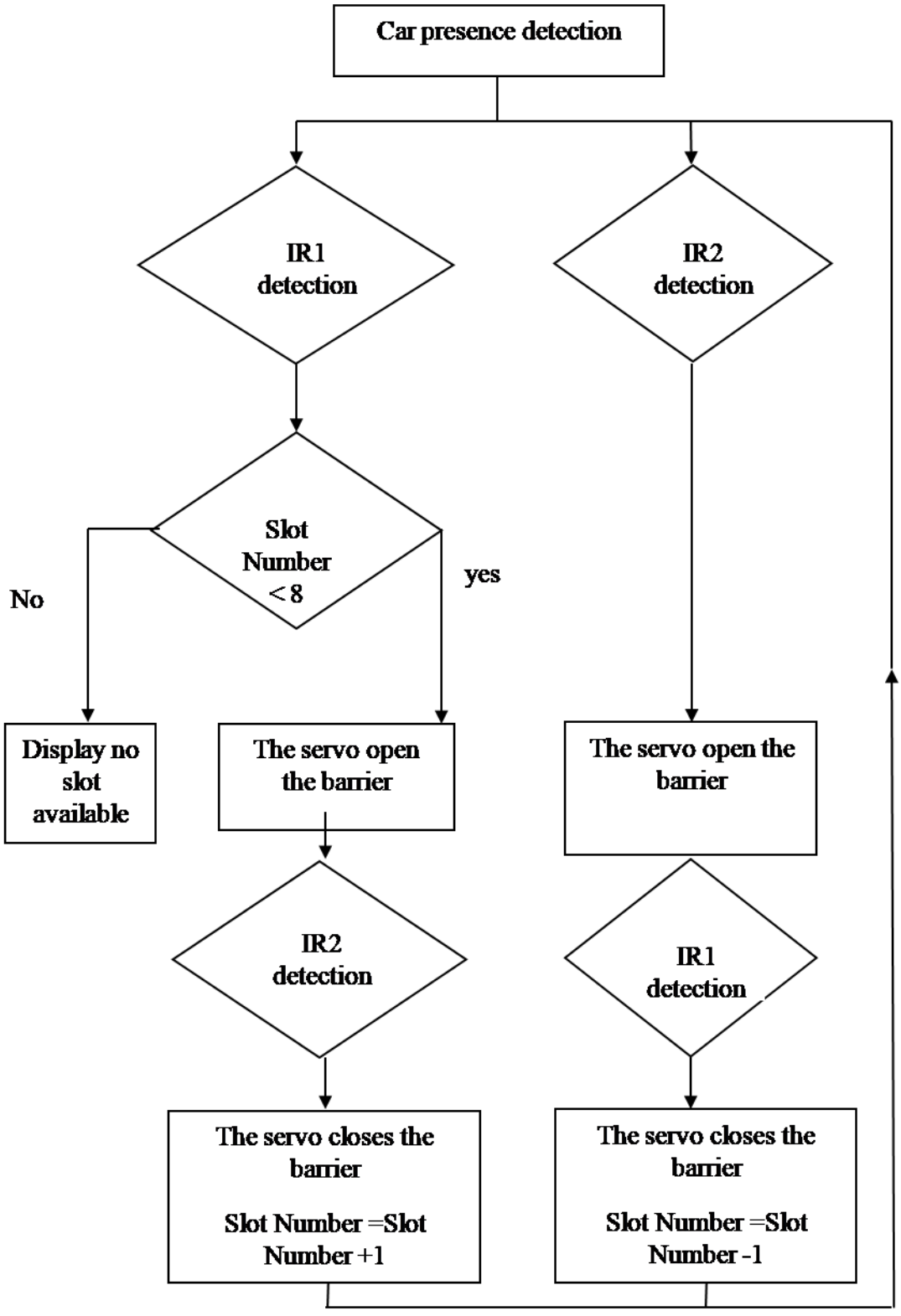

Figure 3 - barrier control flowchart.

2. 1. The Automated Barrier Parking System

There are several ways to handle this parking system's control using various methods tailored for this or similar systems. This paper elaborates on three control methods based on the type of sensors deployed.

Some of the components required for all the following methods are:

- DC or AC motor

- 4x4 keypad to input the vehicle number

- Arduino UNO board

- LCD display

- DC power

Time-Based Method:

In this method, the user selects the desired vehicle using the keypad, by entering a number corresponding to the eight buttons, which refer to the position and level of the parking slot where the vehicle is sitting. As shown in Figure 4, Depending on the location of the vehicle, four-time cycles (T1, T2, T3, and T4) that the vehicle can take to come down to the ground level.

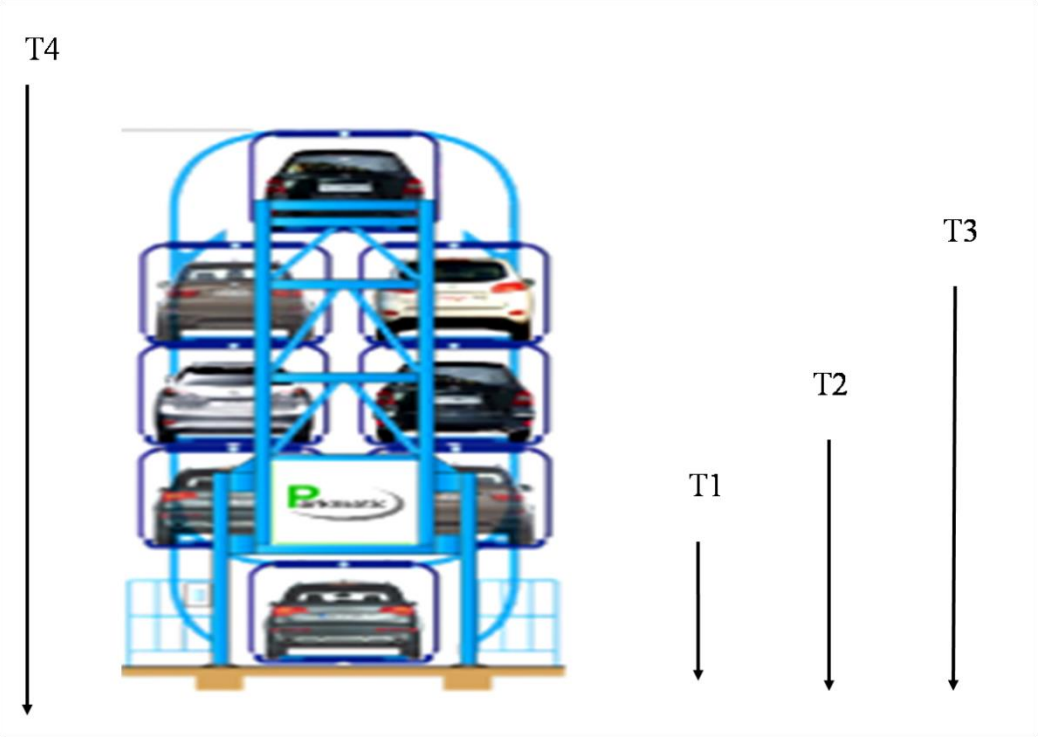

Figure 4 – Illustration of the possible time durations for the vehicle to come down.

Figure 5 represents the time-based method hardware.

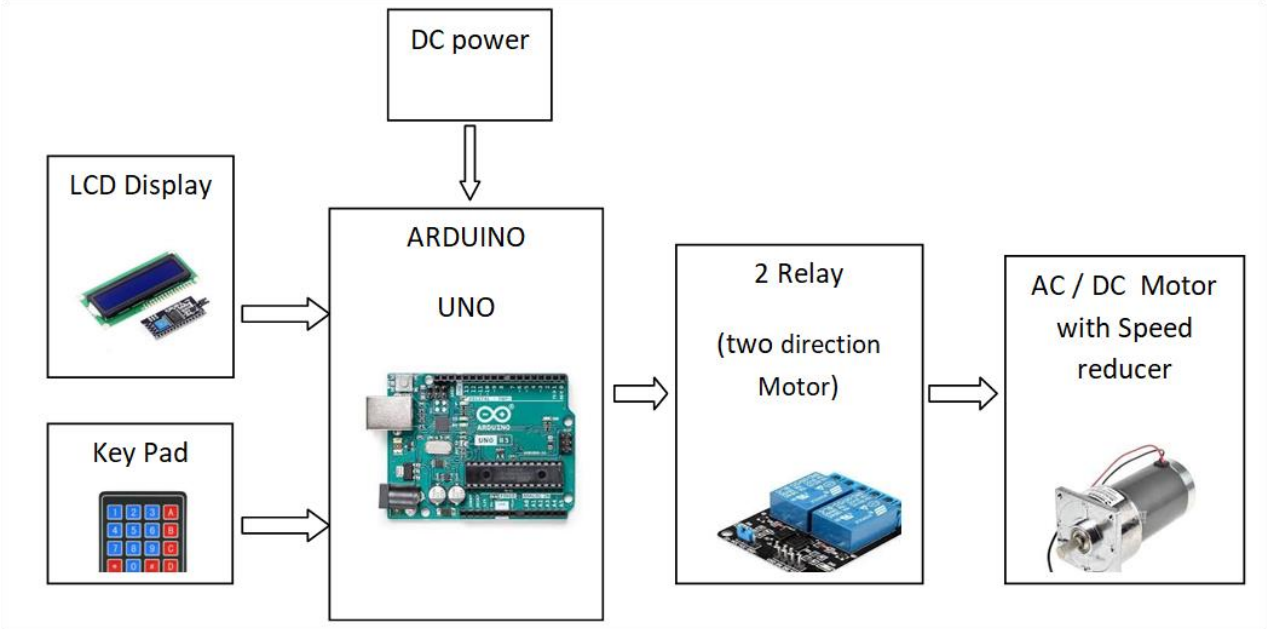

Figure 5 – Time-based method diagram.

For programming the Arduino board, as indicated in Figure 6 above, the rotation direction is done automatically in a way that the shortest path to the desired position is taken to enhance its performance. This automation makes the process of retrieving vehicles smooth and organized, thus maximizing the rotary parking system's operation.

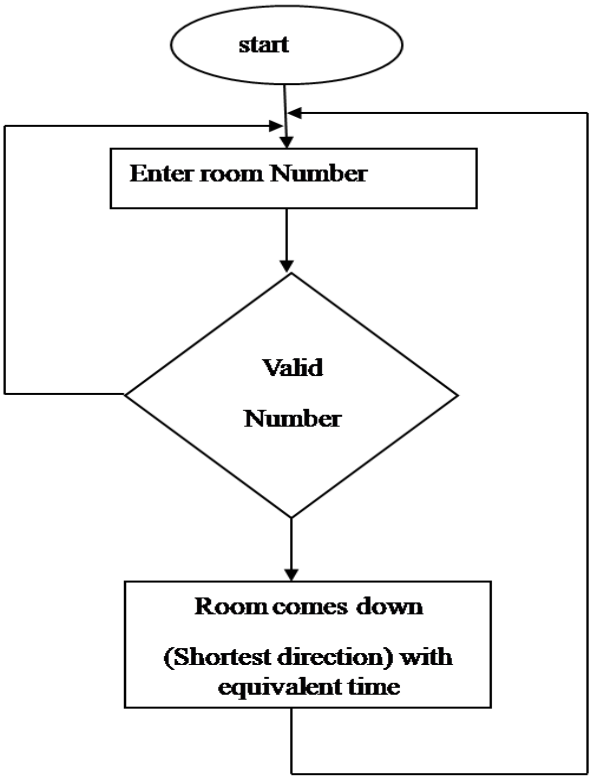

Figure 6 –Flowchart of time-based method control.

Control method by Limit Switches:

As depicted in the two figures above, there are a total of eight limit switches mounted on both panels of the rotary parking system. This helper will play a vital role in detecting that the requested parking slot (the vehicle) arrives at the exit point. When the vehicle reaches the point of egress, limit switches should provide feedback to the control system, thus ensuring that the vehicle is positioned to exit the parking area in a controlled and efficient manner. This boosts reliability and safety against possible collisions and ensures accurate retrieval of vehicles.

This method involves using two push buttons in addition to the eight buttons for vehicle requests. The setup does not automate the choice of rotation direction, i.e., the user must select the direction in which the motor should turn for the shortest path of travel to bring the vehicle when called for. This method offers a greater degree of flexibility and control, as it requires the user to input the direction of rotation of the motor which assures that the vehicle can be swiftly brought out through the exit with minimal waiting time.

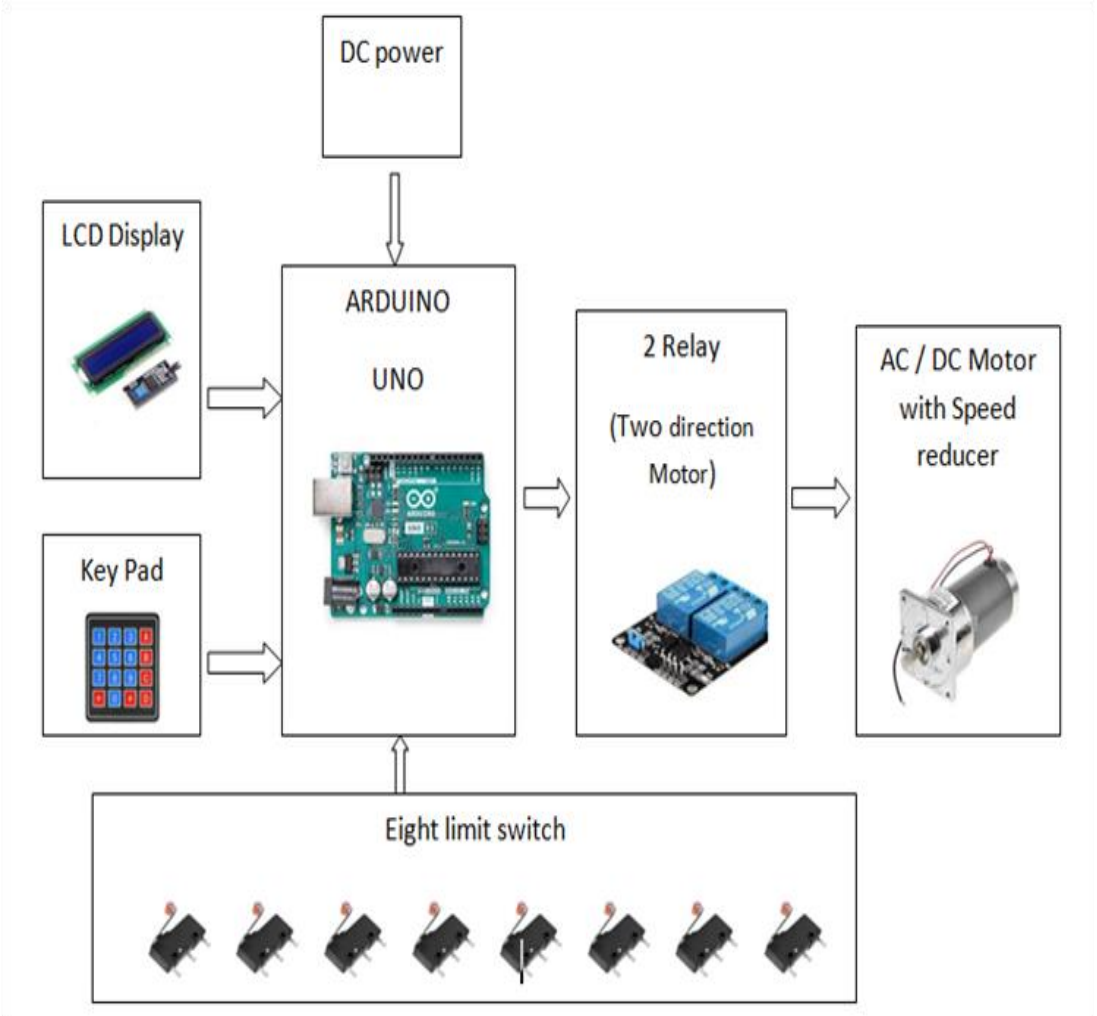

Figure 7 – Control system diagram with limit switches.

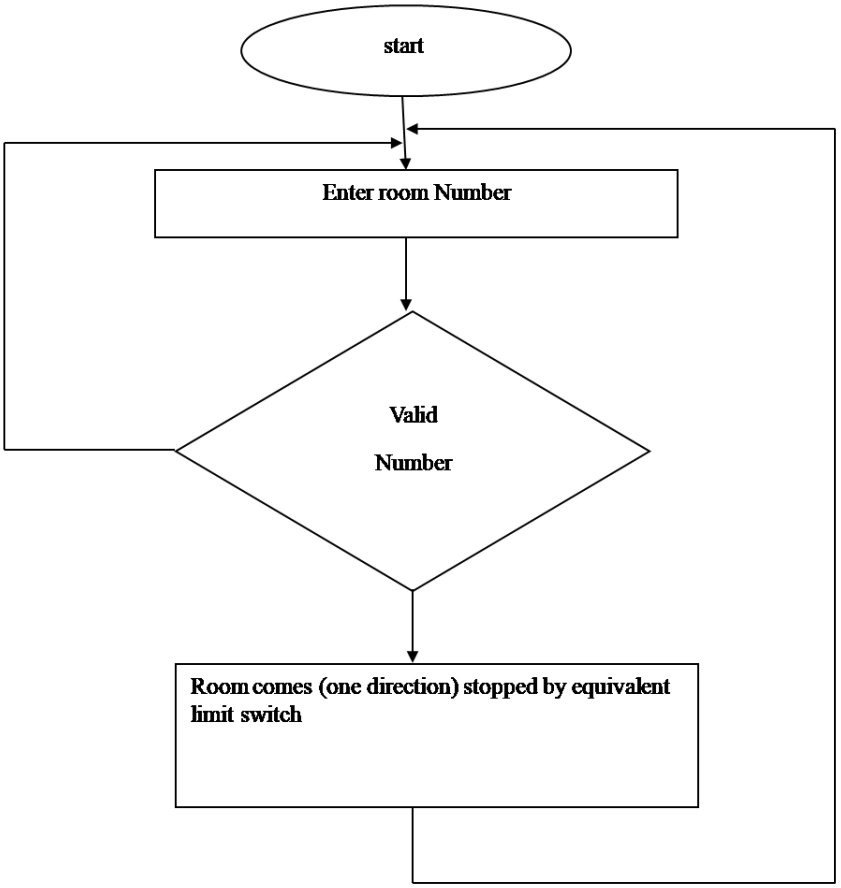

Figure 8 –Flow chart control system with limit switches.

Control method with Color sensor:

The control strategy involves using a color sensor rather than limit switches for the detection of vehicle arrivals in the rotary parking system; it works, however, just as described. As shown in the diagram in Figures 9 and 10, the color sensor is mounted at the bottom of the system to detect the color of the requested parking slot as the vehicle arrives at the exit of the rotary parking system. In this application, the TCS3200 sensor was selected, which is driven by an Arduino Uno.

The TCS3200 color sensor is a color frequency translator. It consists of a group of silicon photodiodes and a current-to-frequency converter integrated into the same CMOS monolithic integrated circuit. It can measure the RGB components of the surface of colored objects under illumination (Surbakti *et al*., 2022).

Depending on the vehicle accommodation, eight colors are worked out for every maximum vehicle unit in the system. Consequently, there are in total ten buttons whose functionality should, however, be programmed: eight for vehicle selection and two for rotational direction control (picking the shortest path). In this way, identification of the parking slots based on color detection will increase the efficiency during vehicle retrieval.

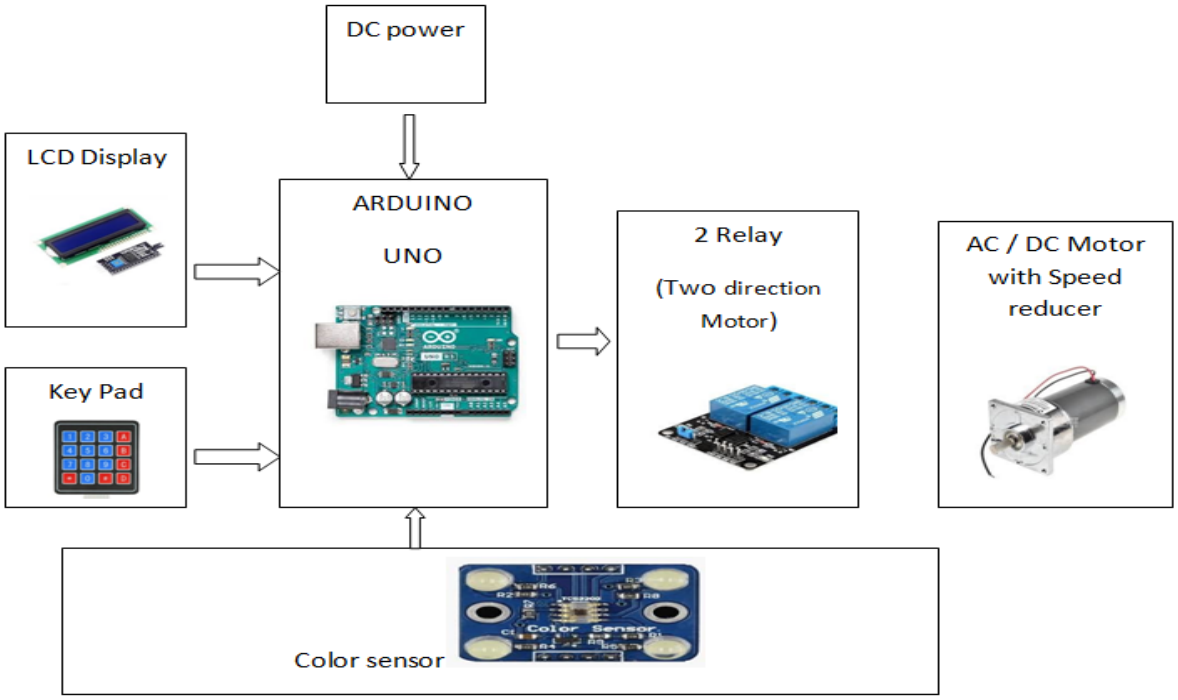

Figure 9 – Control system diagram with a color sensor.

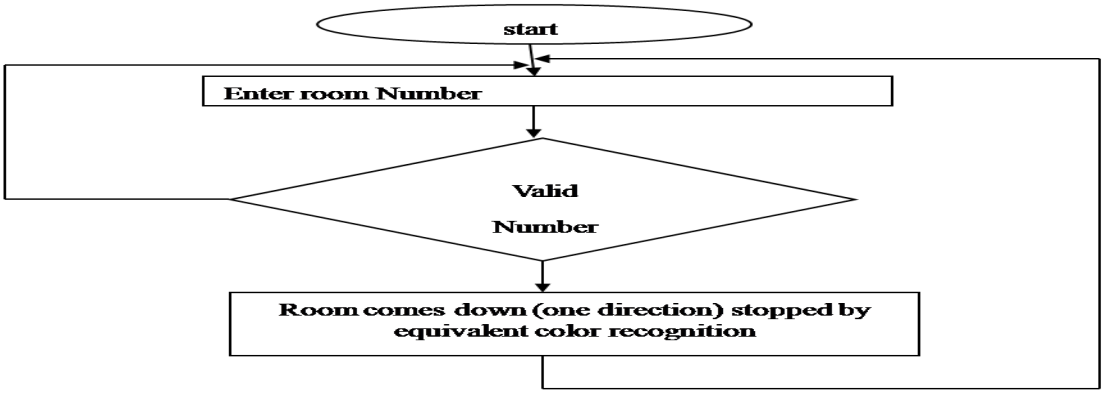

Figure 10 –Flow chart control system with a color sensor.

3. Comparison and Discussion

This experiment shows that our system could effectively function; the infrared sensors could adequately sense whether or not there are cars parked in the parking bays. When the car arrives, it is detected by the IR sensor acting as a button in the circuitry. Motor drive starts to lift the arm, and after a slight delay, the motor operates in a counterclockwise direction to close the arm. The count of cars is displayed on the LCD at the same time.

The program implemented on the hardware followed the proposed model for barrier control, which ensures that the barrier will open and close for incoming vehicles. LCD is used to present the number of vehicles in the parking, and the barrier is closed once it reaches its capacity. Therein, it is written through the LCD that the parking slot is full. The state of parking slots is monitored online through the Wi-Fi module, which saves driving effort and time searching for free slots. This control model does not depend on RFID cards or a payment system for a specified service. The automated parking facility is established with the aid of sensors to detect slot availability and grant parked cars access (Kumar and Siddarth, 2010).

In conclusion, the discussed project has met its objectives. The method has been improved by applying an IoT device to reserve available parking spots. The established system is flexible enough since it can be installed under various provisions being both convenient and slightly efficient.

As shown in Table 1, when comparing the three various methods in all these regards, we consider the installation cost, number of inputs(Arduino), programming complexity, ease of implementation or use, precision, and reliability, among other considerations.

The first method is characterized by fewer components than others, which requires only the keypad for the input to the Arduino. Consequently, the installation cost is low. It is fairly simple to program; however, the reliability depends on the accuracy of the mechanical aspects of the rotary parking system (Tang *et al*., 2006).

There are more inputs for connections on the installation based on limit switches than there were in the first one, which would require more cost for their installation. Their accuracy and speed of operation depend on the technology used for limit switches and the precise calibration of the installation, although the control program remains rather simple.

The setup with the color sensor connects two inputs, the keypad, and the color sensor, but is costlier than the first one. The quality of the color sensor governs the accuracy and reliability of this installation, and the control program becomes, therefore, more complex and lengthy.

All presented systems can go all the way from being residential to working in an industry by being universally applicable in more than a single use. The relatively simple circuitry allows it to be usable even by the most naive in terms of hardware problems. The automated car parking system is used as a vehicle's parking control, thus saving time by being displayed on an LCD using IR sensors at the entrance (Suhr *et al*., 2010).

Table 1 - Comparison of Automated Parking System Methods.

	Methods		
Criteria	**Keypad Only**	**Limit Switches**	**Color Sensor**
Installation Cost	Low, as it requires fewer components	Medium, more components required	High, due to the cost of the color sensor
Number of Inputs (Arduino)	Low, only keypad input is needed	Higher, requires several inputs	Low, only two inputs (keypad and color sensor)
Programming Complexity	Simple	Simple	Complex, with a longer program
Simplicity	Very simple to install and program	Simple, but requires adjustments for switch calibration	Moderately simple, depending on the quality of the color sensor
Precision	Medium depends on the mechanical precision of the rotary system	High, depends on the technology and calibration	Very high, depending heavily on the quality of the color sensor.
Reliability	Medium, prone to mechanical faults	High, as Limit Switches are reliable when properly calibrated	Very high, if a high-quality sensor is used
Development Cost	Low	Medium	High

5. Conclusion

Manuscripts In conclusion, the study attempts to offer insights into the functioning of intelligent systems for managing automatic rotary parking systems. Such systems are generally considered effective structures in urban habitations with a high-density population, especially in narrow spaces, as they improve living standards, result in lesser traffic congestion, and carry out operations without personnel. These systems are normally facilitated by electric energy and the usage of electric motors controlled by sensors, thus presenting a well-off and good future.

We further introduced the concept of automatization in parking systems, which embodies the specifications in determining the control elements configured and operational units required. This paper describes the hardware and software components of smart parking systems and discusses the advantages of the inclusion of artificial intelligence within these systems. Added contributions from us included the creation of a mobile application designed to complement this smart parking system.

Vertical rotary parking is a radically inventive solution to parking problems in densely populated urban sites, where land for parking is already scarce. The system as such is reasonably designed to allow vertical parking of several cars stacked one above the other at different levels, thus cutting down the ground area needed for regiment parking. This work is intended to design and fabricate a prototype for a control system that can manage eight vehicles with the aid of sensors, servomotors, and an Arduino controller.

The textual content discusses problems related to increasing urbanization and parking space management, emphasizing the significance of answers like clever parking for enhancing site visitors flow and lowering greenhouse gas emissions. It also presents diverse kinds of computerized parking systems and information on the functioning of a prototype, which includes a control device for a parking barrier and a mechanism for shifting motors within a rotary parking space. Ultimately, the prototype is designed to perform autonomously, without personnel, whilst optimizing automobile waft control and making sure efficient use of parking infrastructure. The desires of this venture were met, effectively addressing the project of finding parking areas through the usage of an IoT tool for reserving spots. The designed gadget can be implemented in numerous places due to its ease of use and effectiveness. Moreover, the gadget provides actual-time statistics on unfastened areas and extracts the remaining to-be-had slots. The targeted spots can be displayed as loose at the cell applications of the automobile owners, enhancing user comfort and performance in parking control.

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