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RESEARCH ARTICLE - MATHEMATICS

Efficient predictive model for multilevel parking system based Arduino

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Abstract

Nowadays**,** finding a free parking slot can be very stressful in densely populated areas like Karbala, especially in visiting days. Such parking process takes a long time, wastes significant gasoline and emits extra vehicle exhaust that harms the environment. The problem becomes even more significant when entering a multilevel parking lot, only to discover that there are no free spaces. This results in wasted time and frustration. To address this problems, an efficient smart parking management system is needed in all multilevel parking lots to ensure confusion-free and convenient parking. In this paper, we design a smart multilevel parking system using an Arduino microcontroller. This system will enable drivers to quickly identify available parking spaces, thereby reducing time, energy consumption, and air pollution. Also, we propose a predictive mathematical model to expect the state of the parking lot, thus enhancing the proposed management system in terms of reducing waiting time of the Arduino action for getting a free space from the IR parking sensor of the parking floors.

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Keywords: Multilevel parking system, Arduino, Parking free space, Predictive model, Smart parking system.

1. Introduction

Parking is a major problem in our country. Drivers in our country cannot properly park their vehicle in the parking slot because of unsuitable parking system. Sometimes when they do not find any parking space, they park their vehicle in the roadside and as a result roads become so narrow and occurs traffic jam **[1].** Also, sometimes it seems that people start fighting for a parking spot in the parking lot. This also wastes a lot of time and energy **[2] .**Until now, no smart technology has been available to solve this problem. This work aims to standardize parking systems in parking lots of city of Karbala. It is designed to provide enhanced services to drivers, ensuring a better overall experience. A smart parking system streamlines the process, making it more efficient and convenient compared to traditional manual methods. The proposed system tracks the number of vehicles in the parking lot and determines the availability of parking free spaces. It features an entry and exit path, where the display shows the number of vehicles inside upon entry. Whenever a vehicle leaves, the count decreases and is updated on the outside display. If the parking lot is full, the system displays a message indicating that no spaces are available.

The main contributions of this paper can be summarized as follows:

- Designing a smart management system based Arduino for parking lot to provide enhanced parking services to drivers.
- Proposing a predictive mathematical model to expect the available parking free spaces based on arrival and leaving time of vehicles.
- Introducing a predictive procedure based on the proposed mathematical model to reduce the waiting time for getting a free space.

2. Literature review

Reference[3] developed an electronic fee collection system by detecting vehicle number plates. To enable the parking and payment system, image processing was employed to recognize number plates. The system utilized an algorithm-based approach to extract license plates from automobile images, followed by character segmentation and rearrangement. **Reference [4]** proposed an automated parking system based on ultrasonic sensors. It is an electronic component to detect the presence of obstacles using ultrasound waves. The authors successfully identified parking space surroundings, replicated the driver's parking method, and performed both roadside and reverse parking using a smart wheeled mobile robot (SWMR). The SWMR autonomously controls the servomotors of its two wheels, allowing it to turn, move forward, reverse, and stop when the ultrasonic sensors detect sufficient parking space. **Reference[5]** designed an automatically system to manage a parking lot as a subscription-based service. The Radio Frequency Identifier (RFID) is used to verify a user's identity upon entering a parking area. In this study, a small portal door system was simulated to control the entry and exit of vehicles utilizing RFID tags as subscriber in the design of the parking system. **Reference[6]** focused on collision avoidance and a reliable vehicle parking system. The slot fill level is computed by measuring distance information by ultrasonic sensor. During parking, sensor systems employ ultrasonic sensors to alert drivers of nearby obstacles. This technology is beneficial for unforeseen parking scenarios, reducing both time and fuel waste. Consequently, a parking spot with minimal fuel consumption can be quickly located. Monitoring and managing vehicle access in government and private sector parking lots is crucial for enhancing global security systems.

Therefore, the **Reference[7]** designed a smart parking system utilizing mobile application technology. The created system can control allowed vehicle admission into parking lots while blocking illegal vehicles. In addition, a parking charge payment system was built. **Reference[8]** automated both vehicle movement and parking. Their project featured a small-scale model of an automated parking system capable of controlling and managing the number of vehicles that can be parked in a given location at any time, based on parking space availability. **Reference[9]** proposed an automated parking with an Android-based application to control the entrance and exit of the parking lot. The goal of this system was to minimize human intervention by automating both the vehicles and the parking process. In contrast, most existing systems still require human staff or vehicle owners to park manually. **Reference[1]** proposed a Smart Parking System (SPS) using the Internet of Things (IoT). The system primarily focuses on reducing the time spent searching for parking spaces while preventing unnecessary travel through fully occupied lots. Consequently, it minimizes fuel consumption, which in turn reduces carbon footprints in the environment. To improve parking management, Parking Guidance Information (PGI) systems were introduced by **Reference[10] .**Parking information can be displayed on Variable Message Signs (VMS) along major roads and streets or disseminated via the internet. Within PGI systems, e-parking is an innovative platform that enables drivers to access parking availability information before or during their trip and reserve a parking spot in advance.

Reference[2] presented an IoT based cloud integrated smart parking system. The proposed system consists of an on-site deployment of an IoT module that is used to monitor and signalize the state of availability of each single parking space. **Reference[11]** presented an intelligent parking space detection system based on image processing. The system captures and processes brown circular markings drawn in the parking lot to determine available parking spaces. The information is displayed in real time on a seven-segment display unit, indicating the number of currently available parking spots. This proposed system has been developed on both software and hardware platforms. In **[12],** a research was developed to acquire vehicle park occupancy information using an integrated approach of image processing algorithms. Security surveillance cameras, which are commonly available in most vehicle parks, can be used to capture images of the parking area.

This project, known as the Vehicle Park Occupancy Information System (COINS), was tested using both simulation models and real-case scenarios. **Reference[13]** introduced an intelligent parking system using IoT technology, consisting of multiple layers to optimize vehicle parking management. The system detects available spaces, helps drivers find and reserve parking, and integrates cloud-based services for real-time tracking, supervision, and access control. **Reference[14]** implemented a system

model with wireless access in an open-source physical computing platform based on Arduino with RFID technology. It used smartphone that acts as a user interface between the cloud and the vehicles to check the feasibility of the proposed system model. **Reference[15]** introduced two innovative services: an intelligent parking cloud service and a vehicular data mining cloud service, both of them aimed to improve the efficiency in transportation system.

3. Proposed work

The required hardware components of the proposed system is explained in the Fig.1. Accordingly, we can see the proposed system consists of the following components:

- **Arduino board:** is an open-source platform, where it consists of both a physical programmable board and a piece of software code that runs on it after uploading from the computer. The physical board includes digital and analogue input/output pins that can be used to connect to other components and circuits.
- **IR proximity sensors:** identify nearby objects by emitting infrared light and assessing the reflected signal. These sensors are used in a variety of applications, such as obstacle avoidance in robotics, automatic door opening, parking assistance, security alarms, and contactless tachometers**[16] .**
- **Servo motor:** is a motor capable of rotating to precise angles when programmed via an Arduino. The servo unit contains built-in electronics that regulate the motor's movement **[17].**
- **LCD (I2C-16x2)**: is a popular display module used in electronics projects. It contains 16 columns and 2 rows, making it ideal for displaying text or simple data**.**
- **RFID Module:** RFID is a wireless non-contact method, that uses a radio frequency electromagnetic field as a medium for communication for identifying a tag attached to an object**[18] .**The RFID system is a combination of an RFID reader and a transponder (i.e. Tag).

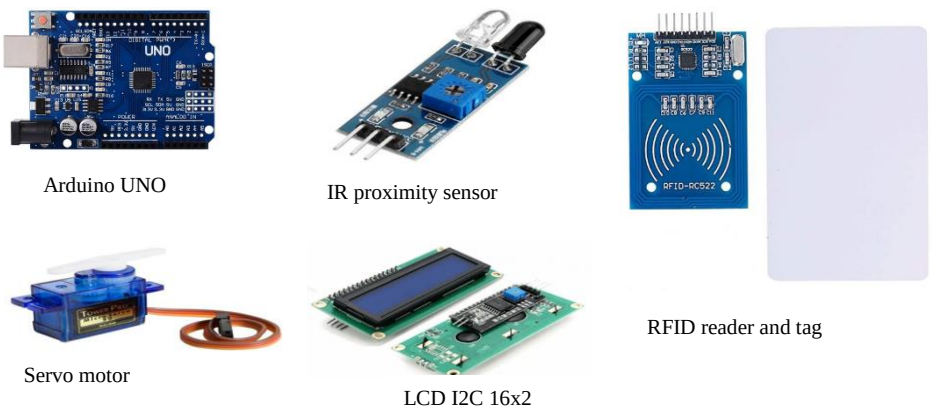

Fig. 1. The main components of the proposed system

4. Block diagram

The block diagram of the proposed system is presented in Fig.2.From Fig2., we can see all the hardware components are connected directly to the Arduino. The system utilizes seven IR proximity sensors, one IR sensor is located at the entrance parking gate to detect incoming vehicle, four IR sensors located on the first floor of parking lot and two others on the second floor. Theses sensor serves as an input signals for the Arduino, which controls the operation of gates (i.e., Entrance and Exit) through two servo motors for opening and closing the gates. Additionally, the entrance servo motor receive signal from the IR entrance sensor when a vehicle enters parking lot, whereas the exit servo motor receive signal from RFID tags when a vehicle leaves the parking lot. The availability of parking free spaces of both floors will be show on the outside LCD display located at the beginning of the parking lot.

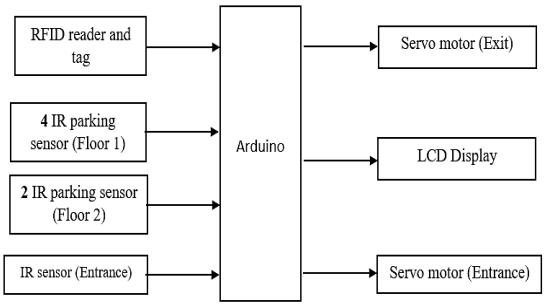

Fig.2: Block diagram of the proposed system

5. Wiring circuit diagram

Fig. 3. Explains the wire circuit connection of the proposed system. The circuit diagram is set up by using fritzing program **[19]**. From the figure, we can see that the red and blue colors represent the power lines, while the other colors represent the signal lines. For more details, we list the following connection wires below:

5.1. Blue wire: positive power supply (5V or 3.3V)

5.2. Red wire: negative power supply (GND)

5.3. Violet wire: signal line

5.4 Sensor Connections:

5.4.1. Lower four IR sensors: Analog pin A4

5.4.2. Upper two sensors: Digital pins 5 & 8

5.4.3. Gate sensor: Digital pin 3

5.5. RFID Tag: connected to digital pins 9 through 13 (inclusive)

5.5.1. Display Connections:

5.5.2. LCD I2C interface:

5.5.3. SDA: Analog pin A4

5.5.4. SCL: Analog pin A5

5.6. Servo Motor Connections:

5.6.1. Upper servo: Digital pin 7

5.6.2. Lower servo: Digital pin 4

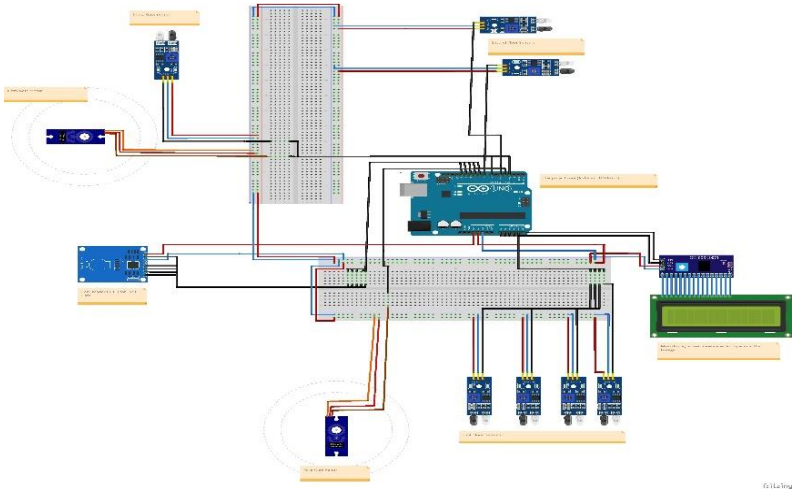

Fig.3. Wiring circuit diagram of the proposed system

6. Flowchart and implementation example

The working procedure of the proposed system will be as follow: Initially the Arduino will get the data of floors which are the parking free space of the floor one and two from all IR parking sensor, then the data of both floors will be updated and presented on the outside display. In case incoming vehicle, the Arduino check the free spaces in the floors if exit, the entrance gate of the parking lot will open by the entrance servo motor, else the gate will remain close and waiting until leaving a vehicle from the exit gate by tagging RFID card to get available space. All these states will update the date of both floors and displayed on the outside display. The sketch code of this flowchart is available in **[20].**

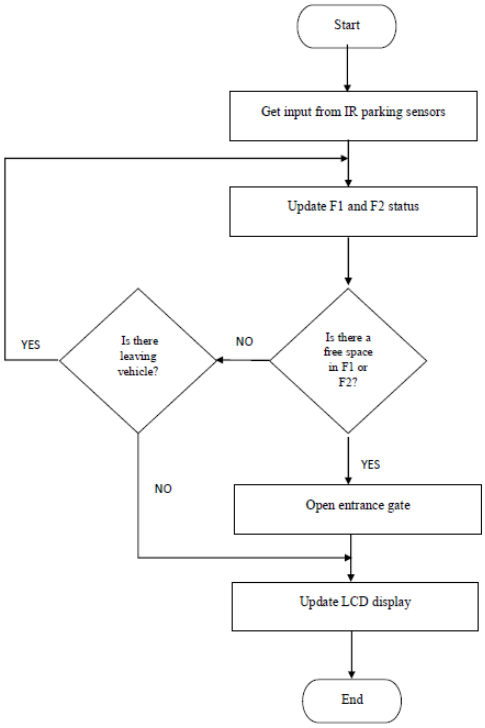

Fig.3. Multilevel smart parking system flowchart

Example: Assume that each floor (i.e., F1 and F2) is represented by two possible states: '0' and '1'. The state '0' indicates that there is a parking free space on the floor, whereas '1' indicates that the floor is fully occupied. Table 1 explains the working of the proposed system. From the Table, we can see the entrance gate is still closed whenever the state of the F1 and F2 have no free space, whereas the entrance gate is open whenever the F1 or F2 has a free space.

Table 1. Working procedure

INPUT		OUTPUT	
F1	**F2**	**Entrance Gate**	**LCD Display**
0	0	Open	Parking available
1	0	Open	Parking available
0	1	Open	Parking available
1	1	Close	Parking full

7. Mathematical predictive model

To improve the proposed parking system by displaying the real time of the parking lot on the display before waiting some time to get the feedback information of the IR parking sensor. We assume each arriving vehicle record arrival and leaving time at the entrance gate. The Arduino can get this information as notification message from the entrance IR sensor of the parking lot. As result the Arduino can expect the number of joining or leaving parked vehicles in the parking lot, where this number may change over time. Based on **[21]** we will conduct a theoretical analysis of the parking lot's changes over time to demonstrate the viability of our proposed parking system. The number of parked vehicles in parking lot known from the last notification message is supposed to be $N(t)$. Let A and L be the number of vehicles arriving and leaving the parking lot in each unit time, respectively. Accordingly, the number of vehicles after time period Δt is:

$$N(t+\Delta t) = \max\{0, \min\{N(t) + A\Delta t - L\Delta t, C\} \quad (1)$$

Where C is the maximum capacity of the parking lot. From (1), we can see the number of the parked vehicles at present is only related to the last moment which means that the queuing process is a Markov chain process. Thus, the transition probability of $N(t+\Delta t) = j$ can be given as follows:

$$P\{N(t+\Delta t) = j\} = \begin{cases} P\{(A-L)\Delta t = j - N(t)\}, 0 \le j \le C \\ 0, C < j < 0 \end{cases} \quad (2)$$

According to above mathematical model the pseudo-code of the predictive procedure of the Arduino to expect the real time state of the parking lot is shown Fig.4.

Arduino predictive procedure

- **Given**

  A , number of arriving vehicles in each unit time

  L , number of leaving vehicles in each unit time

1. **Predictive procedure ()**
2. Get input data from IR entrance sensor
3. Use eq. (1) & (2) to predict the real time state of the parking lot
4. Update F1 and F2 status
5. If parking free space available
6. Open entrance gate

```
7   Else
8       Remain entrance gate close for some time
9   Update LCD display
10  end procedure
```

Fig.3. The pseudo-code of predictive procedure.

8. Conclusion and future work

We have designed an efficient smart multilevel vehicle parking system to address the problem of traffic congestion vehicles and poorly managed multilevel parking lots. The proposed system can save the time of the drivers and consumption energy of the vehicles in finding a parking free space in multilevel parking. Additionally, the drivers can see the availability of parking free spaces on a display outside the parking lot, without having to enter and waste time or energy. Also, to enhance the proposed management system and reduce the waiting time of the Arduino for getting the available parking free spaces from the IR parking sensors, a mathematical predictive model is introduced which will enhance the effective of the Arduino. In future work, we plan to implement this system in all parking lots across the city of Karbala, ensuring high security to prevent stolen vehicles from being parked. Furthermore, utilizing the internet to integrate this parking system would enable the efficient distribution of parking locations and highlight available parking free spaces on the smartphone by a proposed phone application.

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Reference

[1] T. N. Pham, M.-F. Tsai, D. B. Nguyen, C.-R. Dow, and D.-J. Deng, "A cloud-based smart-parking system based on Internet-of-Things technologies," *IEEE access*, vol. 3, pp. 1581-1591, 2015.

[2] Y. Geng and C. G. Cassandras, "New “smart parking” system based on resource allocation and reservations," *IEEE Transactions on intelligent transportation systems*, vol. 14, no. 3, pp. 1129-1139, 2013.

[3] M. M. Rashid, A. Musa, M. A. Rahman, N. Farahana, and A. Farhana, "Automatic parking management system and parking fee collection based on number plate recognition," *International Journal of Machine Learning and Computing*, vol. 2, no. 2, p. 94, 2012.

[4] T.-F. Wu, P.-S. Tsai, N.-T. Hu, and J.-Y. Chen, "Research and implementation of auto parking system based on ultrasonic sensors," in *2016 International Conference on Advanced Materials for Science and Engineering (ICAMSE)*, 2016: IEEE, pp. 643-645.

[5] R. Hidayat, S. Afiyah, R. Sufyani, and F. Adani, "Development of Radio Frequency Identification (RFID) in the Campus Parking System based on Microcontroller," in *Journal of Physics: Conference Series*, 2021, vol. 1783, no. 1: IOP Publishing, p. 012022.

[6] B. N. Mohapatra, R. K. Mohapatra, M. Mirpagar, and A. Quershi, "Ultrasonic based easy parking system based on Microcontroller," *International Journal of Innovative Technology and Interdisciplinary Sciences*, vol. 3, no. 2, pp. 429-434, 2020.

[7] M. O. B. Sabbea, M. Irfan, S. K. ALtamimi, S. M. Saeed, A. Almawgani, and H. Alghamdi, "Design and development of a smart parking system," *Journal of Automation and Control Engineering Vol*, vol. 6, no. 2, 2018.

[8] D. Bonde, R. S. Shende, A. S. Kedari, K. S. Gaikwad, and A. U. Bhokre, "Automated car parking system commanded by Android application," in *2014 International Conference on Computer Communication and Informatics*, 2014: IEEE, pp. 1-4.

[9] D. Azshwanth, M. T. Koshy, and M. T. Balachander, "Automated car parking system," in *Journal of Physics: Conference Series*, 2019, vol. 1362, no. 1: IOP Publishing, p. 012059.

[10] S. Deepthi and A. Anil, "A Survey on Smart Parking System Based on Internet of Things," *International Journal of Engineering Science and Computing*, vol. 6, pp. 3175-3178, 2016.

[11] R. Yusnita, F. Norbaya, and N. Basharuddin, "Intelligent parking space detection system based on image processing," *International Journal of Innovation, Management and Technology*, vol. 3, no. 3, pp. 232-235, 2012.

[12] H. R. Al-Absi, J. D. D. Devaraj, P. Sebastian, and Y. V. Voon, "Vision-based automated parking system," in *10th International Conference on Information Science, Signal Processing and their Applications (ISSPA 2010)*, 2010: IEEE, pp. 757-760.

[13] Z. Ji, I. Ganchev, M. O'Droma, and X. Zhang, "A cloud-based intelligent car parking services for smart cities," in *2014 XXXIth URSI General Assembly and Scientific Symposium (URSI GASS)*, 2014: IEEE, pp. 1-4.

[14] C. Shiyao, W. Ming, L. Chen, and R. Na, "The research and implement of the intelligent parking reservation management system based on ZigBee technology," in *2014 sixth international conference on measuring technology and mechatronics automation*, 2014: IEEE, pp. 741-744.

[15] K. Ashokkumar, B. Sam, and R. Arshadprabhu, "Cloud based intelligent transport system," *Procedia Computer Science*, vol. 50, pp. 58-63, 2015.

[16] "What is IR Sensor ?" https://www.watelectronics.com/ir-sensor/ (accessed.

[17] "What is a Servo Motor?." [Online]. Available: https://circuitdigest.com/article/servo-motor-working-and-basics.

[18] "What is RFID? ." [Online]. Available: https://lastminuteengineers.com/how-rfid-works-rc522-arduino-tutorial/.

[19] "Fritzing." [Online]. Available: https://fritzing.org/.

[20] "Code." [Online]. Available: https://github.com/allaabbas/CODES.

[21] 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, 2021.