IoT Based Smart Parking System

Diya Kharel
BSc. (Hons) Computer Science with Artificial Intelligence, Sunway College
Birmingham City University, BCU
Kathmandu, Nepal
Diya.Kharel@mail.bcu.ac.uk

***Abstract* — the advancement of technology especially the internet of things (IoT) has over the recent past impacted several aspects of living beings. A good example of IotT application is smart parking system, which changes the way of parking management by means of the hardware and IoT modules. It provides a variety of functions, including identifying the number of parking spaces that are free incorporating safety and security alerts into the system, to increase general effectiveness. The following paper offers information concerning IoT background where it is described as a decentralized technology that is also heterogeneous, which makes it efficient and scalable. It focuses on the importance of smart parking systems in the cities where the technological solutions are moving from the wired to wireless, through the use of sensors, navigation system, real time monitoring and many others. The system uses and consists of several physical components such as ultrasonic sensors, micro servo motors, resistors, LED bulbs, Arduino Uno, and LCDs to detect and manage parts for parking in real time. With a descriptive methodology, hardware architecture, logic diagram, and truth tables, the paper describes how the system actually works. The paper prioritizes how IoT can advance parking infrastructure, reduce traffic problems, as well as enhance the driver's experiences.**

Keywords— IoT, smart parking system, hardware implementation, security, real-time monitoring.

I. Introduction

Over the past few years, development of technology has impacted various aspects of human life. Among them, the most well-known one is the internet of things (IoT) (Fahim et al., 2021).Internet of Things (IoT) is defined as the massive interconnection of increasing miscellaneous physical objects that are interconnected over the Internet. This networking ecosystem facilitates miscellaneous objects or devices such as computers, smartphones and Personal Digital Assistant (PDA), etc to remain connected over the internet. IoT emerges internet to device operations allowing intelligence to do range of tasks worldwide involving data, networks and resources which requires networking and computing technologies like Multi-Access Edge Computing (MEC). Internet of things can be regarded as the nervous and sensory system of the future Information and Communication Technology (ICT) (Kalla et al., 2019).Therefore, the idea of smart cities has developed with the expansion of IoT. Smart parking system is an automated intelligent system that improves the parking system through the use of technology. It serves as a solution to present day challenges that requires the use of hardware, with an IoT module with different features like parking space identification, safety and security alerts. Smart parking system uses the concept of IoT to manage the physical objects that are involved in the system including several sensors with other objects which have the ability to interact and exchange data in real time with the internet (Venkata Sudhakar et al., 2023).

II. Literature Review

A. Internet Of Things

Since few decades, Internet of things has emerged as superior technology in terms of technology and has achieved many milestones and setting global standards. The term IoT means connect all the object of the world through single interface. Not only, this grants individual can access these objects but also receive timely updates (Venkata Sudhakar et al., 2023). Issues like infrastructure, communication, protocols, interfaces and standards are all to blame for development of IoT. The perfect description of IoT is that it is decentralized, and it fosters including efficiency, scalability and resilience and heterogeneous nature including integration of devices (Laghari et al., 2021). Since implementation of parking system in real-time is a major concern, IoT assists in solving problem with the help of sensors and actuators as it makes parking time intelligent, intelligent use of land and also reduces on traffic pollution. (Agarwal et al., 2021).

B. Innovation Of IoT

In the fast moving world of technology, previous methods of progression of objects encountered some difficulties. As the internet developed, it metamorphosed into IoT where it revolutionizes how the living and nonliving entities interact (Wang et al., 2021). As smart cities evolved, the idea of modern technology has gone from wired to wireless through automated computing including

sensors, mobile application, navigation & alarm systems and many more (Biyik et al. , 2021). Internet of things is not only about modification of the hardware. Improved software solutions along with AI and Machine learning could be the possible cause of advanced automation and predictive analyzation. This approach allows the use of informed decision making by individuals, industries, and remote monitoring and control, predictive maintenance, optimized resource allocation, and many more (Ullah et al. , 2023).

C. Security

Since smart parking systems use different automated technologies associated with communication devices where information are shared over networks. TLS, FTP, and IP protocols are used for secure transaction of data in network and application layers. Also, data authentication, encryption are performed for unauthorized access from user (Puspitasari et al., 2021). It is not only constructed based on the user's data but also for infrastructure in those certain areas. To ensure prevention, cyber security in the event of a virus, hackers, phishing scams and physical security through the use of cameras and alarms access restrictions are integrated. Apart from that informing the drivers about the security of smart parking can be efficient practice method. Therefore, implementation of security has vital roles to ensure secure and efficient integration and availability of system (Alqazzaz et al., 2018).

D. Current And Future Trends

From simple activities to intricate processes, IoT appears to have possibilities in both the individual and professional domains lives. The number of data users and connected devices is increasing ten to hundred times using edge computing, 5G connection which enables a higher number of connected devices. Currently, Io architecture comprises of three fundamental elements that interface with network. They are hardware, middleware and presentation layer which assists in the integration with the system (Shafique et al., 2020). However, despite these inventions being labeled as new technologies, they have limitation. To overcome its limitations, the emerging technologies, for instance, deep learning, blockchain, sophisticated sensing computer may be used in the future where objects and structures will be able to interact with each other. Also, mostly in multi- parking zones, GPS is not effective so 3D localization map could be used (Khalid et al., 2021).

III. METHODOLOGY

The study revealed that especially during rush hour, drivers appear to experience significant challenges in finding a parking space without any problem where 30% of the traffic jam are attributed to cruising in search of parking space it takes approximately 7. 8 minutes per person per day (Fahim et al., 2021). Apart from this, it has been challenging to locate parking areas in areas like shopping center, hospital, movies, restaurant etc as the number of vehicles on roads are increasing (Waheed et al., 2021). Thus, this section addresses the process of system development which mainly entails the following concerns itself with the progression of parking structures.

A. Hardware Implementation

a) Hardware Requirements

i. Ultrasonic sensor: It is based on the working principle of propagation of sound waves among the objects. This sensor primarily does energy conversion between sound and electrical energy, which can be found as an occupancy or motion detector among a wide range of applications (Sulistyawan et al., 2023).

ii. Micro servo motor: It is a device that moves /rotates various objects with high precision, difference positions and angles can be accurately adjusted (Allbadi et al., 2021).

iii. Resistor: Resistor is an electrical component which impedes the current in a circuit. Its characteristics are resistance, tolerance, power rating and temperature coefficient (Perković et al., 2020).

iv. LED bulbs: It shows the status of each parking spot (occupied or vacant) and switches on if a spot is occupied to guide drivers to available spaces visually (Allbadi et al., 2021).

v. Arduino Uno R3: Arduino Uno is a microcontroller which based on ATmega328 uses as a main component in the proposed system with flash memory of 32KB, SRAM of 2KB. IT performs overall functions of the system (Veeramanickam et al., 2022).

vi. LCD Screen: The Liquid Crystal Display (LCD) is one of the widely used display that has a great popularity on the Arduino market (Allbadi et al., 2021).

vii. The Passive Infrared Sensor (PIR) : A PIR which detects when people or object enters its region When there is an object in front of it, the micro servo goes open the gate (Krishna Chaitanya et al., 2021)

b) Working mechanism of the proposed system

The smart parking system begins with a stable power source that puts all things into action such as the Arduino, ultrasonic sensors, LED bulbs and LCD screen. The system is initiated by configuring the ultrasonic sensors to detect vehicles and the LCD screen to display the status of parking slots. The power stability is checked without stopping. Without power, this system stops working. At the time of turning on power, an ultrasonic sensor at a gate detects incoming vehicles through emitting ultrasonic pulses and measuring how long it takes these pulses to bounce back. By processing this data, Arduino decides whether there is a vehicle at a gate or not. If there are no cars detected, then the system keeps monitoring .The detection of a car will prompt checking slot availability using the assigned slot-ultrasonic sensors. Should there be no empty slots, it will indicate "Parking Full." Wherever an empty slot exists, Arduino displays it on LCD screen while simultaneously lighting up a corresponding LED bulb over that empty space making use of First-Come-First-Served (FCFS) algorithm for slot allocation. It provides a visual guide to the driver through the LCD screen as well as open the gate for the vehicle.

The Arduino continuously updates an onboard LCD screen on current status of parking slots and calculates pricing based on parking duration. Thus, this system constantly monitors and updates itself in real time making it a complete solution for modern parking infrastructure.

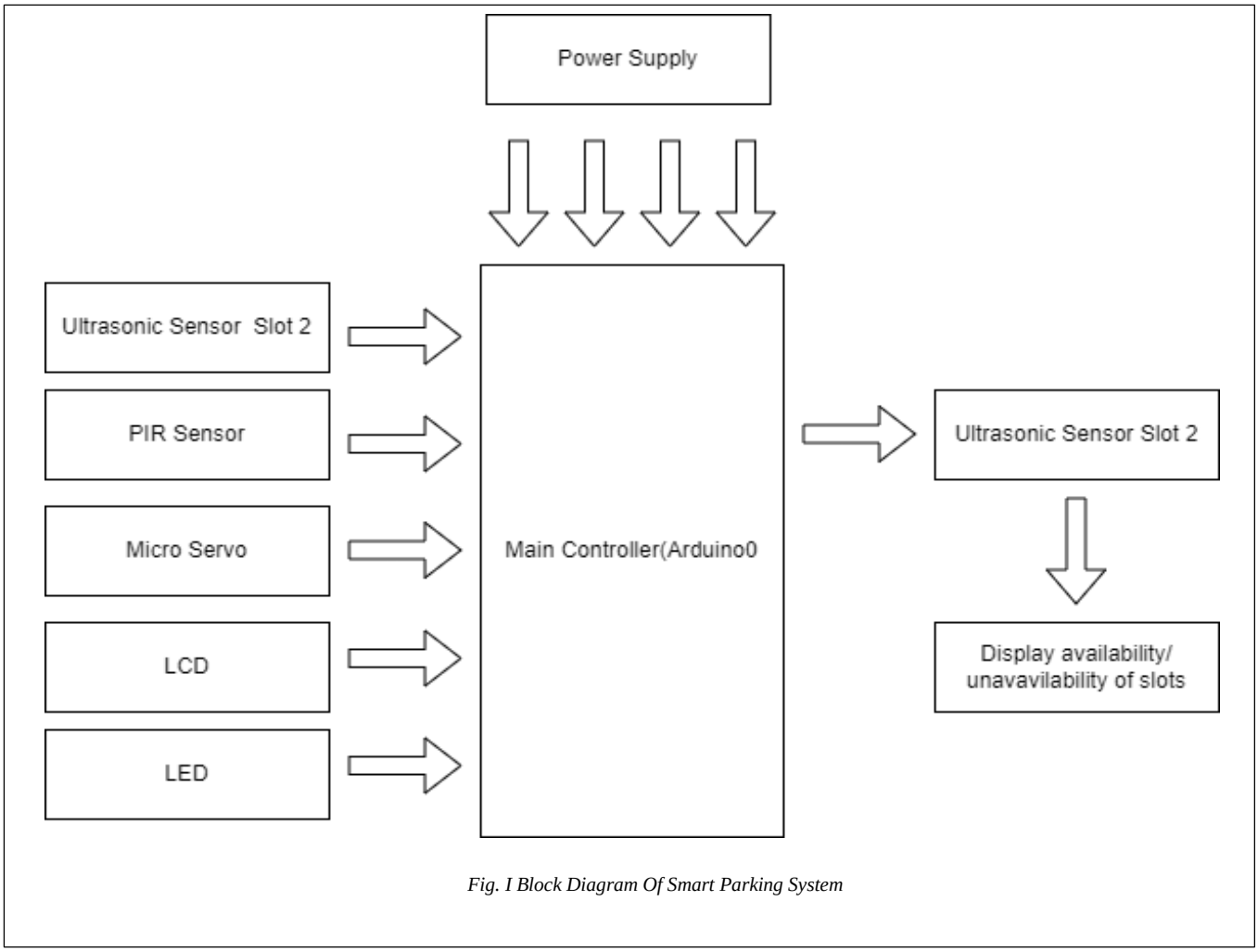

Fig. I Block Diagram Of Smart Parking System

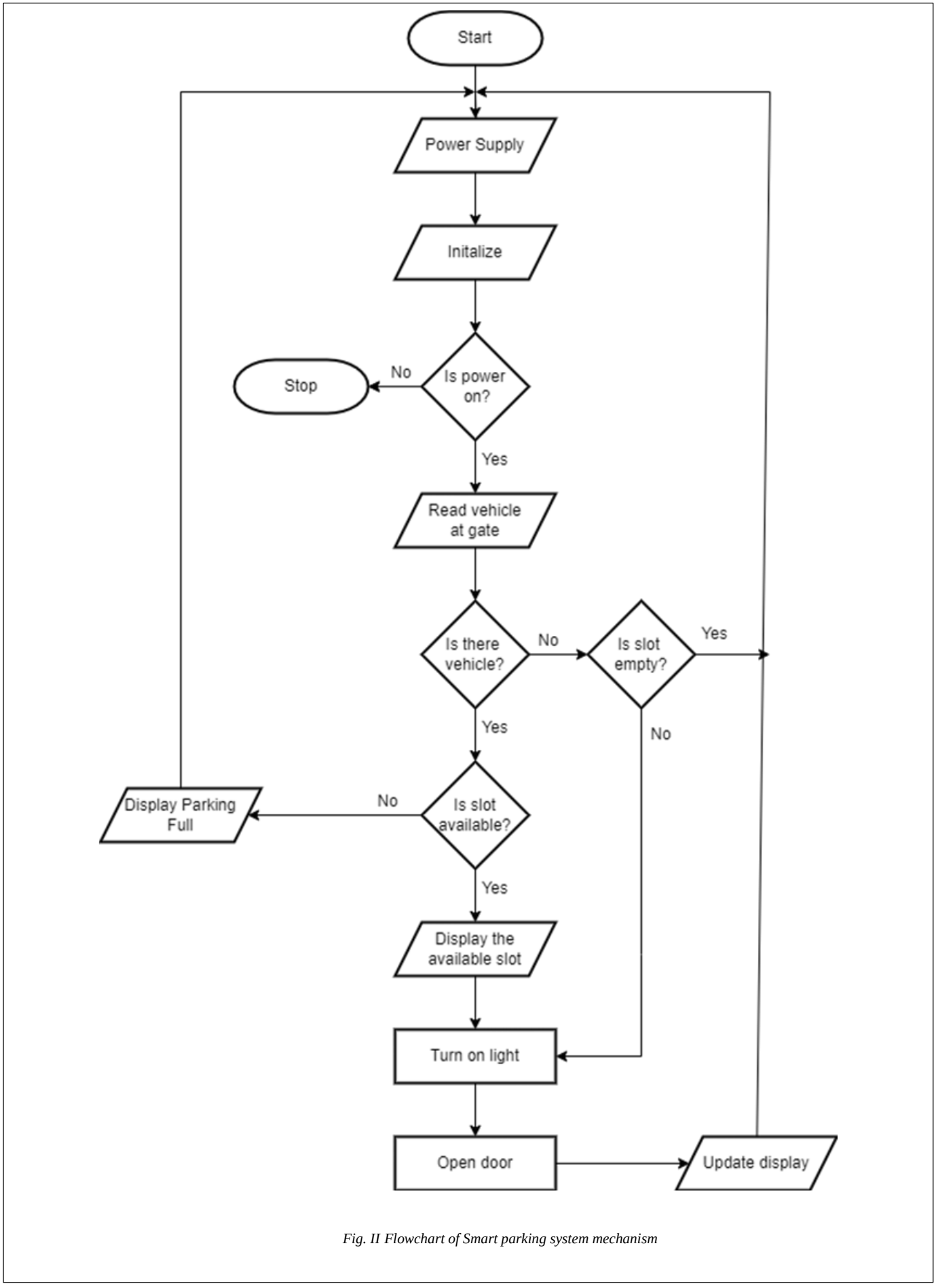

Fig. II Flowchart of Smart parking system mechanism

B. Hardware Architecture

For this model system, Tinker cad is used to create the prototype and for simulating the system C++ code is implemented. Smart parking system's hardware architecture effectively handles parking slots and gives real time updates. It begins with a stable power supply that maintains all components in its operational state. The central control unit Arduino UNO coordinates functions of the system including ultrasonic sensors placed at entrances as well as each parking slot. At the gate position one sensor detects incoming vehicles while others at different slots keep checking whether it is occupied or not.

When a vehicle is detected, Arduino will check if there are empty slots and accordingly update an LCD screen on which messages such as slot numbers available or "Parking Full" can be seen by motorists. Availability of spaces in each slot can also be confirmed by using LED indicators located above them. Gates, controlled by servo motors permit entry whenever there are unoccupied slots.

This installation guarantees efficient parking management via continuous monitoring of slot statuses, driver guiding and enabling smooth entry of vehicles into premises during various periods.

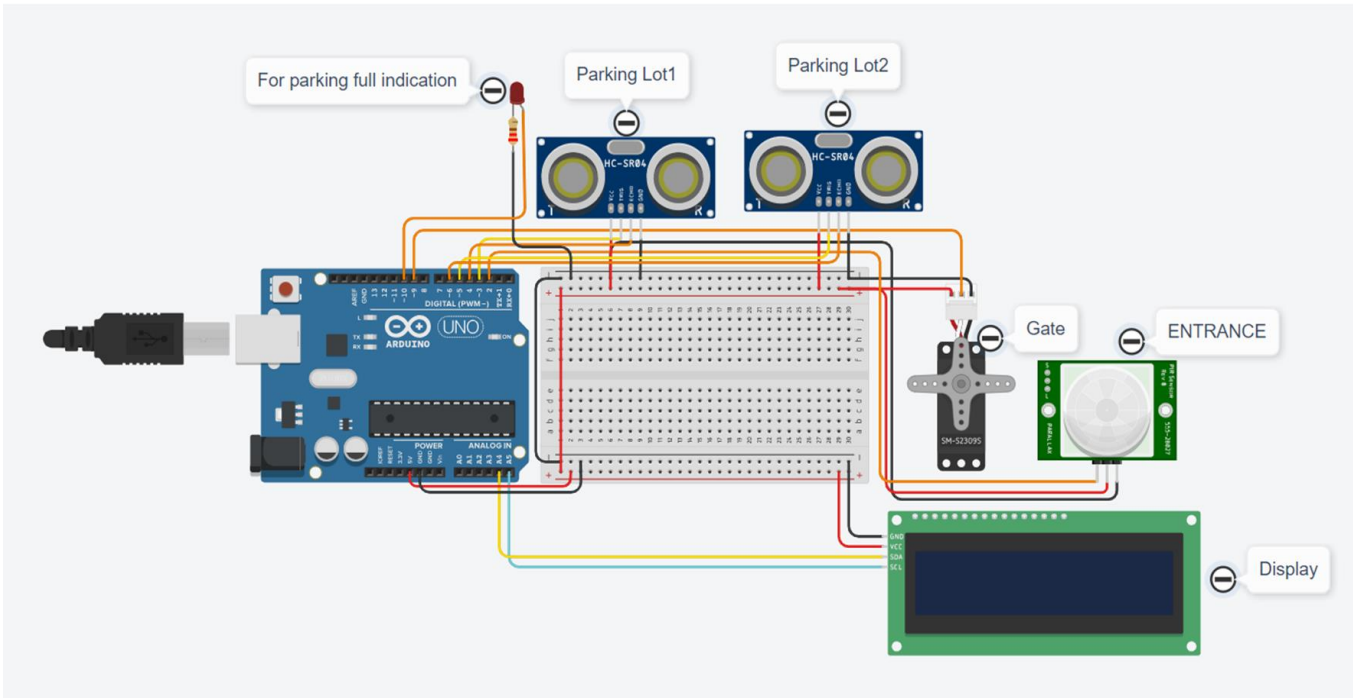

Fig. III Circuit diagram of the system (Tinker cad)

Name	Quantity	Component
U3	1	Arduino Uno R3
SERVO1	1	Micro Servo
PIR1	1	PIR Sensor
DIST1 DIST2	2	Ultrasonic Distance Sensor (4-pin)
U1	1	PCF8574-based, 32 (0x20) LCD 16 x 2 (I2C)
D1	1	Red LED
R1	1	220 Ω Resistor

Fig. IV Component list of the system (Tinker cad)

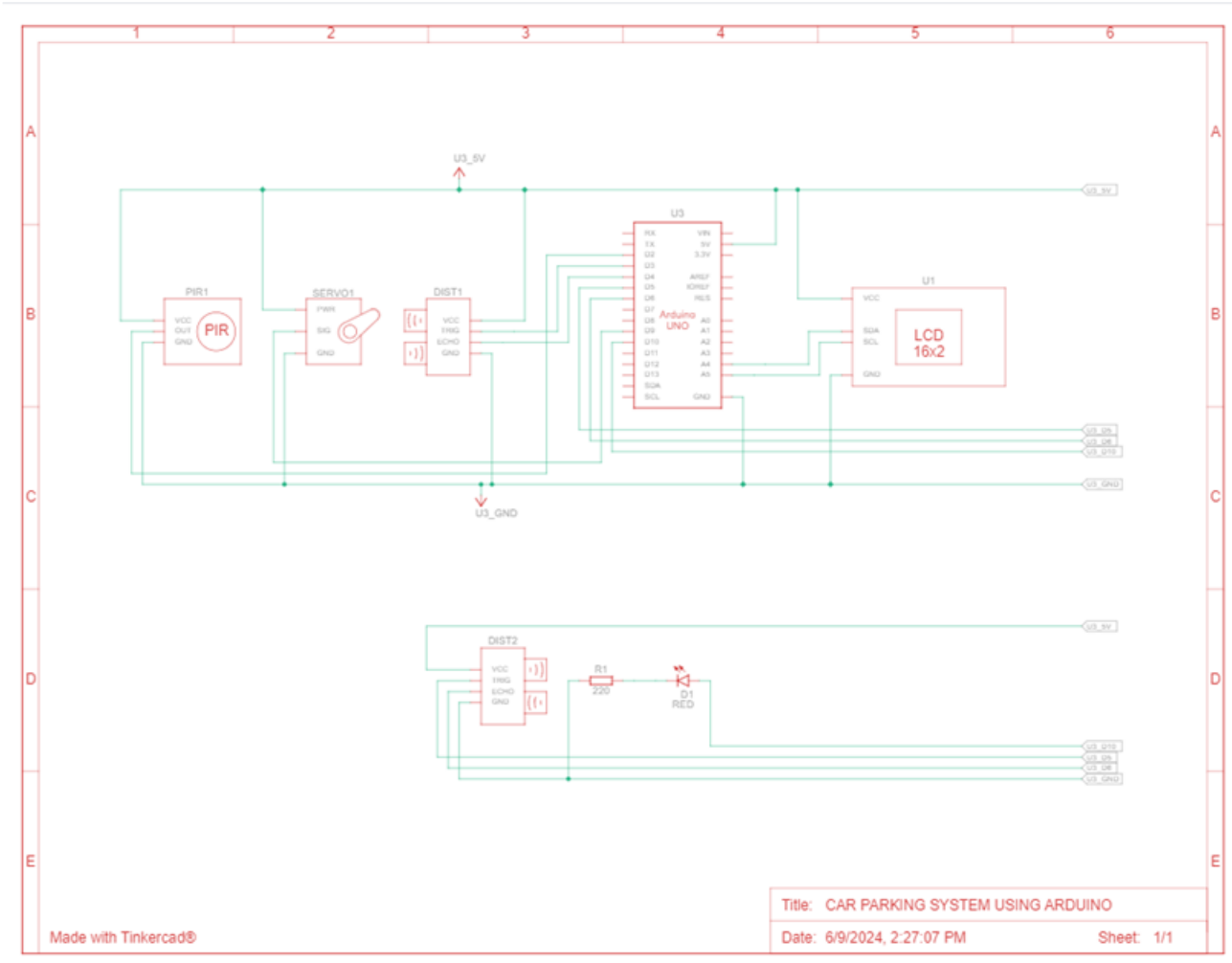

Fig. V Schematic diagram of the system (Tinker cad)

```cpp
#include <Servo.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// Initialize LCD object with 32 as I2C address, 16 columns, and 2 rows
LiquidCrystal_I2C lcd(32, 16, 2);

// Define pin numbers for components
#define PIR_PIN 2
#define TRIGGER_PIN1 3
#define ECHO_PIN1 4
#define TRIGGER_PIN2 5
#define ECHO_PIN2 6
#define LED_PIN1 10
#define SERVO_PIN 9

// Initialize Servo motor object
Servo gateServo;

// Variables to track parking slot occupancy
bool isSlot1Empty = false;
bool isSlot2Empty = false;

void setup() {
  // Set pin modes for components
  pinMode(PIR_PIN, INPUT);
  pinMode(TRIGGER_PIN1, OUTPUT);
  pinMode(ECHO_PIN1, INPUT);
  pinMode(TRIGGER_PIN2, OUTPUT);
  pinMode(ECHO_PIN2, INPUT);
  pinMode(LED_PIN1, OUTPUT);

  // Initialize and configure LCD display
  lcd.begin(16, 2);
  lcd.init();
  lcd.backlight();

  // Attach servo motor to designated pin
  gateServo.attach(SERVO_PIN);
}

void loop() {
  // Check if vehicle is detected by PIR sensor
  if (isVehicleDetected()) {
    // Update slot occupancy status
    isSlot1Empty = !isSlotOccupied(1);
    isSlot2Empty = !isSlotOccupied(2);

    // If either slot is empty, open the gate
    if (isSlot1Empty || isSlot2Empty) {
      // Open gate to 180 degrees
      gateServo.write(180);
      // Turn on LED indicating availability
      digitalWrite(LED_PIN1, HIGH);
      // Display status on LCD
      lcd.clear();
```

```
      lcd.setCursor(0, 0);
      // Display appropriate message based on slot occupancy
      if (isSlot1Empty && isSlot2Empty) {
        lcd.print("Both slots empty.");
      } else if (isSlot1Empty) {
        lcd.print("Slot 1 empty.");
      } else {
        lcd.print("Slot 2 empty.");
      }
      // Delay to display message
      delay(5000);
      // Turn off LED and close gate after delay
      digitalWrite(LED_PIN1, LOW);
      gateServo.write(0);
    } else {
      // If both slots are occupied, display parking full message
      closeGate();
      digitalWrite(LED_PIN1, LOW);
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Parking is occupied.");
      delay(5000);
    }
  }
}

// Function to check if vehicle is detected by PIR sensor
bool isVehicleDetected() {
  return digitalRead(PIR_PIN) == HIGH;
}

// Function to check if parking slot is occupied
bool isSlotOccupied(int slot) {
  // Check distance using ultrasonic sensor to determine occupancy
  if (slot == 1) {
    return getDistance(TRIGGER_PIN1, ECHO_PIN1) < 50;
  } else if (slot == 2) {
    return getDistance(TRIGGER_PIN2, ECHO_PIN2) < 50;
  }
}

// Function to measure distance using ultrasonic sensor
float getDistance(int triggerPin, int echoPin) {
  // Send ultrasonic pulse
  digitalWrite(triggerPin, LOW);
  delayMicroseconds(2);
  digitalWrite(triggerPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(triggerPin, LOW);
  // Measure duration of pulse
  float duration = pulseIn(echoPin, HIGH);
  // Convert duration to distance in centimeters
  float distance = duration * 0.034 / 2;
```

```
  return distance;
}

// Function to close the gate
void closeGate() {
  gateServo.write(0);
}
```

Fig .VI C++ programming code of the system (tinker cad)

a. Logic Diagram

The diagram provided depicts connections in the system using logic functions. The Proposed system depicts logic gates using the standard AND, NOT and OR operation symbols.

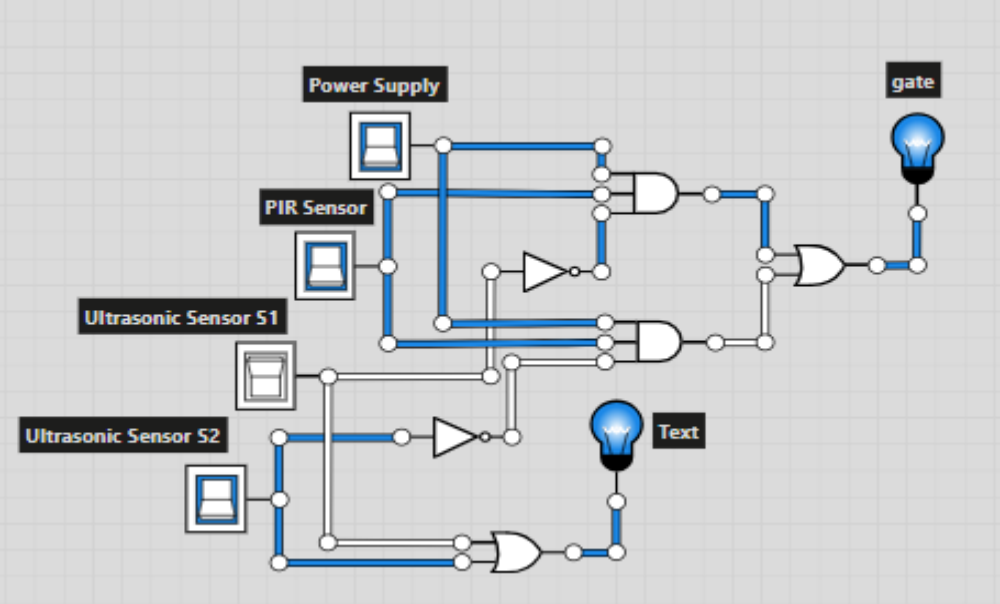

Fig .VII Logic diagram of the system using Logicly

b. Truth Table

The table outlines the output of the proposed system based on input from the Main Switch, ultrasonic sensor S1, ultrasonic sensor S2 and PIR sensor.

Input

1. Main Switch: MS
2. PIR Sensor: PIR
3. Ultrasonic Sensor Slot 1:S1
4. Ultrasonic Sensor Slot 2: S2
5. Output of Gate: G
6. Output of Light: L

MS	PIR	S1	S2	G	L
0	0	0	0	0	0
0	0	0	1	0	1
0	0	1	0	0	1
0	0	1	1	0	1
0	1	0	0	0	0
0	1	0	1	0	1
0	1	1	0	0	1
0	1	1	1	0	1
1	0	0	0	0	0
1	0	0	1	0	1
1	0	1	0	0	1
1	0	1	1	0	1
1	1	0	0	1	0
1	1	0	1	1	1
1	1	1	0	1	1
1	1	1	1	0	1

Boolean expression:

i. Gate

If the gate is to open (G=1) then the main switch must be turned on (MS=1), the PIR sensor must detect a vehicle (PIR=1), and there must be an open parking slot in either section 1 (S1=0) or section 2 (S2=0).The Boolean expression for the gate is as follows:

G=MS*PIR*(S1+S2) = MS*PIR*($\overline{S1}$ +$\overline{S2}$)

ii. Light

If the light is to be illuminated (L=1) then the main switch must be turned on (MS=1), and an open parking slot must be available in either section 1 (S1=0) or section 2 (S2=0). The Boolean expression for the light is as follows:

L=MS*(S1+S2) = MS*($\overline{S1}$ +$\overline{S2}$)

IV. Results

The implementation and trial of the smart parking system based on the IoT demonstrated promising successes. The system efficiently managed parking spaces and provided real-time updates to users. By combining hardware modifications and IoT, the system addressed the driver's pain points by providing reduced traffic congestion and increased experience. Utilizing ultrasonic sensors, micro servo motors, and Arduino Uno, the system was able to find parking availability accurately, while LEDs and LCDs gave clear indications to the driver. Overall, the system is effective at making parking infrastructure more efficient to optimize urban mobility.

V. Discussion

A. *Discussion on smart parking system*

After analyzing the content presented in the sections above, it seems apparent that the proposed smart parking system could be a very efficient, reliable, and highly-useable system because of its minimal maintenance costs and maximum sustainability for the consumer market. Even though the proposed system uses just two sensors, it can cover a wide area in usability, security, and access. However, both the ultrasonic sensors and PIR sensors are vulnerable to environmental constraints. Consequently, the sensors are more compatible in closed parking facilities such as supermarkets and hospitals, as well as to be user interaction with an LCD panel in specific locations to show preferred path and innovative price display. Its attention is also provided in a moderate manner in performance to parking, security, and vehicle guidance. IoT based smart parking system, align with UN Sustainable Development Goals globally which are given below:

- Goal 9: Industry, Innovation, and Infrastructure
- Goal 11: Sustainable Cities and Communities
- Goal 13: Climate Action
- Goal 17: Partnerships for the Goals

B. *Security considerations*

Security considerations are a crucial aspect in the deployment of IoT-based intelligent parking systems, to ensure the safety of the data, infrastructure, and personal information of the user. It must include the use of encryption, authentication, and secure protocols for communication of data between various devices and servers for protection and to avoid any unauthorized access and data leakage. Physical security is important, such as having security cameras and managing the property in a way so that theft and vandalism is limited. In addition to these other security measures are necessary, such as having systems such as firewalls and intrusion detection, which are important to protect against cyber threats like malware or hacking. Education and the knowledge of all users, of the best practices of cyber protection can also improve the security posture of the system.

VI. Conclusion

To sum up, the IoT-based smart parking infrastructure is a significant leap in the realm of parking management, leveraging IoT technologies to enhance parking infrastructure and improve urban mobility. The successful inclusion and real-time monitoring services developed in this project indicate this system's capability. In addressing the issues related to parking availability and traffic congestion indicates the system's effectiveness. But, security and privacy measures are still the most crucial aspect of the system, indicating security measures should be in place for data, and the integrity of the architecture, to secure infrastructure and software. To move further, research and work in this area should be pursued, to facilitate the spread of smart parking infrastructures, and benefit of urban sustainable development and improve quality of life for city dwellers and visitors.

References

Agarwal, Y. *et al.* (2021) 'IOT based Smart Parking System', *2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS)* [Preprint]. doi:10.1109/iciccs51141.2021.9432196.

Allbadi, Y., Shehab, J.N. and Jasim, M.M. (2021) 'The smart parking system using ultrasonic control sensors', *IOP Conference Series: Materials Science and Engineering*, 1076(1), p. 012064. doi:10.1088/1757-899x/1076/1/012064.

Alqazzaz, A. *et al.* (2018) 'SecSPS: A secure and privacy-preserving framework for Smart Parking Systems', *Journal of Information Security*, 09(04), pp. 299–314. doi:10.4236/jis.2018.94020.

Biyik, C. *et al.* (2021) 'Smart Parking Systems: Reviewing the literature, Architecture and Ways Forward', *Smart Cities*, 4(2), pp. 623–642 .doi:10.3390/smartcities4020032.

Fahim, A., Hasan, M. and Chowdhury, M.A. (2021) 'Smart Parking Systems: Comprehensive Review based on various aspects', *Heliyon*, 7(5). doi:10.1016/j.heliyon.2021.e07050.

Kalla, A., Prombage, P. and Liyanage, M. (2019) 'Introduction to IOT', IoT Security, pp. 1-25. doi:10.1002/9781119527978.ch1.

Kharel, D. (2024) Login, Tinkercad. Available at: https://www.tinkercad.com/things/iDHAo11q7DX-car-parking-system-using-arduino/editel?returnTo=%2Fthings%2FiDHAo11q7DX-copy-of-car-parking-system-using-arduino (Accessed: 1 June 2024).

Krishna Chaitanya, V. *et al.* (2021) 'Smart Parking Management System', *IOP Conference Series: Earth and Environmental Science*, 796(1), p. 012014. doi:10.1088/1755-1315/796/1/012014.

Kumar, G.V.N. *et al.* (2021) 'Smart Home Light Intensity Control using potentiometer method for energy conservation', *2021 International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT)* [Preprint]. doi:10.1109/rteict52294.2021.9573521.

Laghari, A.A. *et al.* (2021) 'Retracted article: A review and state of art of internet of things (IOT)', *Archives of Computational Methods in Engineering*, 29(3), pp. 1395–1413 .doi:10.1007/s11831-021-09622-6.

Perković, T. *et al.* (2020) 'Smart parking sensors: State of the art and performance evaluation', *Journal of Cleaner Production*, 262, p. 121181. doi:10.1016/j.jclepro.2020.121181.

Puspitasari, D. *et al.* (2021) 'Development of smart parking system using internet of things concept', *Indonesian Journal of Electrical Engineering and Computer Science*, 24(1), p. 611. doi:10.11591/ijeecs.v24.i1.pp611-620.

Sadhu, P.K., Yanambaka, V.P. and Abdelgawad, A. (2022) 'Internet of things: Security and solutions survey', Sensors, 22(19), p. 7433 .doi:10.3390/s22197433.

Shafique, K. *et al.* (2020) 'Internet of things (IOT) for next-generation smart systems: A review of current challenges, future trends and prospects for emerging 5G-IOT scenarios', *IEEE Access*, 8, pp. 23022–23040. doi:10.1109/access.2020.2970118.

Sulistyawan, V.N. *et al.* (2023) 'Parking tracking system using ultrasonic sensor HC-SR04 and Nodemcu ESP8266 based IOT', *IOP Conference Series: Earth and Environmental Science*, 1203(1), p. 012028. doi:10.1088/17551315/1203/1/012028.

Ullah, A. *et al.* (2023) 'Smart cities: The role of internet of things and machine learning in realizing a data-centric smart environment', *Complex & Intelligent Systems*, 10(1), pp. 1607–1637 .doi:10.1007/s40747-023-01175-4.

Veeramanickam, M.R.M. *et al.* (2022) 'IOT based smart parking model using Arduino Uno with FCFS priority scheduling', *Measurement: Sensors*, 24, p. 100524. doi:10.1016/j.measen.2022.100524.

Venkata Sudhakar, M. et al. (2023) 'Development of Smart Parking Management System', Materials Today: Proceedings, 80, pp. 2794–2798. doi:10.1016/j.matpr.2021.07.040.

Waheed, A. *et al.* (2021) 'Learning automata and reservation based Secure Smart Parking System: Methodology and simulation analysis, *Simulation Modelling Practice and Theory*, 106, p. 102205. doi:10.1016/j.simpat.2020.102205.

Wang, J. *et al.* (2021) 'The evolution of the internet of things (IOT) over the past 20 years', *Computers & Industrial Engineering*, 155, p. 107174. doi:10.1016/j.cie.2021.107174.