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Regulating the Vehicle Speed in Accident Prone Zones Integrated with Effective Parking Management System

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Abstract

Speed levels of road crashes and traffic offenses in restricted areas, such as residential areas, health centers, and schools, require the application of appropriate measures to ensure speed automation. This paper describes the design and development of an automatic speed control device for vehicles utilizing Zigbee technology for control and real-time monitoring. The focal point of the system is a microcontroller and Zigbee communication modules in both directions, from the vehicle to surveillance devices installed within the restricted area. Zigbee network data transmission and reception facilitate efficient monitoring of speed and control. The speed of a vehicle as it enters the restricted area is automatically decreased to the designated limit without any human intervention. Effectiveness in the system is achieved through simulation and actual field testing, which have been proven to be effective, responsive, and reliable in enhancing road safety in high-impact areas. The technology is functional and scalable, providing a robust solution for avoiding speed-related crashes, which are crucial in traffic management systems. Smart parking solutions detect vacant parking spaces in real time using sensors and inform drivers via a virtual screen or mobile app. This reduces wasteful parking search time, is easy to install, and promotes efficient space utilization. It is based on IoT technologies and data processing, ensuring efficient and accurate operation. In this system, time and fuel are saved, and traffic is reduced.

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1. Introduction

Traffic regulation in residential zones such as colonies, schools, and hospitals is tough since drivers must move their cars very slowly due to safety concerns. Speed breakers and roadblocks are erected with signboards, but drivers often ignore them, thereby increasing the chances of accidents and fatalities. Traditional enforcement methods like speed cameras and police patrols react to crimes that have already occurred rather than preventing them. With wireless technologies like Zigbee, there are new opportunities for enhancing road safety by monitoring and managing real-time conditions. The low power utilization, long battery life, and mesh networking feature of Zigbee make it an ideal candidate for implementing an economical and scalable automatic speed control system. By applying Zigbee technology, there are opportunities to have communication modules in vehicles that send and receive messages with roadside transmitters in restricted zones, controlling vehicle speed to reach the recommended limit automatically without driver intervention. This is a documentation of the design and operation of an auto speed control system for restricted areas. The system employs a microcontroller to interface with the Zigbee modules so that real-time transmission of data from the vehicle directly to the restricted area monitoring system takes place. The primary objective is to automatically control incoming vehicles in secured zones, ensuring that to hold their speeds are held within safe limits in an attempt to improve security and avoid accidents.

The rest of this paper has the following outline: Section II consists of a very brief review of literature and technologies already utilized to regulate vehicle and traffic speeds in different regions of the world. Section III defines system architecture, i.e., hardware and software. Section IV discusses simulation and field test results and analyzes the performance of the system. Finally, Section V discusses the application potential of this technology and concludes with research recommendations. The aim of this project is to develop a system that can be utilized appropriately to mark vacant parking bays. The system uses sensors and a controller in marking vacant spaces and issue notifications to people through live streaming. This helps drivers find vacant parking within seconds without wasting search time and causing traffic on the streets. The solution is intended to facilitate parking management and enhance customer convenience. It is economical and scalable for today's parking lots.

2. Related Work

Parking management systems have also caught up faster, most of them being achieved through integrating predictive models, the Internet of Things (IoT), and geographic information systems (GIS). Yingjie [1] developed a university-based parking management system that incorporated predictive analysis and decision support to reduce the shortage of space and wasteful parking on campuses. Based on this, Neupane et al. [2] developed SHINE as an accessible parking management system for individuals with disabilities grounded in deep learning, which integrated AI and real-time feedback for optimizing distribution. Our own design focuses on accessibility as well as fairness in urban planning.

The coordination between parking infrastructure and safety on roads has also come into question. Alkhatni et al. [3] applied spatial analysis to detect the effect of parking services on the incidence of accidents on restricted-access roads and highlighted the importance of planning in the construction of infrastructure. Unsal [4] proposed a GIS-based evaluation tool to estimate the impact of unauthorized parking on urban street capacity and identify bottlenecks and inefficiencies due to inadequate enforcement of parking policy. Subsequently, Katanalp et al. [5] applied a GIS-based multicriteria decision-support system to identify pedestrian-vehicle accident hotspots at a geospatial level and proposed an integrated model addressing parking layout, safety, and metropolitan mobility [6].

Leading the automation drive, Medina et al. [7] provided a clear explanation of autonomous car parking systems, covering existing methods, engineering issues, and pathways to automated vehicle steering and decision-making in real time. Fahim et al.'s [8] survey is similar, classifying smart parking systems into architecture, sensor technology, and application areas while providing a sound baseline by which system developers can be judged. Alam et al. [9] have also submitted a companion paper presenting an overview of IoT-based smart parking systems, addressing issues such as data privacy, scalability, and interoperability, as well as a future research agenda.

Lastly, emergency responsiveness is also being attributed to intelligent parking and traffic systems. Peelam et al. [10] assessed emergency vehicle management procedures and identified how intelligent parking infrastructure can be utilized to enable quicker routing and improved coordination while responding to emergencies particularly in urban areas with high population density.

3. Proposed Work

The block diagram for the car parking system is given below.

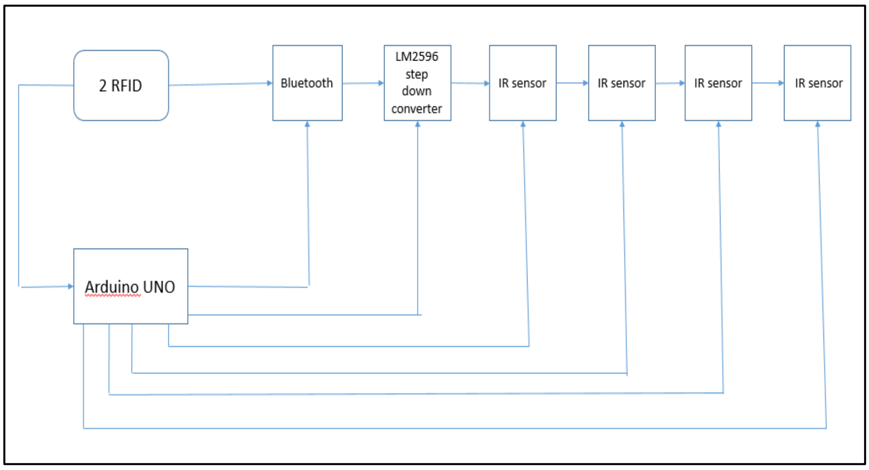

Figure 1. Block Diagram for Car Parking System

The block diagrams for the transmitter and receiver parts in the car speed reducing system are shown in Fig. 2 and Fig. 3.

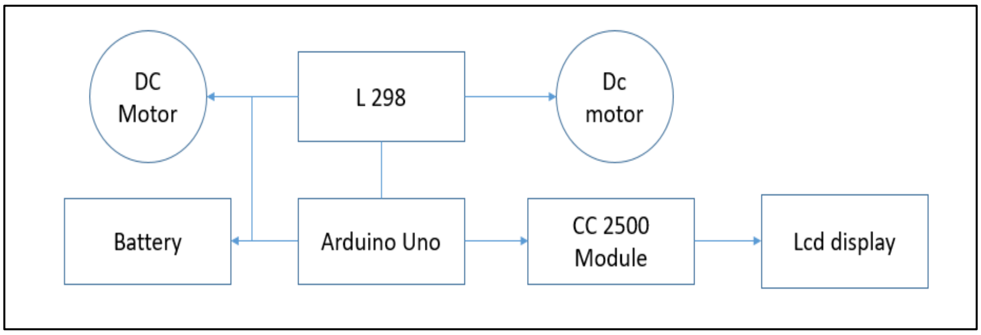

Figure 2. Car Speed Reducing system (Receiver)

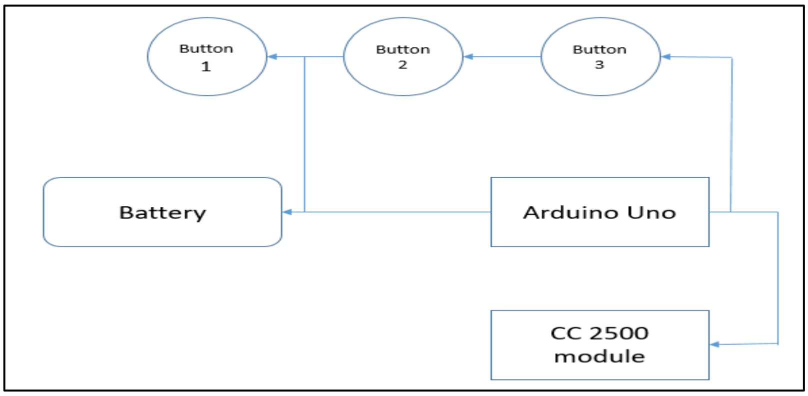

Figure 3. Car Speed Reducing System (Transmitter)

Fig 4 explains the work flow of the car parking system.

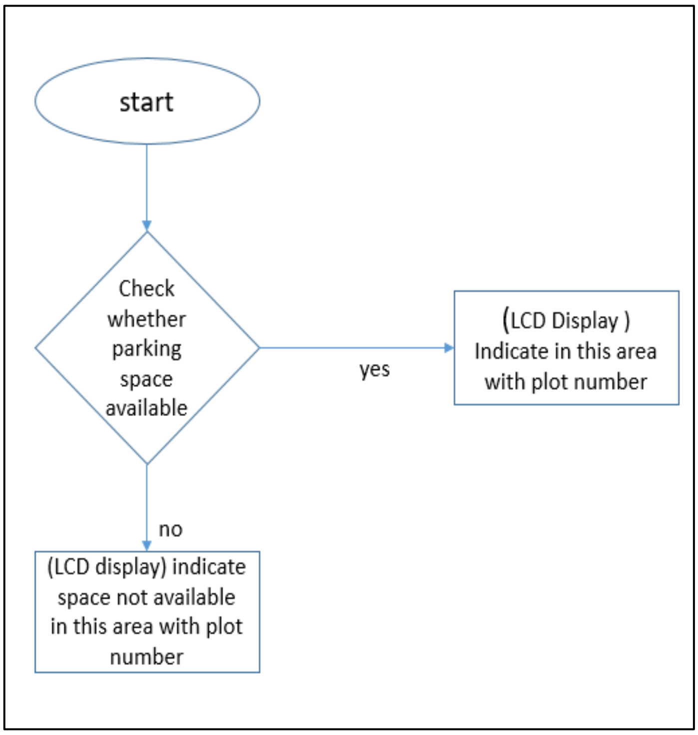

Figure 4. Flow Chart of Car Parking System

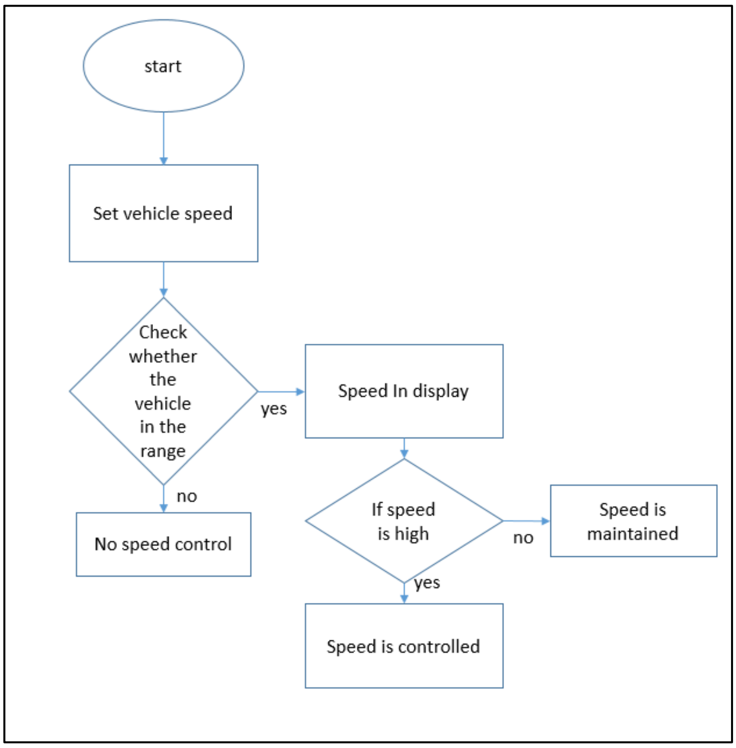

Figure 5. Flow Chart of Vehicle Speed Control System

Fig 5 explains the flowing content:

- When the system is activated, the transmitter receives the analog signal through the CC2500 module frequency ranges.
- The vehicle's speed is adjusted using an increment switch.
- If the vehicle is outside the CC2500 module range, it operates based on the driver's input, and speed control is not applied.
- When the vehicle enters the CC2500 module range, its speed is displayed.
- If the speed exceeds the preset threshold, the system will control the speed.
- If the speed does not exceed the threshold, the vehicle operates normally without speed control.

The circuit diagram of the system is portrayed through circuito.io. Circuito.io is an online platform used to simplify designing and developing electronic projects. It provides a simplified interface for the design, simulation, and development of projects in minutes for practicing engineers and students. Circuito.io simplifies the development of circuit diagrams, coding, and the setting of the components required for the project. The software can accommodate more than one microcontroller and sensors, allowing the user to develop multiple applications like IoT, automation, robotics, etc. Fig 6 is a circuit diagram designed with the above software.

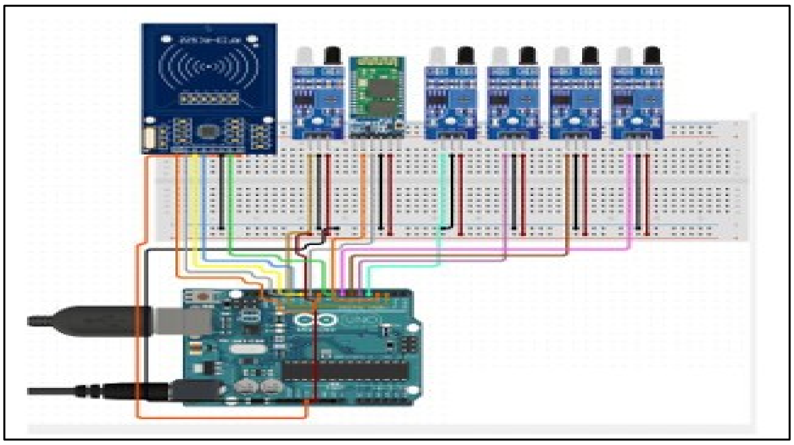

Figure 6. Circuit Design for the Car Parking System

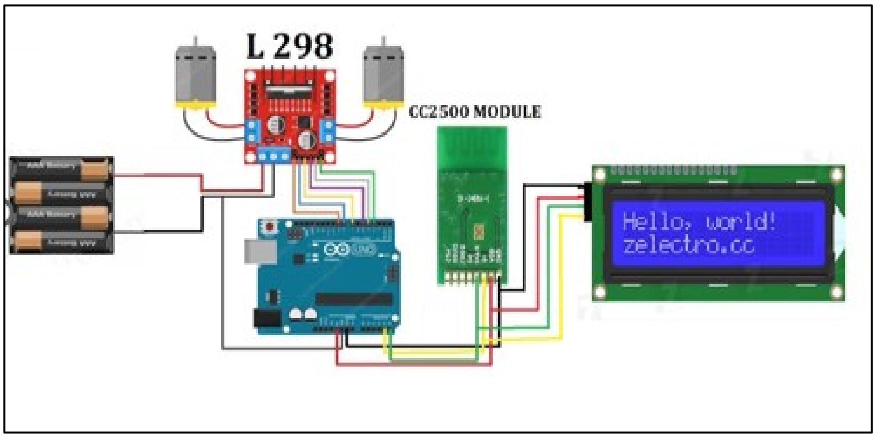

Figure 7. Circuit Design for RF Receiver

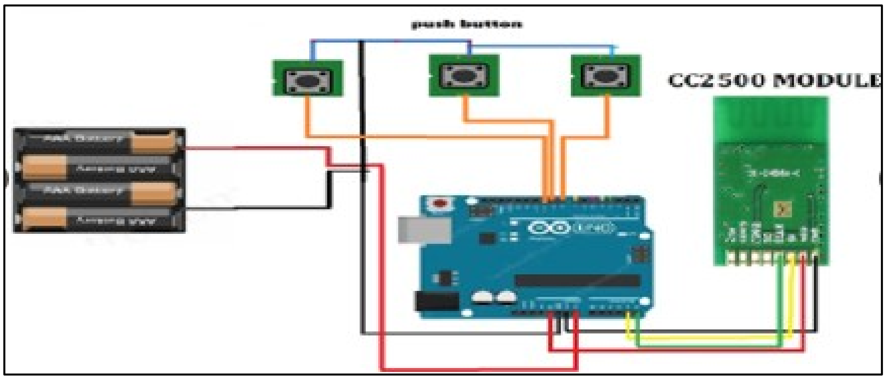

Figure 8. Circuit Design for RF Transmitter

Fig 7 and Fig 8 show that the transmitter employs a CC2500 module, which is operated froma 9V supply. The RF receiver of the car system is the 4-pin CC2500 module. The CC2500 module sends a message to the Arduino UNO and LCD whenever any car enters a certain zone.

The Arduino UNO demodulates the CC2500 module's signal. It determines if the vehicle is over speeding within the zone. If the vehicle is overspeeding, the Arduino UNO sends a message to the L298 motor driver and also to the LCD to notify and rectify the error. During normal driving where the vehicle is not overspeeding, no message is sent to the L298, and the vehicle maintains the same speed.

As the L298 motor driver receives the input from the Arduino UNO, it slows down the motor by decreasing its voltage. The speed of the vehicle is decreased stepwise to the extent that it reaches the speed limit assigned to the zone. This persists as long as the signal is being received by the CC2500 module, and the Arduino UNO continues to maintain the speed above the permissible limit.

4. Results and Discussion

The Zigbee automatic vehicle speed control system, as proposed, was simulated and tested on roads. Test results were conducted to ensure that the system effectively slowed down approaching vehicles at the restraint points, maintaining their speed within specified levels. Zigbee modules and the microcontroller worked together to provide real-time interaction between roadside transmitters and vehicles. Generally, the result is that the proposed system can meaningfully contribute to improving road safety within controlled areas by ensuring automatic compliance with speed regulations. The technology offers an affordable yet reliable traffic management method in susceptible areas, reducing the accident rate and guaranteeing the safety of pedestrians and other modes of transport. The project successfully identifies parking spaces through sensors and an in-built system, enhancing the effectiveness of parking. The signal of available spaces is correctly communicated in real-time through sending. Installation of the system saves search time for parking, reduces traffic, and is user-friendly. Its performance boasts high detection accuracy under variable conditions. Compatibility with a user interface for a mobile app is one potential area for future research.

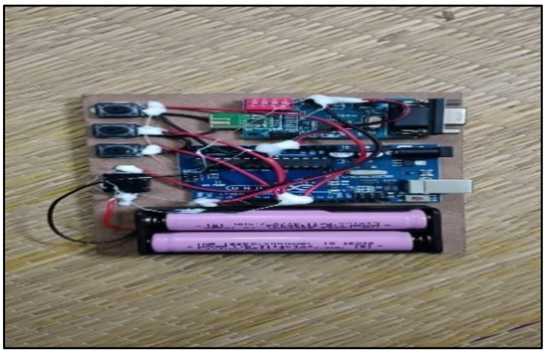

Figure 9. Working Model - RF Transmitter

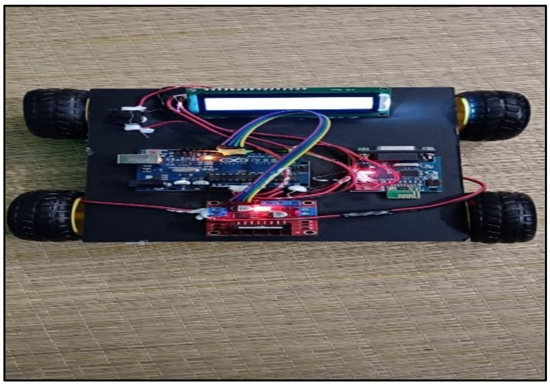

Figure 10. Working Model - Top View for the Vehicle Speed Control System

Figure 11. Working Model – Demo of Vehicle Speed Control System in a Hospital Zone

Figure 12. Working Model – Demo of Vehicle Speed Control System in Police Zone

Figure 13. Working Model – Demo of Vehicle Speed Control System in a School Zone

Table 2. Variation of Speed in Different Area

No	Zone Area	Working % Of Dc Motor	The Rpm of the DC Motor
1	without any zone	0%	150 rpm
2	police zone	60%	60 rpm

3	hospital zone	70%	45 rpm
4	school zone	80%	30 rpm

Fig 14 illustrates whole module operation to find free space for car parking. A car with RFID transmitter (RFID RC522) drives up to the parking space gate where there is an RFID receiver (RFID RC522). The parking gate is automatically opened when it detects the signal from the transmitter and the car is driven in.

The booking of the parking space is conveyed upon arrival through a smartphone app, where data is transmitted through the HC-05 Bluetooth module. The app is set to inquire about the availability of the parking space from an IR sensor and alert drivers real-time when there are empty spaces.

When a vehicle comes to rest in a stopping place where stopping is not allowed, an alarm sound is triggered to alert the driver and others nearby, encouraging compliance with parking regulations. This system achieves maximum compliance with parking space usage and efficiency.

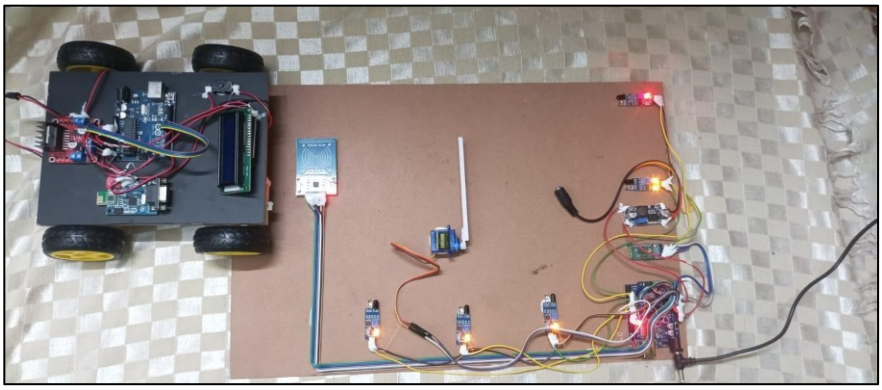

Figure 14. Complete Working Model for Car Parking System

Fig 15 explains the output taken through the Serial Bluetooth Terminal App. The system monitors the status of five car parking spaces, labeled as S1, S2, S3, S4, and S5. Each parking space has an indicator to show its availability. If a car occupies the first parking space, the system displays that S1 is filled. Conversely, if the first parking space is vacant, it indicates that S1 is empty. This approach is consistent for all five parking spaces, providing real-time information on the availability of each spot.

Figure 15. Output for the Space Available in Parking System

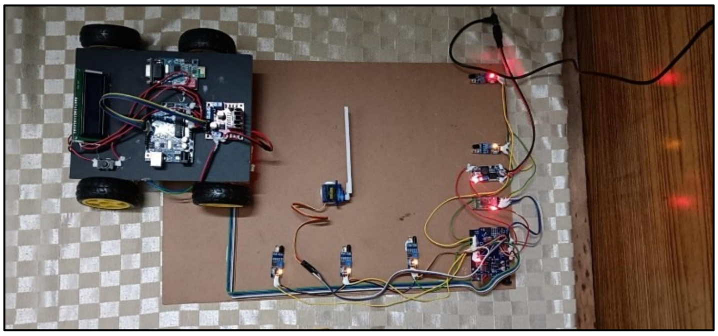

Figure 16. Working Model- Indication of Empty Space Available in Parking Area Through LED

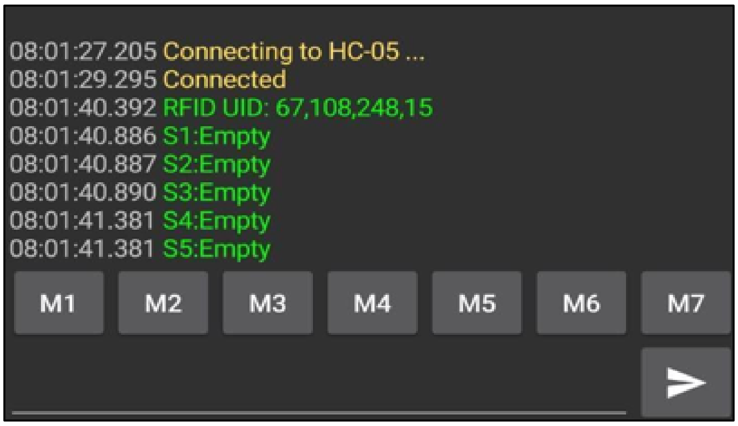

Figure 17. Output Through Mobile App for Empty Space Available in Parking Area

In Figures 16 and 17, the empty space available in the parking area is indicated, and no cars have been parked in the plot.

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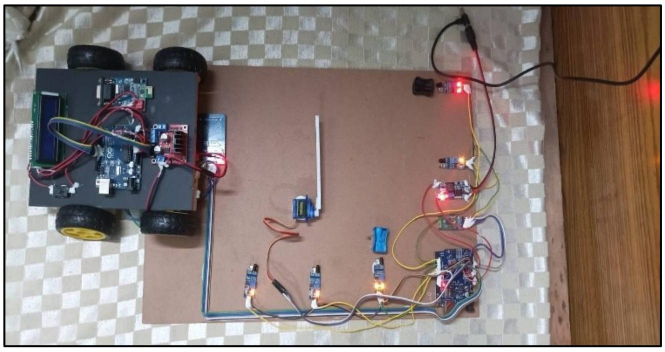

Figure 18. Car Parking Space Analysis in S3 and S5

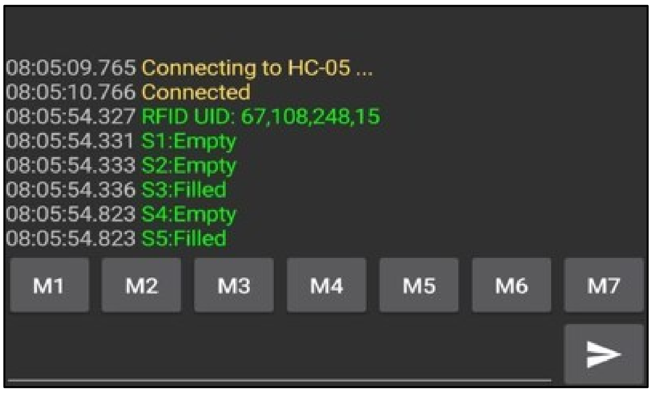

Figure 19. Car Parking Space Availability in S3 and S5

Figures 18 and 19 denote the indication of space available in the parking area, and the car has been parked in two places named S3 and S4. All data will be shown in the app in real-time.

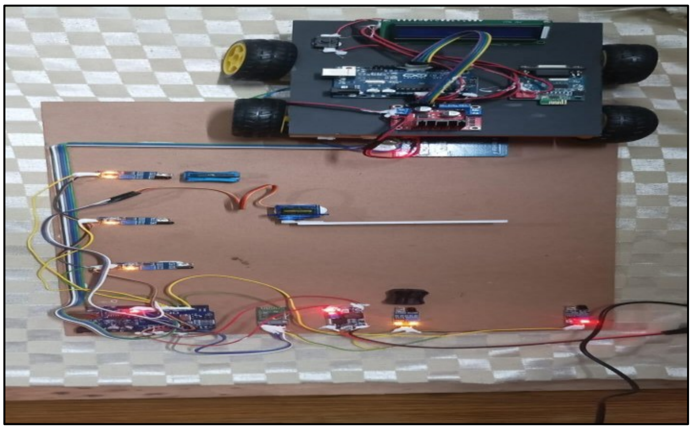

Figure 20. Car Parking Space Analysis in S1 and S4

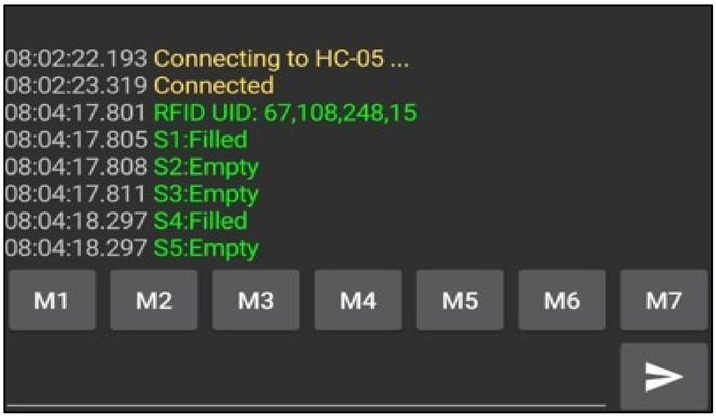

Figure 21. Car Parking Space Availability in S1 and S4

Figures 20 and 21 denote the indication of space available in a parking area, and the cars have been parked in the two places named S1 and S4. All data will be shown in the app in real-time.

5. Conclusion

Applying Zigbee-based communication for automatic speed control in restricted zones is an effective and scalable solution for enhancing traffic safety. Without anticipating drivers' behavior, the system compels compliance by automatically slowing down upon entering sensitive zones, including hospitals or schools. The effectiveness, responsiveness, and reliability of the system in preventing slow-speed violations are confirmed through field trials and simulations. Besides, the use of an intelligent car parking system utilizing real-time analysis and the Internet of Things simplifies city parking, reduces fuel use, and alleviates traffic jams. Cumulatively, all these technologies signify a dramatic improvement in intelligent, safe, and efficient city traffic management.

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