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Design and Implementation of an Intelligent Safety and Security System for Vehicles Based on GSM Communication and IoT Network for Real-Time Tracking

Hamzah M. Marhoon [1*], Ali Ihsan Alanssari [2], Noorulden Basil [3]
[1, 2] Department of Systems Engineering, College of Information Engineering, Al-Nahrain University, Jadriya, Bagdad, Iraq
[3] Department of Electrical Engineering, College of Engineering, Mustansiriyah University, Baghdad, Iraq
Email: [1] hamzah.marhoon@nahrainuniv.edu.iq, [2] ali.ihsan.aaa@nahrainuniv.edu.iq,[3] noorulden@uomustansiriyah.edu.iq
*Corresponding Author

Abstract—**In recent years, the surge in car theft cases, often linked to illicit activities, has become a growing concern. Simultaneously, countries grappling with oil shortages have shifted towards converting vehicles to run on liquid propane gas, presenting new safety challenges for car owners. This paper introduces a novel integrated intelligent system designed to address the challenges of car theft and safety concerns associated with gas-based vehicles. By seamlessly integrating these concerns into a single system, it aims to achieve significantly improved performance compared to traditional alarm systems. The proposed system consists of three primary parts: the car security subsystem, an Internet of Things (IoT)-based real-time car tracking subsystem, and the car safety subsystem. Utilizing key technologies such as the Arduino Microcontroller, Bluetooth module, vibration sensor, keypad, solenoid lock, GSM module, NodeMCU microcontroller, GPS module, MQ-4 gas sensor, flame sensor, temperature sensor, and Bluetooth module, the system aims to provide a comprehensive solution for the mentioned issues. Furthermore, the vibration sensor plays a crucial role in identifying unauthorized vehicle operations. Its significance lies in detecting the vibrations emanating from the running engine. Concurrently, other modules and sensors are utilized for real-time tracking and enhancing vehicle safety. These measures include safeguarding against incidents like fire outbreaks or gas leaks within the gas container. Finally, the system was compiled and practically tested, with results that worked well. This work provides some basic steps to enhance vehicle safety and security, as well as to prevent theft and overcome safety concerns related to gas leaks**

Keywords—Car Security; Car Theft; Arduino; NodeMCU; GSM; IoT.

I. INTRODUCTION

In recent years, there has been a particularly high rate of auto theft, causing significant distress to individuals and communities [1]. This rise in auto theft can be attributed to several factors, including improved theft techniques and an increase in black-market car theft [2]. At the same time, oil prices and the largest in the world, for primary fuel vehicles. Due to this scarcity of oil, many people are considering switching to alternative energy sources such as gas-powered cars or electric vehicles to reduce their dependence on fossil fuels, this dual challenge coupled with rising vehicle thefts and the critical need to address oil scarcity ensures the safety and sustainability of our available transportation systems, it highlights the critical need for innovative solutions in the industry.

A. Car Theft and its Evolution

Today, the community is grappling with the problem of car theft, resulting in the development of theft tactics and countermeasures alliances [4]. This historical pattern can be linked to the rise in popularity of automobiles in the early 20th century. Primarily, car thieves mainly utilised simple methods such as hot wires (i.e., shorting the switches) or physical entry (i.e., breaking the class) [6]. However, crime techniques have also evolved as vehicle technology has adapted to new developed security systems [7].

Following that, in the mid-20th century, the car fixed keys and ignition systems became standard [8]. So that in response to this growing threat, the cars manufacturers introduced new products such as car alarming systems and restrictions came into place in order to prevent theft and unauthorised entry into the car. The beginning of the electronic keystrokes and the smart keys marked a new era, creating electronic security challenges [9]. Criminals utilise technology to intercept signals, prompting the auto industry to support the improved in the electronic security measures [10].

Today the recent trends comprise the developed attacks, which influence on the vital signals in the car engine, and hack brains of the modern cars [11]. Collaborative efforts among law enforcement, automakers, and technology companies have led to the development of countermeasures such as advanced encryption, two-factor authentication, and enhanced cybersecurity measures which were intended to reduce theft cases [12]. The history of the car theft serves as a testament to an ongoing battle between the criminal ingenuity and the security innovations, underscoring the importance of constant vigilance and pre-emptive actions to ensure the safety for the vehicles [13].

B. LPG-Powered Vehicles and their Security /Safety Needs

In parallel with the persistent challenge of car theft, many countries worldwide are grappling with shortages of traditional petroleum-based fuels, impacting various facets of daily life [14]. As a result, alternative solutions like electric vehicles [15] and vehicles powered by Liquid Propane Gas (LPG) [16] have gained traction. The adoption of LPG as a source of automotive fuel offers many economic and environmental benefits. Vehicles powered by fuel LPG, commonly referred to as gas-powered vehicles, benefit from lower fuel costs compared to conventional fuels, making them an option enjoyment in economy for economy-minded drivers Besides burning LPG, there are fewer harmful emissions, resulting in cleaner air, carbon and reduced footprint [17], [18].

However, the retrofitting of older fuel cell vehicles to be refueled with LPG raises concerns, especially related to theft due to the complete lack of safety technologies in these modifications [19]. safety and intelligent security systems to be developed for LPG-powered vehicles to address such issues [20]. A system comprising the Internet of Things (IoT) connectivity and the real-time analytics together can ensure that these cars are not only friendly with the environment but also have immunity against the theft and are safe against accidents, also it adds extra safety to the advantages of LPG-based transport [21], [22].

IoT refers to physical devices, vehicles, actuators, and other connected objects that are equipped with sensors, software, and communication capabilities that enable data collection as well as exchange. The IoT enables these devices to communicate and interact with each other usually without the need for the direct human efforts. IoT architecture involves the integration of hardware components, software approaches, and communication systems [24], [25]. Sensors and actuators in IoT networks are responsible on the collection of data from the environment, which are then transmitted by the means of the networks to the IoT cloud for analysis and decision-making [26], as shown in Figure 1.

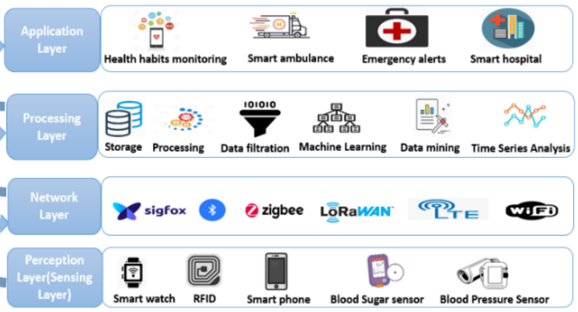


Fig. 1. General Fundamental Structure of an IoT System

IoT has brought about a fundamental change in how security systems are implemented in the cars or other systems. By integrating IoT technologies, security systems can achieve advanced applications such as real-time analytics, predictive analytics, and artificial intelligence [27]. The automotive industry is a popular example, where safety and security systems associated with IoT can enable real-time vehicle surveillance and remotely monitored conditions This data can be analysed to identify any unusual behaviours or patterns that may indicate theft or not were not involved [28]. Additionally, in extreme cases, IoT-integrated security systems can initiate automatic responses such as locking doors, shutting down engines, or alerts for the police centres [29], [30].

The next section of the paper provides a detailed methodology of the suggested system, particularly for three important areas: car safety, LPG-based car safety, and car tracking in real-time through IoT technology

II. PROPOSED METHODOLOGY

In this paper, an intelligent safety and security system is suggested to be designed and implemented, particularly for LPG-based cars. The proposed system consists of three major components (i.e., parts) which can be summarized as follows:

- The first part of the system is the car security subsystem, where the car owner is required to input a unique password via the keypad and another password through a dedicated Android app. Once both passwords are entered correctly, the car can be operated as usual. In the event that the keypad password is entered incorrectly more than three times, or if the car is attempted to be operated without entering the passwords, a vibration sensor detects any variations in movement and illegal operation for the engine. Consequently, the alarm system activates, the doors are automatically locked using a solenoid lock, and an alarming message is transmitted to the car owner via both the Bluetooth module and GSM technology.
- The second part of the system involves the car tracking subsystem, which leverages IoT technology. This aspect utilizes a programmed Android app along with the NodeMCU microcontroller and Global Positioning System (GPS) for precise vehicle tracking.
- The third part of the system is the car's safety subsystem, which monitors for LPG leaks, fires, and temperature increases at the gas container, which is typically positioned in the trunk. Fig. 2 was made to provide a quick and easy-to-understand visual aid for the proposed work.

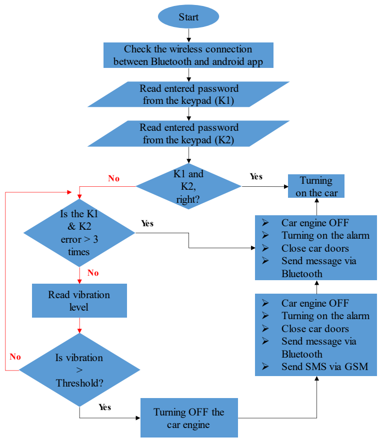


Fig. 2. Graphical flowchart for the suggested system

III. HARDWARE COMPONENTS

In this section, we provide an extensive summary of the hardware elements that are employed to design the system, which encompass the Arduino Microcontroller, Bluetooth module, vibration sensor, GSM module, NodeMCU microcontroller, and GPS module.

A. Arduino Microcontroller

The Arduino UNO microcontroller board is an inexpensive hardware platform centred on the basis of the ATmega328P microprocessor [31]. The device provides a total of 14 digital input/output pins, out of which 6 are capable of pulse-width modulation. Additionally, it offers 6 analogue input channels [32]. The board is outfitted with a 16MHz ceramic resonator oscillator, a USB connection for programming and communication, a power jack for the purpose of the external feeding, In-Circuit Serial Programming pins for further programming, and a reset button [33], as exhibited in Fig. 3.

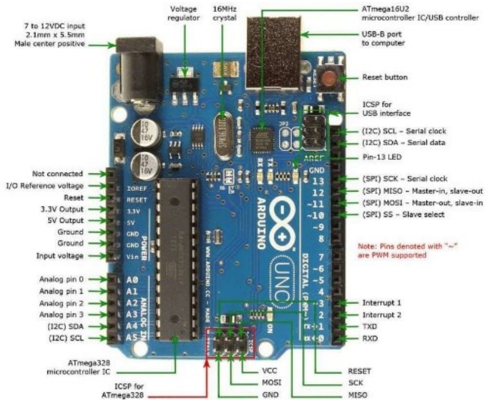


Fig. 3. Arduino microcontroller kit

B. Bluetooth Module

The HC-05 module is a notable small module that provides the functionality to facilitate full-duplex for indoor or short-range wireless communications across a number of hand-held applications [34]. This module is very valuable for facilitating connection between two processing devices, such as Arduino microcontrollers or any microcontroller that is capable of supporting Bluetooth connectivity [35]. The module enables the communication between microcontroller kits via a USART interface, with a typical baud rate of up to 9600 [36]. The utilise of this module also simplifies the process of configuring interfaces that are compatible with microcontroller kits and with USART support [37].

C. Vibration Sensor

The sensor is designed to monitoring and measuring the levels of the vibration in a variety of the applications. The vibration sensor module has a built-in SW-420 sensor and a small potentiometer, which provides a change in sensitivity [38]. Furthermore, the module utilises a small LED that acts as a power indicator and visually represents the status of the digital output value. The module has a simple 3-pins that are VCC, GND, Do (digital output) or Ao (analogue output).

D. MQ-04 Gas Sensor

The MQ 04 gas sensor is a small device designed to detect the presence of gases in our environment [40]. It works by utilising aerodynamics as a principle in order to accurately detect gas groups such as LPG, natural gas and methane [41]. The compact and adjustable sensors play an important role in safety supply and environmental monitoring in a variety of applications, including gas leak detection, industrial safety, and air quality. The MQ-04 gas sensor includes three main pins two of which for the power feeding and the left pin is for the analogue output [42].

E. GSM Module

One of the considerably employed GSM shields in the field of the embedded systems is the SIM900. This shield makes the Arduino or other microcontrollers able to establish connections with the available cell phones using the GSM/GPRS interface [43]. With this shield, the Arduino microcontroller can initiate actions such as dialling phone numbers (making voice calls) or transmitting text messages utilising straightforward AT commands [44].

F. NodeMCU

An open-source module, the NodeMCU microcontroller kit is mostly used to create IoT applications [45]. This kit includes firmware that is specifically made to work with Espressif Systems' ESP8266 Wi-Fi SoC, which is embedded as a built-in chip [46]. The ESP-12 kit provides the foundation for the hardware design. NodeMCU is able to read analogue and digital signals from the outside world, much like Arduino microcontroller kits can [47].

G. GPS Module

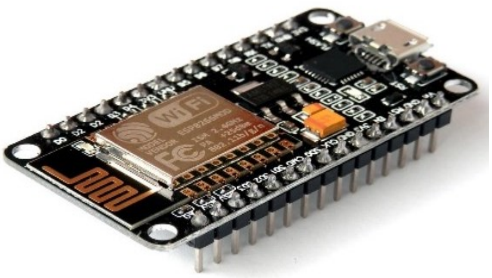
GPS, which stands for the Global Positioning System, is an international satellite-based navigation system used to provide information about position, velocity, and time synchronization [48]. GPS systems can be integrated into cars, smartphones, and even watches. The satellite system comprises 24 satellites distributed across 6 Earth-centred orbital planes, with each plane hosting 4 satellites [49]. These satellites orbit at an altitude of 13,000 miles (20,000 kilometres) above Earth and travel at a speed of 8,700 miles per hour (14,000 kilometres per hour) [50], [51]. To visually depict the hardware components utilized in building the proposed work, Fig. 4 is introduced.

(a) HC-05 Bluetooth

(b) SW-420 vibration sensor

(c) MQ-O4 gas sensor

(d) SIM900 GSM



(e) NodeMCU Microcontroller

(f) NEO-6M GPS

Fig. 4. Utilised hardware components

IV. Software Requirements

This work relies primarily on two essential software applications: BlueTerm, which facilitates Bluetooth communication between a smart mobile phone and the HC-05 module, and the Arduino IDE, which is used for compiling code onto the Arduino board. Below, is a brief definition of each software:

- BlueTerm is a versatile Bluetooth application tailored for Arduino users. This user-friendly app simplifies the process of establishing Bluetooth communication between Arduino devices and smartphones or tablets. With its intuitive interface, BlueTerm enables users to effortlessly send and receive data, making as a proper tool for various Arduino-based projects like tinkering with robotics, home automation, or IoT applications, BlueTerm streamlines the connection process, enhancing the overall Arduino experience for the short-range indoor communications [52].

- The Arduino IDE is a software platform designed with the specific purpose of simplifying programming and code-uploading procedures for Arduino microcontrollers. The platform is distinguished by its user-friendly interface, designed to optimise usability for individuals engaging with the system. The software provides a user-friendly and inclusive interface, catering to users with varying skill levels. This makes it a suitable tool for a wide range of industrial applications. The Arduino IDE supports the development of interactive devices and graphics by providing several pre-existing codes and complete documentation. The open nature of the platform creates vibrant individuals who are actively involved in generating and developing ideas. This dynamic environment creates a diverse ecosystem that encourages creative exploration and effective problem-solving in electronics [53].

V. System Implementation

This section includes a number of subsections that examine the steps required to develop and implement the proposed system. Additionally, results obtained after the completion of practical tests are presented.

VI. Design of Car Security Subsystem

This section presents the design and implementation of our proposed system for the vehicle security subsystem designed to protect vehicles from theft. This proposed part is based on two Arduino UNO microcontroller boards, a 4 × 4 keyboard, a vibration sensor, a specially designed Bluetooth module with a corresponding Android app, and finally a GSM shield. All sensors and modules have been connected to an individual Arduino board and the GSM is connected to another board. It should be noted that the GSM module consumes a lot of power and requires a constant current to ensure proper operation. If the current supplied by an Arduino drops even slightly, it can cause communication to be cut off from its base station tower. Moreover, the performance of GSM shield is affected by external factors such as ambient temperature and heat generated due to low voltage These factors can contribute to transmission latency, as depicted in Fig. 5. To address these power-related challenges, a solution has been implemented. The GSM module and the vibration sensor are connected to a separate Arduino UNO kit. This modification significantly enhances the overall system reliability and eliminates the system's dependency on a single point of failure. In the event that one of the microcontrollers becomes defective, the remainder of the system continues to operate seamlessly. This modification effectively addresses the challenges posed by power fluctuations and external environmental factors.

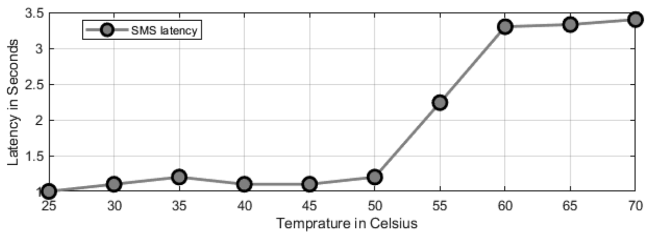


Fig. 5. Temperature effect on GSM performance

When the car engine is illicitly activated, it produces vibrations that are promptly detected by the vibration sensor. Following this detection, the Arduino UNO sends instructions to the GSM shield, which subsequently dispatches a warning SMS to the car owner's phone through the GSM module.

This alert notifies the owner that an unauthorized attempt to start the car has taken place. Concurrently, the Arduino UNO connected to the GSM module sends a logical signal

"1" to the first Arduino UNO kit. This signal triggers a sequence of actions, which encompass turning off the car engine, transmitting a message through Bluetooth to the BlueTerm app, activating the car alarm, and enhancing security by engaging the solenoid lock to immobilize the thief within the vehicle.

For regular car operation, the car owner needs to enter two distinct passwords: the first one through the 4×4 keypad and the second via the Android app. The car can only be operated when both passwords are correctly entered. However, if the keypad password is entered incorrectly more than three times or if an unauthorized individual tries to operate the car without the correct password, a warning message is transmitted to the BlueTerm app. This prompts a repetition of the previous security procedure.

This procedure proves highly effective in safeguarding cars against various modern theft techniques. It establishes two levels of security: the initial level involves entering the password using the keypad, while the second level requires inputting an additional password through the Android app. This dual-layered security ensures that only the car owner can operate the vehicle. Fig. 6 to Fig. 8, respectively, illustrate the block diagram and the implemented car security subsystem.

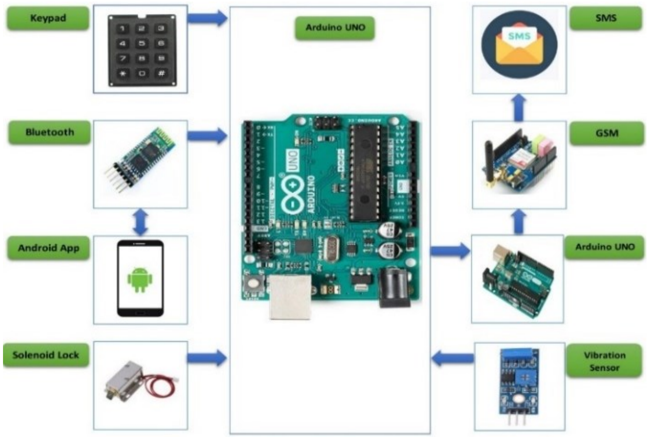


Fig. 6. Block diagram of the car security subsystem

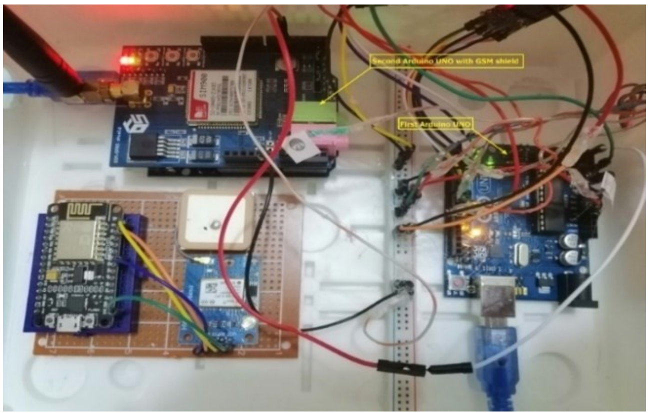


Fig. 7. Internal view for the implemented subsystem

Fig. 8. External view for the implemented subsystem

VII. Real-Time Car Tracking Subsystem

This subsection outlines the essential procedure for designing and manufacturing the IoT-based real-time subsystem that is introduced for the purpose of the car tracking subsystem by using the NodeMCU microcontroller, the NEO-6M GPS module, and finally, the Blynk platform with its compatible App.

A. Blynk Platform

The Blynk platform is specifically designed for IoT applications. Through this platform, users can create various apps for wireless control of appliances, display data from different sensors, store data, and visualize it. The Blynk platform is comprises of three fundamental components:

- **Apps:** This component allows the clients or the users to design diverse interfaces tailored to their project needs by utilizing a variety of widgets offered by the means of the platform.
- **Server:** This component is responsible for facilitating all communications between the user's smartphone and the hardware devices. Users have the option to utilize the Blynk cloud, an open-source solution that can seamlessly manage numerous appliances. Additionally, the Blynk server can even be deployed on the Raspberry Pi board for further flexibility.
- **Libraries:** This component comprises a collection of commands and software that empower users to effectively utilize the scheme on a range of different boards.

B. System Design

This part of the suggested system focuses mostly on car tracking. This subsystem makes use of the NodeMCU microcontroller, which supports IoT technologies. Real-time tracking is provided by the GPS module. As shown in Fig. 9, a customised Android app that enables Google Maps-based car position tracking was also developed using the Blynk platform. The application shows the vehicle's speed, direction, longitude, and latitude at the location where it stops using information from the GPS module. The application additionally employs a Google map to display the car's precise location in real-time. Fig. 10 and Fig. 11 illustrate, respectively, the block diagram for the real-time car tracking subsystem and the implemented circuit for the recommended subsystem.

Fig. 9. Programmed app for the real-time car tracking

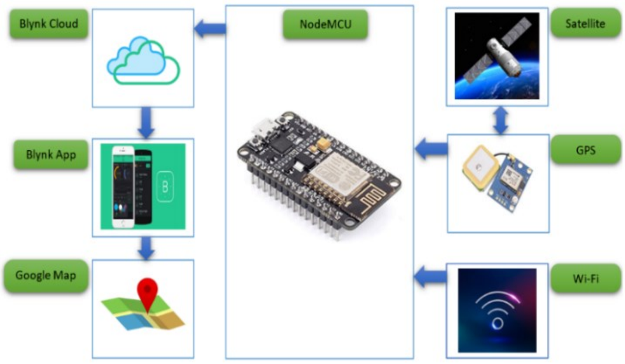


Fig. 10. Block diagram of the proposed real-time car tracking subsystem

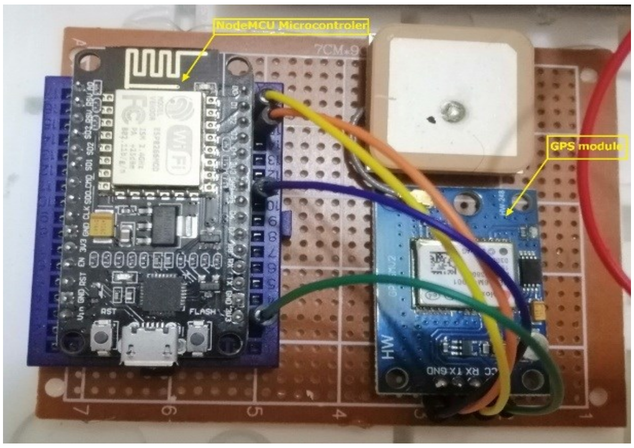


Fig. 11. Implemented real-time car tracking subsystem

VIII. Car Safety Subsystem

This section of the proposed system is specifically intended for gas-based cars, aiming to ensure both the safety of the car and its driver. This subsystem relies on the Arduino UNO microcontroller kit, a temperature sensor to monitor the temperature of the area surrounding the gas container, a gas sensor to detect LPG leaks, a flame sensor to identify the presence of fire and a Bluetooth module with its compatible Android app to wirelessly receive all sensor data. This organisation is demonstrated in the graphical block diagram shown in Fig. 12.

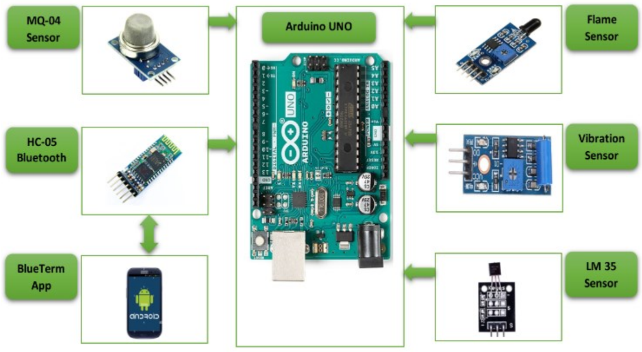


Fig. 12. Graphical diagram for the car safety part

Within this section of the implemented system, the monitoring of the temperature of the car's petrol cylinder is conducted, and afterwards, this temperature data is wirelessly communicated to a smartphone through the utilisation of short-range Bluetooth technology. The temperature is shown on the user interface of the BlueTerm app, which is a free and open-source application utilised for this specific task. In addition, the included flame sensor serves the purpose of detecting fire in the immediate vicinity of the LPG cylinder. Upon detection of a fire, a timely notification is expeditiously transmitted to the BlueTerm application, thereby notifying the vehicle owner of the possible fire risk.

Furthermore, the system employs the MQ-04 gas sensor to identify any potential LPG leaks. In the event of a gas leak being detected, a warning message is transmitted to the BlueTerm application via Bluetooth, once again notifying the car owner of the detected gas leak.

For the practical implementation, the aforementioned sensors are mounted on a Ferro board and securely joined using a thermal adhesive and solder wire, as clearly illustrated in Fig. 13. In practical use, these sensors are strategically positioned in close proximity to the car's gas cylinder. The temperature sensor makes direct contact with the gas cylinder by gluing to ensure accurate temperature measurement. The gas sensor is placed near the gas valve within the cylinder, and the flame sensor is purposefully oriented on the gas cylinder to efficiently detect flames.

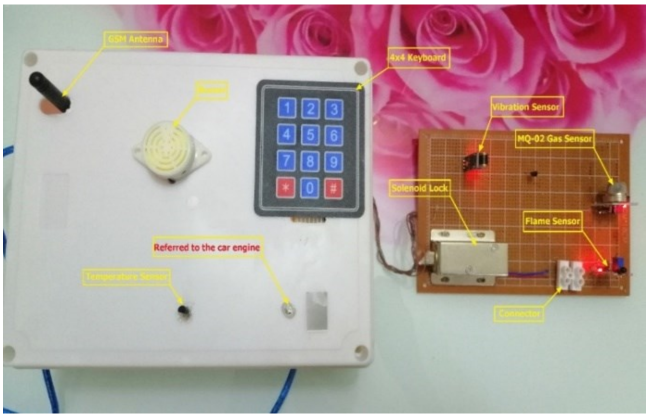


Fig. 13. Implement car security and safety system

IX. Proposed System Reliability

Indeed, the division of the proposed system into three fundamental and separate parts enhances its reliability significantly. This design approach ensures that the system does not rely on a single failure point. In other words, if one component or part, such as the microcontroller or one of the elements of the real-time tracking, were to fail, the other parts of the system would continue to operate properly. This redundancy and decentralization of control are achieved by having different microcontrollers for each part of the system, effectively distributing the intelligence throughout.

X. Results and Validation

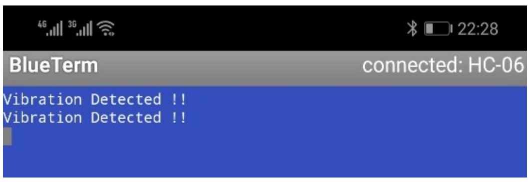
In this section, we will present the outcomes derived from the practical testing of the individual parts that make up the proposed system, including the security part, the safety part, and finally, the IoT-based real-time tracking part.

A. Results of Car Security Subsystem

The procedure for conducting practical tests on the fabricated parts of the proposed system can be outlined as follows:

- **Vibration Sensor Test:** To assess the functionality of the vibration sensor, it is subjected to impact by striking the vicinity near its designated installation point. Subsequently, the car engine is turned off by cutting the electricity for the engine, the alarm system will activate, triggering a warning alert. Simultaneously, a notification will be transmitted to the car owner's mobile device via the GSM module, and a message will be relayed to the BlueTerm app. This multi-tiered alert mechanism is designed to promptly apprise the car owner of a potential theft situation, as depicted in Fig. 14.

(a) Received SMS on the mobile phone



(b) Received message on the BlueTerm

Fig. 14. Received warning messages once the vibration detected

- **Two-level Authentication Security:** This part of the designed system relies on a 4×4 keyboard and a Bluetooth module. To initiate the proper operation of the car engine, a password must be entered via the keyboard. Additionally, a specific character (i.e., a certain number or letter) needs to be sent from the BlueTerm app (i.e., the Bluetooth application) to the Arduino UNO kit. Upon successful input of both passwords, the car engine will function as usual. This process is visualized in Fig. 15. If either of these passwords is entered incorrectly, the car engine will remain inactive. Furthermore, if the keyboard password is inaccurately entered more than three times, the alarm will activate, and an alert will be transmitted to the BlueTerm app, notifying the car owner of the suspicious activity. This scenario is depicted in Fig. 16. Moreover, an additional security measure involves the activation of a solenoid lock that secures the car doors. This feature is intended to confine any potential thief within the car, further enhancing the security of the vehicle.

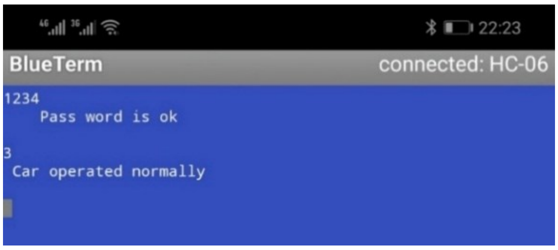


Fig. 15. Normal operation procedure for the vehicle

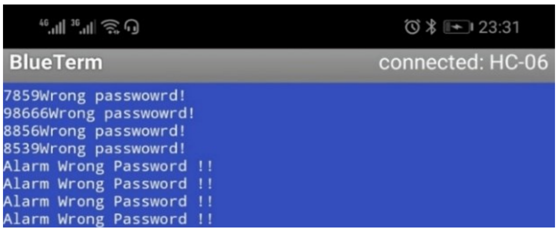
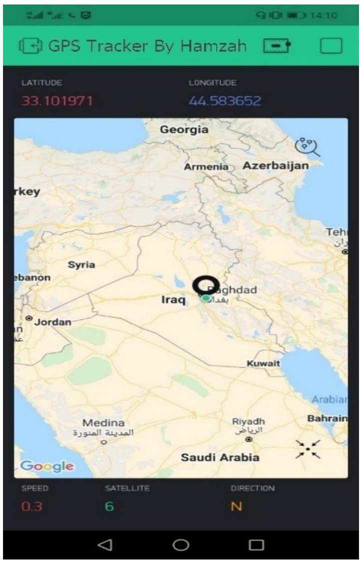


Fig. 16. Received message once the entered password is error

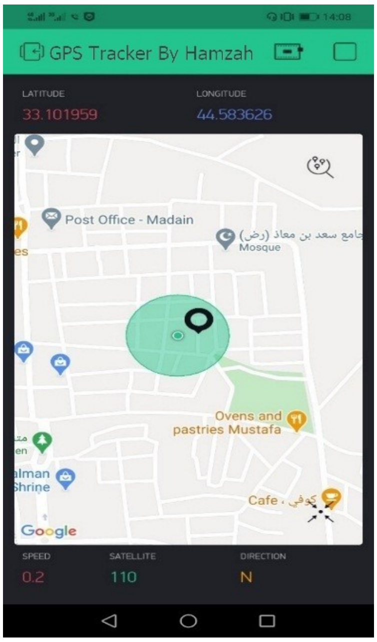
B. Results of Real-Time Car Tracking Subsystem

Upon powering the NodeMCU microcontroller and establishing wireless communication with the Wi-Fi source, the GPS module initiates the connection with satellites to obtain the car's precise longitude and latitude coordinates. This acquired location data is subsequently relayed to the NodeMCU microcontroller. The microcontroller, in turn, transmits this data to the Blynk cloud. The Blynk platform is programmed to exhibit this information through a dedicated application. The application showcases the longitude and latitude coordinates, and furthermore, harnesses the capabilities of Google Maps to visually represent the car's location on an interactive map interface. This depiction is exemplified in Fig. 17.

To validate the proper functionality of the proposed system, a test was conducted by slightly altering the location of the paired smartphone relative to the system. This adjustment aimed to detect corresponding variations in the reported longitude and latitude values, which indeed transpired as anticipated. During this test, the smartphone utilized Zain's-Iraq 4G LTE Internet service for connectivity, while the NodeMCU microcontroller established a connection with a distinct internet network through the TP-Link router's Wi-Fi. This configuration ensures the system's capability to track the car's position from any global location, underscoring its worldwide accessibility.



(a) Car position



(b) Zoomed view to another car position

Fig. 17. Different car positions on the map

C. Results of Car Safety Subsystem

The procedure for conducting practical tests on the components of the proposed system can be explained as follows:

- **Flame Sensor Test:** The functionality of the flame sensor is evaluated by introducing a flame source in its proximity, such as a lighter's flame. Subsequent to this action, the sensor is designed to detect the existence of a flame. This detection triggers the Arduino UNO kit to activate the alarm system and transmit an alert message through Bluetooth to the BlueTerm app. This instant notification serves to warn the driver about the potential presence of a fire hazard. For the visual illustration Fig. 18 is introduced to presents this test.

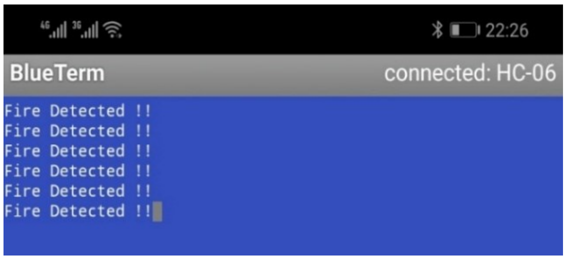


Fig. 18. Received message once the fire detected

- **Gas Sensor Test:** The operational capabilities of the MQ-04 gas sensor were assessed by introducing a source of LPG, readily available in a lighter, in close proximity. After fine-tuning the sensor's sensitivity using the potentiometer located on its back, the sensor was expected to respond to the presence of gas by activating its shielding mechanism. This reaction, in turn, triggered the activation of the alarm system within the Arduino UNO kit, followed by the transmission of a Bluetooth message to the BlueTerm application. The purpose of this immediate alert was to notify the driver of the detected gas leak. For a visual representation of this test, please refer to Fig. 19.

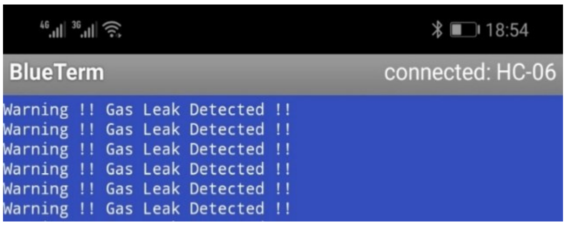


Fig. 19. Received message once the gas leak detected

- **LM-35 Temperature Sensor Test:** The functionality of the LM-35 temperature sensor is assessed by introducing a heat source in close proximity, akin to that of a lighter or candle flame. Subsequent to this action, the sensor is expected to generate a temperature reading corresponding to the surrounding area. In response, the Arduino UNO kit activates the alarm system and subsequently sends a Bluetooth message to the BlueTerm app. This immediate notification serves to alert the driver to the detection of overheating, particularly when the temperature surpasses 50°C. This testing process is visualized in Fig. 20.

Fig. 20. Received message once the overheating detected

The proposed system excels in offering a comprehensive and seamlessly integrated approach to LPG car safety, security, and real-time tracking through the implementation of IoT. It successfully amalgamates a range of sensors, authentication mechanisms, and cutting-edge communication technologies to provide an elevated level of protection, instantaneous notifications, and a user-friendly experience. This considerable combination differentiates it from conventional and less integrated systems, which often lack the sophistication and connectivity that the proposed system provides. To quantitatively compare the performance of the proposed system with other existing solutions, we present the results in Table I.

TABLE I. COMPARATIVE PERFORMANCE ANALYSIS OF PROPOSED SYSTEM AND EXISTING SOLUTIONS [54]-[60]

Aspect	Proposed	Traditional
Theft Prevention	Two-level security with keypad and Bluetooth authentication, vibration sensor-based alarm system.	Traditional key-based systems, alarm systems.
Gas Leak Detection	Dedicated MQ-04 gas sensor for LPG leaks, alerts through Bluetooth and app.	Gas detectors with limited connectivity.
Flame Presence Detection	Utilizes flame sensor for immediate detection, alerting car owner.	Relies on conventional smoke or fire detectors.
Temperature Monitoring	LM-35 temperature sensor for gas cylinder, alerts on overheating.	Limited or no temperature monitoring.
Integration of Systems	All systems interconnected for comprehensive protection.	Individual, disconnected security components.
Communication	Bluetooth and app alerts, GSM module for theft notifications.	Often lack smartphone integration.
Real-Time Tracking	Utilizes IoT technology for precise, live vehicle tracking.	Limited or no real-time tracking.
GPS Integration	GPS module for accurate location determination.	Basic GPS tracking without IoT.
Remote Monitoring	Smartphone app to track car's location globally.	Limited tracking accessibility.
User-Friendly Interface	Intuitive app interface with visual representation on maps.	Simple tracking interfaces.
Security Features	Integrates with overall security system for comprehensive protection.	Separately implemented tracking without security integration.
Alerts and Notifications	Immediate alerts to app for theft, geofencing, or predefined events.	Limited alert functionalities.

XI. CONCLUSIONS

The escalation in incidents of automobile theft and associated safety concerns related to LPG-powered vehicles are matters of significant urgency. The primary objective of the proposed integrated system is to address these issues by providing enhanced security and safety measures through the implementation of real-time tracking, theft prevention, and gas-related accident mitigation strategies. More specifically, in this paper, an intelligent system designed to enhance car safety and security measures has been introduced and implemented. The proposed system consists of three parts, each one is completing the functions of the others. While the first part main objective is to prevent theft cases, the second part is designed especially for cars that run based on the LPG. This system includes a number of features, such as the ability to detect flames, identify LPG leaks, and keep track of the temperature of the gas cylinders in real-time. The third part also includes a real-time car tracking subsystem that shows the location of the car on Google Maps by combining IoT, GPS, and the Blynk App. The Arduino Microcontroller, Bluetooth module, vibration sensor, keypad, solenoid lock, GSM module, NodeMCU microcontroller, GPS module, MQ-04 gas sensor, flame sensor, temperature sensor, and a second Bluetooth module are all used to put this system into action. The proposed system has constantly shown amazing accuracy and high-performance capabilities in extensive practical testing. These findings demonstrate the system's success in achieving its goal of enhancing automotive security and safety.

REFERENCES

[1] J. R. Méndez Cam, F. M. Santos López, V. G. Rosales Urbano, and E. G. Santos de la Cruz, "Prediction Models for Car Theft Detection Using CCTV Cameras and Machine Learning: A Systematic Review of the Literature," in *CSEI: International Conference on Computer Science, Electronics and Industrial Engineering (CSEI)*, vol. 678, 2023, doi:10.1007/978-3-031-30592-4_14.

[2] K. Lappanitchayakul, "Anti-theft device for car: Alert system using radio wave," *2019 International Conference on Intelligent Informatics and Biomedical Sciences (ICIIBMS)*, pp. 351-355, 2019, doi: 10.1109/ICIIBMS46890.2019.8991531.

[3] S. M. Ahmed, H. M. Marhoon, and O. Nuri, "Implementation of smart anti-theft car security system based on GSM," *Int. J. Eng. Technol.*, vol. 7, no. 4, pp. 5261-5265, 2018, doi: 10.14419/ijet.v7i4.27765.

[4] A. H. Mukalaf, H. M. Marhoon, I. Suwarno, and A. Ma'arif, "Design and Manufacturing of Smart Car Security System with IoT-Based Real-Time Tracking," *Int. J. Intell. Syst. Appl. Eng.*, vol. 11, no. 6s, pp. 745, 2023.

[5] V. K. Sehgal, S. Mehrotra, and H. Marwah, "Car security using Internet of Things," *2016 IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES)*, pp. 1-5, 2016, doi: 10.1109/ICPEICES.2016.7853207.

[6] D. Fromm, "Insurance technopolitics: Car theft, recovery, and tracking systems in São Paulo," *Security Dialogue*, vol. 54, no. 1, pp. 39-53, 2023, doi: 10.1177/09670106221141355.

[7] S. S. Tippannavar, S. B. Rudraswamy, S. Gayathri, S. P. Kulkarni, A. T. Murthy, and S. D. Yashwanth, "Smart Car - One stop for all Automobile needs," *2022 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS)*, pp. 54-59, 2022, doi: 10.1109/ICCCIS56430.2022.10037715.

[8] B. Balakrishnan, P. Suryarao, R. Singh, S. Shetty, and S. Upadhyay, "Vehicle Anti-theft Face Recognition System, Speed Control and Obstacle Detection using Raspberry Pi," *2022 IEEE 5th International Symposium in Robotics and Manufacturing Automation (ROMA)*, pp. 1-5, 2022, doi: 10.1109/ROMA55875.2022.9915691.

[9] A. Karhale, N. K. Pradeep, and S. Anitha, "Vehicle Theft Detection and Controlling System Using GPS and GSM Security System," *Journal of Control System and Control Instrumentation*, vol. 9, no. 1, pp. 5-10, 2023.

[10] B. Saritha, C. S. S. R. Bharadwaja, M. Nikhitha, C. N. Reddy, K. Arun, and S.M. Ahmed, "An Intelligent Anti-Theft Vehicle Locking System Using IoT," in *ICDSMLA 2020*, vol. 783, 2022, doi:10.1007/978-981-16-3690-5_150.

[11] K. Kim, J. S. Kim, S. Jeong, J. H. Park, and H. K. Kim, "Cybersecurity for autonomous vehicles: Review of attacks and defense," *Computers & Security*, vol. 103, p. 102150, 2021, doi: 10.1016/j.cose.2020.102150.

[12] E. Irraivan and S. K. Phang, "Development of a Two-Factor Authentication System for Enhanced Security of Vehicles at a Carpark," *2022 International Conference on Electrical and Information Technology (IEIT)*, pp. 35-39, 2022, doi: 10.1109/IEIT56384.2022.9967804.

[13] B. G. Blundell, "Surveillance: Technologies, Techniques and Ramifications," in *Ethics in Computing, Science, and Engineering*, pp. 211-292, 2020, doi: 10.1007/978-3-030-27126-8_4.

[14] S. Kanwal, M. T. Mehran, M. Hassan, M. Anwar, S. R. Naqvi, and A. H. Khoja, "An integrated future approach for the energy security of

Pakistan: Replacement of fossil fuels with syngas for better environment and socio-economic development," *Renewable and Sustainable Energy Reviews*, vol. 156, p. 111978, 2022, doi: 10.1016/j.rser.2021.111978.

[15] A. A. Rizi, A. Rezaei, M. G. Rizi, and M. A. Rizi, "Design a New Multiport DC-DC Converter to Charge an Electric Car," *International Journal of Robotics and Control Systems*, vol. 2, no. 1, pp. 87-96, 2022, doi: 10.31763/ijrcs.v2i1.566.

[16] T. M. Salman, H. N. Abdullah, H. M. Marhoon, and Z. A. Karam, "Design and Fabrication of a Smart Monitoring System for Liquefied Petroleum Gas-Operated Cars Based on Global System Mobile," *International Journal of Online & Biomedical Engineering*, vol. 19, no. 11, pp. 96-111, 2023, doi: 10.3991/ijoe.v19i11.41937.

[17] A. E. Adegoriola and I. M. Suleiman, "Adopting gas automobile fuels (LPG & CNG) into the Nigerian transportation system," *Journal of Economics and Sustainable Development*, vol. 10, no. 14, pp. 12-19, 2020, doi: 10.7176/JESD/10-14-02.

[18] O. J. Tola, E. A. Umoh, and E. A. Yahaya, "Pulse Width Modulation Analysis of Five-Level Inverter-Fed Permanent Magnet Synchronous Motors for Electric Vehicle Applications," *International Journal of Robotics and Control Systems*, vol. 1, no. 4, pp. 477-487, 2021, doi: 10.31763/ijrcs.v1i4.483.

[19] G. Chiriboga, R. Chamba, A. Garcia, R. Heredia-Fonseca, and C. Montero-Calderón, "Useful energy is a meaningful approach to building the decarbonization: A case of study of the Ecuadorian transport sector," *Transport Policy*, vol. 132, pp. 76-87, 2023.

[20] T. Kivevele, T. Raja, V. Pirouzfar, B. Waluyo, and M. Setiyo, "LPG-fueled vehicles: An overview of technology and market trend," *Automotive Experiences*, vol. 3, no. 1, pp. 6-19, 2020, doi: 10.31603/ae.v3i1.3334.

[21] K. Saurabh and R. Majumdar, "Functional Use-Based Positioning of Conventional Vehicles in Conjunction with Alternate Low-Emission Fuels," *Renewable Fuels for Sustainable Mobility*, pp. 97-159, 2023, doi: 10.1007/978-981-99-1392-3_5.

[22] D. Brzezińska, "LPG cars in a car park environment—How to make it safe," *International Journal of Environmental Research and Public Health*, vol. 16, no. 6, p. 1062, 2019. doi:10.3390/ijerph16061062.

[23] A. H. Alkhaiwani and B. S. Alsamani, "A Framework and IoT-Based Accident Detection System to Securely Report an Accident and the Driver's Private Information," *Sustainability*, vol. 15, no. 10, p. 8314, 2023, doi: 10.3390/su15108314.

[24] M. A. Obaidat, S. Obeidat, J. Holst, A. Al Hayajneh, and J. Brown, "A comprehensive and systematic survey on the internet of things: Security and privacy challenges, security frameworks, enabling technologies, threats, vulnerabilities and countermeasures," *Computers*, vol. 9, no. 2, p. 44, 2020, doi: 10.3390/computers9020044.

[25] V. Lesch, M. Züfle, A. Bauer, L. Iffländer, C. Krupitzer, and S. Kounev, "A literature review of IoT and CPS—What they are, and what they are not," *Journal of Systems and Software*, vol. 200, p. 111631, 2023, doi: 10.1016/j.jss.2023.111631.

[26] J. P. Dias, A. Restivo, and H. S. Ferreira, "Designing and constructing internet-of-Things systems: An overview of the ecosystem," *Internet of Things*, vol. 19, p. 100529, 2022, doi: 10.1016/j.iot.2022.100529.

[27] N. E. Baqir and M. I. Al-Nouman, "RFID-Based Users' Localization in the Crowded Areas," *Iraqi Journal of Information and Communication Technology*, vol. 4, no. 3, pp. 1-11, 2021, doi: 10.31987/ijict.4.3.145.

[28] J. J. Chung and H. J. Kim, "An automobile environment detection system based on deep neural network and its implementation using IoT-enabled in-vehicle air quality sensors," *Sustainability*, vol. 12, no. 6, p. 2475, 2020, doi: 10.3390/su12062475.

[29] M. Vila, M. R. Sancho, E. Teniente, and X. Vilajosana, "Critical infrastructure awareness based on IoT context data," *Internet of Things*, vol. 23, p. 100855, 2023, doi: 10.1016/j.iot.2023.100855.

[30] H. M. Marhoon, M. I. Mahdi, E. D. Hussein, and A. R. Ibrahim, "Designing and implementing applications of smart home appliances," *Modern Applied Science*, vol. 12, no. 12, pp. 8-17, 2018, doi: 10.5539/mas.v12n12p8.

[31] A. M. Hasan and A. A. Kadhim, "Design and implementation of smart meter for smart city," *Iraqi Journal of Information and Communication Technology*, vol. 3, no. 3, pp. 33-42, 2020, doi: 10.31987/ijict.3.3.127.

[32] M. Murad, O. Bayat, and H. M. Marhoon, "Design and implementation of a smart home system with two levels of security based on IoT technology," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 21, no. 1, pp. 546-557, 2021, doi: 10.11591/ijeecs.v21.i1.

[33] A. A. Sahrab and H. M. Marhoon, "Design and Fabrication of a Low-Cost System for Smart Home Applications," *Journal of Robotics and Control (JRC)*, vol. 3, no. 4, pp. 409-414, 2022, doi: 10.18196/jrc.v3i4.15413.

[34] I. A. Taha and H. M. Marhoon, "Implementation of controlled robot for fire detection and extinguish to closed areas based on Arduino," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 16, no. 2, pp. 654-664, 2018, doi: 10.12928/telkomnika.v16i2.8197.

[35] A. Murad, O. Bayat, and H. M. Marhoon, "Implementation of rover tank firefighting robot for closed areas based on arduino microcontroller," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 21, no. 1, pp. 56-63, 2021, doi: 10.11591/ijeecs.v21.i1.

[36] O. K. Mohammed, O. Bayat, and H. M. Marhoon, "Design and implementation of integrated security and safety system based on internet of things," *International Journal of Engineering & Technology*, vol. 7, no. 4, pp. 5705-5711, 2018, doi: 10.14419/ijet.v7i4.28222.

[37] J. S. Saputro, H. Maghfiroh, F. Adriyanto, M. R. Darmawan, M. H. Ibrahim, and S. Pramono, "Energy Monitoring and Control of Automatic Transfer Switch between Grid and Solar Panel for Home System," *International Journal of Robotics & Control Systems*, vol. 3, no. 1, pp. 59-73, 2023, doi: 10.31763/ijrcs.v3i1.843.

[38] M. Tasakorn *et al*., "A Low-Cost Force and Vibration Measurement Using FSR-402 and SW-420 Sensors for Sports Shoe Inspection," *2022 International Electrical Engineering Congress (iEECON)*, pp. 1-6, 2022, doi: 10.1109/iEECON53204.2022.9741699.

[39] M. H. R. Bhuiyan, I. M. Arafat, M. Rahaman, T. R. Toha, and S. M. M. Alam, "Towards devising a vibration-based machinery health monitoring system," *Materials Today: Proceedings*, vol. 56, pp. 2490-2496, 2022, doi:10.1016/j.matpr.2021.08.270.

[40] F. Furizal, A. Ma'arif, A. A. Firdaus, and W. Rahmaniar, "Future Potential of E-Nose Technology: A Review," *International Journal of Robotics and Control Systems*, vol. 3, no. 3, pp. 449-469, 2023, doi: 10.31763/ijrcs.v3i3.1091.

[41] U. Rahmalisa, A. Febriani, and Y. Irawan, "Detector leakage gas LPG based on Telegram notification using Wemos D1 and MQ-6 sensor," *Journal of Robotics and Control (JRC)*, vol. 2, no. 4, pp. 287-291, 2021, doi: 10.18196/jrc.2493.

[42] H. Fajrin, E. Susanto, P. S. A. Kristianto, F. F. Herdiyana, and S. A. Wibowo, "Design of Ventilator with Gas Mixing, Tidal Volume, and Humidifier Parameters," *Journal of Robotics and Control (JRC)*, vol. 3, no. 3, pp. 348-353, 2022, doi: 10.18196/jrc.v3i3.14510.

[43] I. G. M. N. Desnanjaya, I. N. S. W. Wijaya, W. G. S. Parwita, I. Made, and A. Nugraha, "Arduino MKR Analysis Using the RTC Alarm Method," J*urnal Ilmiah Teknik Elektro Komputer dan Informatika (JITEKI)*, vol. 8, no. 3, pp. 376-387, 2022, doi: 10.26555/jiteki.v8i3.23631.

[44] I. Hassani, I. Ergui, and C. Rekik, "Turning Point and Free Segments Strategies for Navigation of Wheeled Mobile Robot," *International Journal of Robotics and Control Systems*, vol. 2, no. 1, p. 172, 2022, doi: 10.31763/ijrcs.v2i1.586.

[45] A. M. Al-Kadhimi, H. M. Marhoon, and Z. A. Karam, "Implementation of cell phone detection mobile robot for restricted areas using NodeMCU," *Iraqi Journal of Information and Communication Technology*, vol. 1, no. 1, pp. 27-35, 2018.

[46] M. F. Wicaksono and M. D. Rahmatya, "IoT for Residential Monitoring Using ESP8266 and ESP-NOW Protocol," *Jurnal Ilmiah Teknik Elektro Komputer dan Informatika (JITEKI)*, vol. 8, no. 1, pp. 93-106, 2022, doi: 10.26555/jiteki.v8i1.23616.

[47] W. L. Prasetya, A. Ma'arif, H. M. Marhoon, R. Alayi, and A. N. Sharkawy, "Monitoring of Water Flow on Solar-Powered Pump for IoT-Based Agriculture," *Journal of Science in Agrotechnology*, vol. 1, no. 1, pp. 23-35, 2023, doi: 10.21107/jsa.v1i1.6.

[48] X. Shao, S. Li, J. Zhang, F. Zhang, W. Zhang and Q. Zhang, "GPS-Free Collaborative Elliptical Circumnavigation Control for Multiple

Non-Holonomic *Vehicles," in IEEE Transactions on Intelligent Vehicles*, vol. 8, no. 6, pp. 3750-3761, 2023, doi: 10.1109/TIV.2023.3240855.

[49] C. V. S. Revanth, B. Alekhya and M. H. Abbas, "Arduino based Wheelchair Fall Detection System using GPS and GSM Module," *2023 International Conference on Sustainable Computing and Smart Systems (ICSCSS)*, pp. 1022-1026, 2023, doi: 10.1109/ICSCSS57650.2023.10169322.

[50] A. Anbalagan et al., "Smart Dynamic Position Tracking Wearable for Geofencing in Marine Environment," in *IEEE Transactions on Instrumentation and Measurement*, vol. 72, pp. 1-9, 2023, doi: 10.1109/TIM.2023.3311076.

[51] A. Sawant, P. Narayanan, O. Mourya, S. Adhangale and G. Kedare, "GPS/GSM based School Bus Boarding-Deboarding and Location Notifying System," *2023 4th International Conference on Electronics and Sustainable Communication Systems (ICESC)*, pp. 534-539, 2023, doi: 10.1109/ICESC57686.2023.10193226.

[52] R. Nakata and D. Li, "False Alarm Attack and Protection of Smoke Detector," *Smart Grid and Renewable Energy*, vol. 13, no. 10, pp. 235-247, 2022, doi: 10.4236/sgre.2022.1310015.

[53] A. Mustafa, M. I. Aal-Nouman, and O. A. Awad, "Cloud-Based Vehicle Tracking System," *Iraqi Journal of Information and Communication Technology*, vol. 2, no. 4, pp. 21-30, 2019, doi: 10.31987/ijict.2.4.81.

[54] M. Abuzalata, M. Momani, S. Fayyad, and S. Abu-Ein, "A Practical Design of Anti-Theft Car Protection System Based on Microcontroller," *American Journal of Applied Sciences*, vol. 9, no. 5, p. 709, 2012.

[55] S. Singh and P. Kumari, "Automatic Car Theft Detection System Based on GPS and GSM Technology," *International Journal of Trend in Scientific Research and Development*, vol. 3, no. 4, pp. 689-692, 2019.

[56] Z. Brijet, B. S. Kumar, and N. Bharathi, "Vehicle Anti-Theft System Using Fingerprint Recognition Technique," *Open Academic Journal of Advanced Science and Technology*, vol. 1, no. 1, pp. 36-41, 2017.

[57] S. S. Patil, S. S. Patil, N. R. Kumbhar, and M. Sonale, "Modern Car Safety System using PIC Microcontroller," *J. Analog Digit. Devices*, vol. 4, pp. 19-23, 2019.

[58] K. Alsammarraie and T. Inan, "Car Control by using brain waves and Arduino based Mind wave Mobile," *2022 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*, pp. 1-6, 2022, doi: 10.1109/HORA55278.2022.9799911.

[59] A. Nandi *et al*., "Car Safety System with The Inclusion of Sensors," *International Journal of Innovative Research in Physics*, vol. 4, no. 3, pp. 6-7, 2023.

[60] L. Soni and A. Kaur, "Solving Parking Problems with Arduino Smart Car Parking Systems," *2023 5th International Conference on Inventive Research in Computing Applications (ICIRCA)*, pp. 1705-1710, 2023, doi: 10.1109/ICIRCA57980.2023.10220937.