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Vehicle Monitoring and Tracking System

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ABSTRACT

In this paper we present a vehicle monitoring and tracking system. Previous systems focus solely on either theft detection or car/driver monitoring. In this paper we provide an integrated solution that provide both theft detection, tracking and driver behavior monitoring. Our system performs well in detecting theft attempts through RFID and tracking location by GPS. It also monitors the driver behavior using OBD reader. Combining both features in one system has great advantages like cost efficiency, space saving and the possibility of adding new features.

Keywords: Vehicle Monitoring, Theft Detection, RFID, GPS, GSM, OBD.

INTRODUCTION

Vehicle theft has increased exponentially in the past few years. Statistics show that more than 1 million car was stolen in the united states in 2022 which cost more than 8 billion dollars [1]. Thus comes the crucial need for developing a system to prevent the theft from happening and to be able to track the car if theft happens. This paper presents an integrated vehicle monitoring and tracking system that once it detects unauthorized access attempt, it send a realtime location to a registered phone number which might be the car owner or the police to be able to return the stolen car in the suitable time. In addition to that it also monitors the driver behavior.

There has been a lot of research on monitoring systems in the literature. Vineth et al [2] proposed a vehicle monitoring system that detects the level of the fuel and sends the signal to the microcontroller. The microcontroller sends information about fuel level and position (longitude & latitude) to the mobile of the owner using GSM module. It is also displayed on LCD. M. A. Kader et al [3] proposed an IoT Based Vehicle Monitoring with Accident Detection and Rescue System. It is composed of 2 microcontrollers. The first microcontroller (MC1) task is to measure the speed and send it to the second microcontroller (MC2), playing buzzer in case of over speed, detecting the press of the switch in case of an accident, and sending SMS to the authority with the location.

The second microcontroller (MC2) task is to read data from a three-axis accelerometer and processes the data to find a measure of the rolling of the vehicle. It also detects the occurrence of hard brake through a mercury switch and count number of the hard brake.

The purpose of the ESP8266 WiFi microchip is to read all the parameters and to upload the data to the server using the internet.

ESP8266 reads data from the microcontroller through an inter-integrated communication (I2C) protocol, where ESP8266 acts as a master and MC2 as a slave.

M. Karrouchi et al [4] proposed a Black box system for car/driver monitoring to decrease the reasons of road crashes. The speed data is collected through On-Board Diagnostics (OBD-2 port). If the vehicle speed is excessive store the speed and location data in a file in real time on SD card and display them on LCD and send them to the owner through GSM module. If an accident happened take a picture of the interior of the vehicle and send a message to the nearest hospital and police station.

C. M. Jacob et al proposed a system [5] where an alcoholic breath analyzer sensor will continuously monitor the driver's breath. The speed sensor will be connected to the speedometer and checks for over speeding (RPM). The seat belt sensor will warn the driver if he/she is not using a seat belt and the vehicle will not start. The vehicle details including license, pollution details, insurance, etc. will be uploaded to the server or cloud.

A. BinMasoud et al [6] proposed a system where The OBD scan tool collects vehicle information from the OBD-II port of the vehicle, and the Raspberry Pi uploads them onto a cloud server using cellular internet connection. The on-line data as well as the historical data stored on a Cloud server are then accessed by the monitoring application. An algorithm is also proposed to detect faults in engine and cooling systems.

Also, there has been a lot of research about theft detection Systems in the literature. Singh et al in [7] proposed a system where If the engine is started forcefully the GPS collects the longitude and latitude data. GSM sends the GPS data to the owner's mobile phone every 10 seconds and plot the coordinates on google maps to locate the vehicle position.

Mohanasundaram et al in [8] used Face recognition technology is added using open CV python module. Using mobile application, if it is authorized the car is unlocked otherwise the car will be locked and if the thief tries to damage the device data will be sent to the owner.

Anjan et al in [9] proposed a system where after inserting the key and entering the password. If the password is correct start the engine. If it is entered incorrect for more than 3 times send message to police and owner.

S. Jawad et al [10] proposed a system where the location is determined by the GPS module and sent to the cloud through Wi-Fi module so that the owner can detect the location of his car by the mobile application.

Literature survey shows that existing systems often focus solely on either driver/vehicle monitoring or theft detection. Our proposed system introduces an integrated Driver/Car Monitoring and Theft Detection System to address these separate concerns comprehensively.

It is a standalone device as shown in figure 1 that can be used in the cars. The car provides the system with the power supply and OBD reader.

The report is structured as follows: Sections 2 and 3 describe the system design and implementation. Section 4 discusses the results and performance metrics, while Section 5 concludes the paper and suggests potential areas for future work.

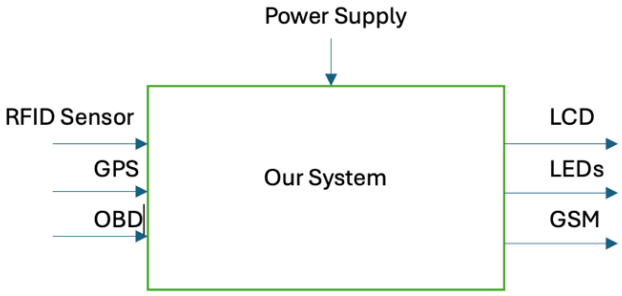


Figure 1: The proposed system within a car environment

THE SYSTEM DESIGN

The block diagram of our proposed system is shown in figure 2. It consists of the following: A microcontroller board, RFID sensor, LCD, and GPS & GSM module. The details of each module will be discussed in the following section.

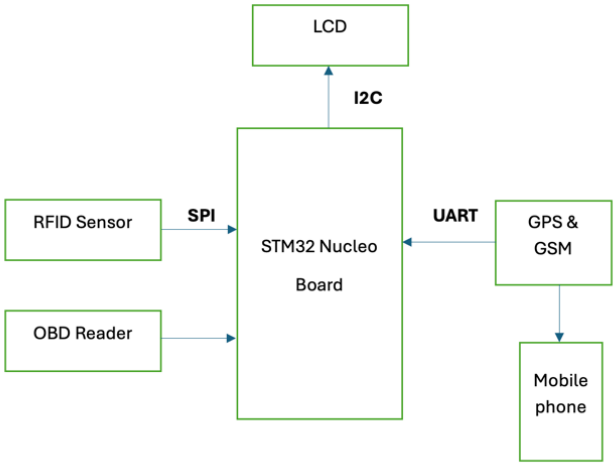


Figure 2: System Architecture Block Diagram

The board used in our proposed system prototype is STM32F030R8 Nucleo board as shown in figure 3. It has the ARM Cortex-M0 microcontroller with flash memory of 64 KB [11]. It is the brain of our system. It interfaces with the external components using GPIO pins and has communication peripherals such as UART (Universal Asynchronous Receiver Transmitter), SPI

(Serial Peripheral Interface), and I2C (Inter Integrated Circuit) which enable it to communicate with the other components.

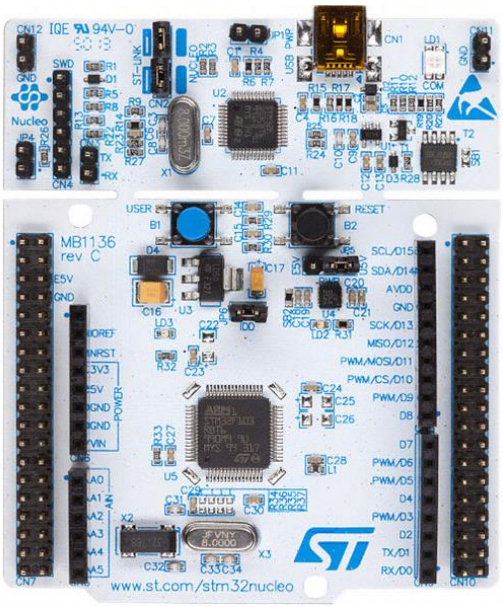


Figure 3: STM32F030R8 Nucleo Board

The RFID sensor as shown in figure 4 used is the RC522. It communicates with the microcontroller via SPI protocol. It detects unauthorized access.



Figure 4: The RFID Sensor

We used one module which contains both GPS and GSM technology. It is the A9G chip as shown in figure 5. The GPS fetches information from the satellites in the NMEA (National Marine Electronics Association) format [12] and send it to the microcontroller which parse the messages and extract the information needed like the longitude and latitude and send it to the owner's mobile phone. The module communicates with the microcontroller via UART.

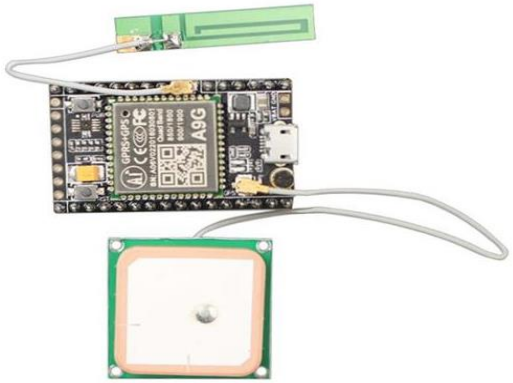


Figure 5: The GPS & GSM Module

The LCD used is HD44780 as shown in figure 6) which has an I2C module attached so it communicates with the microcontroller using I2C which uses only 2 wires instead of 8 if it will connect with parallel connection. It is 16 characters wide and 2 rows. It acts as the user interface for our system.



Figure 6: The LCD used in the proposed system

OBD stands for On-Board Diagnostics, a standardized system in cars that monitors various subsystems of the vehicle and provides diagnostic information. A lot of parameters can be read through The OBD II like: Vehicle Speed, Engine RPM, Throttle Position, Brake Use, Steering Angle (not typically available via OBD-II but can be inferred with additional sensors), Accelerator Pedal Position, Fuel Consumption Rate, Long Term, Fuel Trim, Intake Air Temperature, and Engine Load. In our system we simulated the OBD using push buttons. We have 4 buttons each simulate one of the following: Harsh Acceleration, Harsh Braking, Aggressive Cornering, and Speeding. Each time a button is pressed a message is displayed on the LCD indicating the behavior detected. If the frequency of pressing the button exceeds a certain threshold the corresponding LED is turned on.

THE SYSTEM IMPLEMENTATION

The programming language used is C which is very suitable for hardware. The IDE used is STM32CubeIDE which provide an excellent interface for configuring the microcontroller and provide many libraries.

The flow of the program is shown in figure 7. A code segment of the infinite loop in the main function is shown in figure 8 and a table of all functions called in the main is shown in figure 9. The external interrupt ISR function is shown in figure 10.

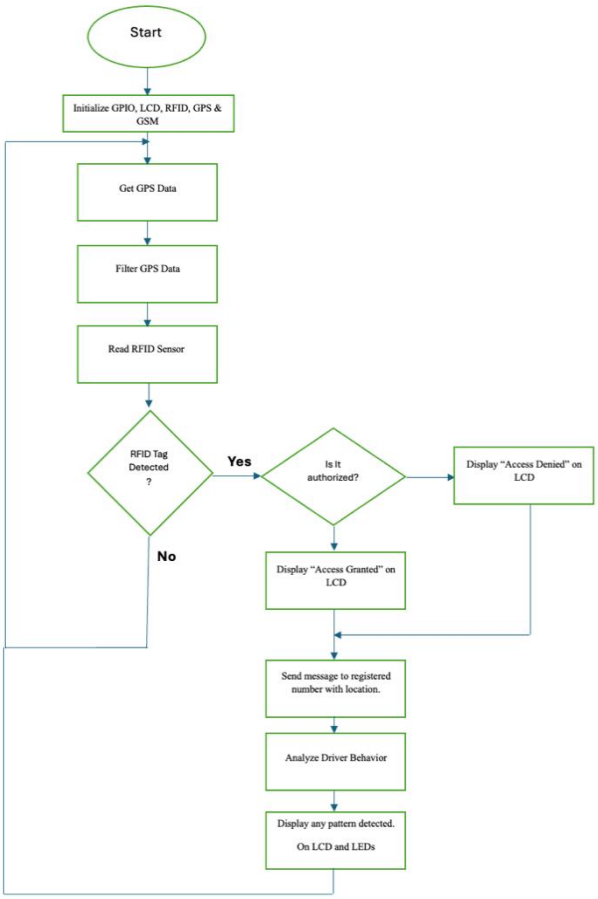


Figure 7: Software Design Flow Chart

```
while (1) {
    GpsGetData();
    FilterGpsData();
    status = MFRC522_Check(id);
    if(LCD_flag == 0){
        HD44780_SetCursor(0, 0);
        HD44780_PrintStr("Tap your card     ");
    }
    else
    {
        HD44780_SetCursor(0, 0);
        HD44780_PrintStr("Monitoring        ");
    }

    if(status == MI_OK)
    {

        compare = MFRC522_Compare( &id[0], &CompareID[0]);

        if(compare == MI_OK)
        {
            LCD_flag = 1;
            HD44780_SetCursor(0, 0);
            HD44780_PrintStr("Access Granted");

            while(MyGps.GGA.Latitude == 0 || MyGps.GGA.Longitude == 0);
            SendGsmData();

        }
        else
        {
            HD44780_SetCursor(0, 0);
            HD44780_PrintStr("Access Denied");

            while(MyGps.GGA.Latitude == 0 || MyGps.GGA.Longitude == 0);
            SendGsmData();


        }
        analyzeDriverBehavior();
    }
```

Figure 8: The Infinite Loop that implements the proposed system

Driver	Function	Input	Output	Description
GPS & GSM	GpsInit	Void	Void	Initialize GPS module
	GpsGetData	Void	Void	Receive data from GPS via UART and store it in a variable called RxData
	FilterGpsData	Void	0 or 1	Extract information from the variable RxData like time and coordinates
	SendGsmData	Void	Void	Send a warning message with location to the registered phone number
RFID	MFRC522_Init	Void	Void	Initialize RFID(RC522) sensor
	MFRC522_Check	No inputs	Card ID & Status	Check if there is RFID Tag
	MFRC522_Compare	Status	CardID & CompareID	Check if the tag is authorized or not by comparing it with the saved ID
LCD	HD44780_Init	Number of Rows	Void	Initialize the LCD
	HD44780_SetCursor	Row & column Number	Void	Place the cursor at the desired position
	HD44780_PrintStr	String to be displayed	Void	Print message on LCD
OBD	simulateHarshAcceleration	Void	Void	Increase the acceleration counter by 1 and display a message on LCD
	simulateHarshBraking	Void	Void	Increase the braking counter by 1 and display a message on LCD
	simulateAggressiveCornering	Void	Void	Increase the cornering counter by 1 and display a message on LCD
	simulateSpeeding	Void	Void	Increase the speeding counter by 1 and display a message on LCD
	analyzeDriverBehavior	Void	Void	Check all the counters and if frequent behavior detected the corresponding LED is switched on
External Interrupt	HAL_GPIO_EXTI_Callback	Void	Void	When a button is pressed external interrupt is triggered. In the ISR we check which button is pressed and act accordingly

Figure 9: Table of functions used to implement the system

```
void HAL_GPIO_EXTI_Callback(uint16_t GPIO_Pin)
{
    if(GPIO_Pin == GPIO_PIN_0) {
        simulateHarshAcceleration();

    }
    else if(GPIO_Pin == GPIO_PIN_1)
    {
        simulateHarshBraking();

    }else if(GPIO_Pin == GPIO_PIN_2)
    {
        simulateAggressiveCornering();

    }
    else if(GPIO_Pin == GPIO_PIN_3)
    {
        simulateSpeeding();

    }
    else {
        __NOP();
    }
}
```

Figure 10: The External Interrupt ISR

TESTING AND RESULTS

Each module in the system was tested separately by connecting the debugger and monitoring the variables through the live expressions tab as shown in figure 11. The whole system was

tested in the end. There are 2 scenarios the authorized access and unauthorized access. In case of authorized access, it is displayed on the LCD that access is granted as shown in figure 12. In case of unauthorized access, it is displayed on the LCD that access is denied as shown in figure 13 and an SMS is sent to the car owner with a warning message and the location and time as shown in figure 14.

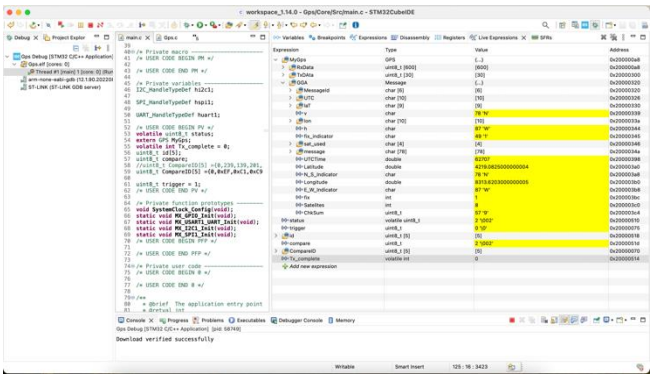


Figure 11: Live Expressions

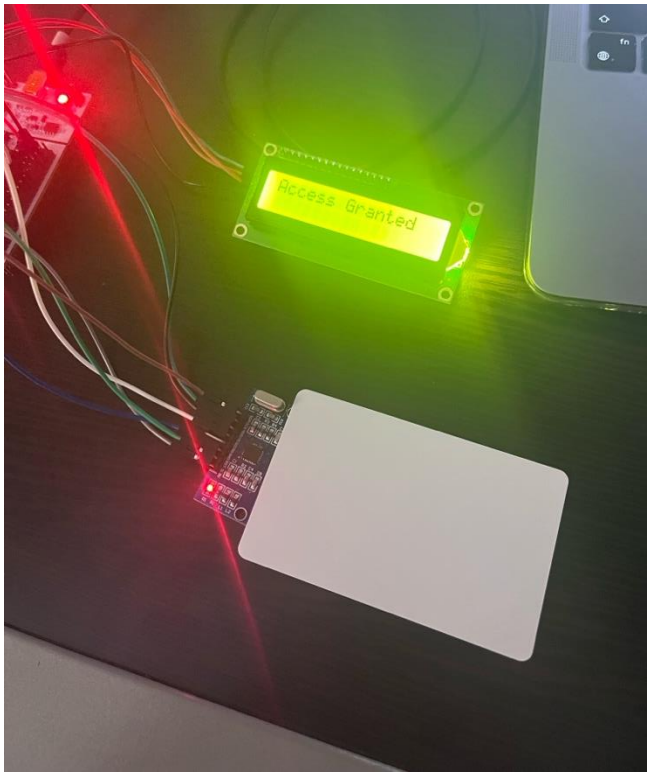


Figure 12: Authorized Access

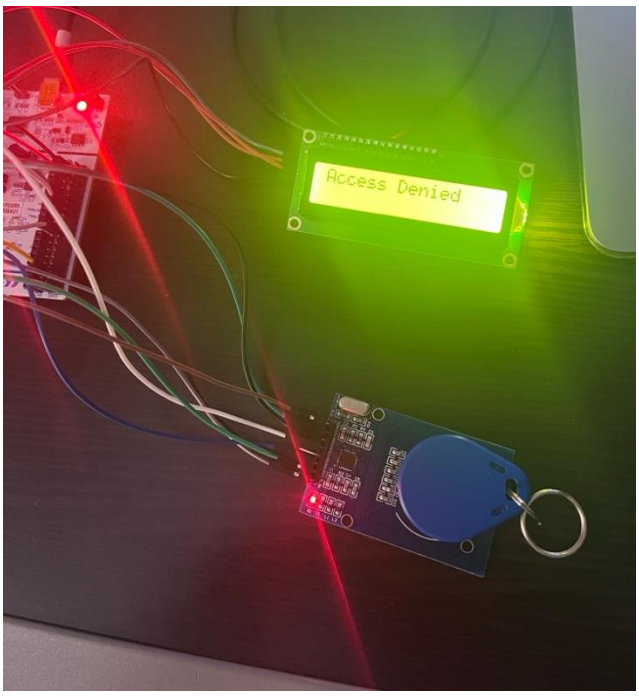


Figure 13: Unauthorized access

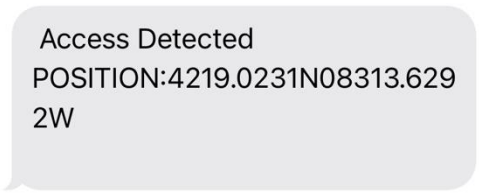


Figure 14: SMS with the location

Table 1 shows the test result that was conducted on the proposed system. It shows that each requirement is presented, and how it was tested and the result of the test.

Table 1: System test

Requirement	Test Description	Result
Detect unauthorized access using RFID	Presented authorized and unauthorized RFID tags to the system. Monitored the status and compare variables.	Successfully detected authorized and unauthorized tags with 100% accuracy
Provide real-time location tracking using GPS	Monitored GPS data in both static and dynamic environments. Verified the use of NMEA format and GGA message.	GPS provided accurate and continuous location updates, with data in NMEA format and GGA message.
Send alert notifications via GSM	Simulated unauthorized access and measured the time taken for SMS alerts to reach the registered phone number.	GSM module sent SMS alerts within an average of 10 seconds.

Detect Harsh Braking	Pressing the corresponding button frequently	LCD display that harsh braking is detected after 3 presses the corresponding LED is on.
Detect Harsh speeding	Pressing the corresponding button frequently	LCD display that harsh speeding is detected after 3 presses the corresponding LED is on.
Detect Harsh cornering	Pressing the corresponding button frequently	LCD display that harsh corbering is detected after 3 presses the corresponding LED is on.
Detect Harsh acceleration	Pressing the corresponding button frequently	LCD display that harsh acceleration is detected after 3 presses the corresponding LED is on.

CONCLUSION

In conclusion, in this paper we presented a vehicle monitoring and tracking system as shown in figure 15 which provide an integrated solution that combines between driver monitoring and theft detection in contrast to previous system that focus solely on one purpose. We used STM32F030R8 as the microcontroller board along with RFID sensor, GPS, GSM and LCD. The system proved its effiency and robustness. It is also simple, easy to use, and does not require connection to internet.

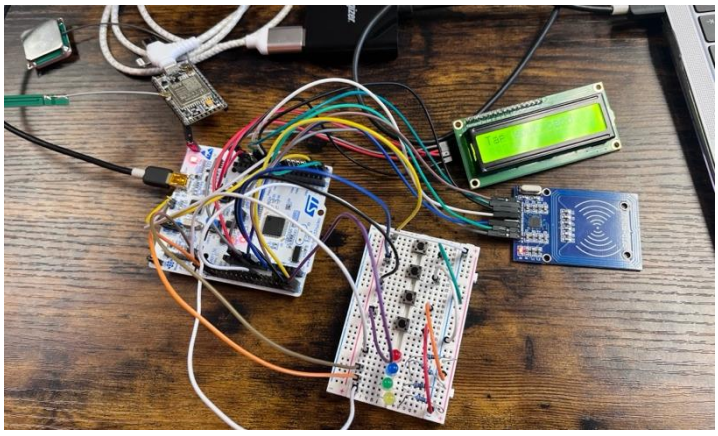


Figure 15: The Prototype for the proposed Vehicle Monitoring and Tracking System

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