JTE HCMUTE
ISSN: 2615-9740
JOURNAL OF TECHNICAL EDUCATION SCIENCE
Ho Chi Minh City University of Technology and Education
Website: https://jte.edu.vn
Email: jte@hcmute.edu.vn

Design and Development of an IoT System Prototype for Safe Traffic Assurance System

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ARTICLE INFO

Received:	03/01/2024
Revised:	26/02/2024
Accepted:	27/02/2024
Published:	28/02/2024

KEYWORDS

Internet of things;
Embedded Systems;
Arduino;
Sensors;
GPS.

ABSTRACT

In 18 months (from 2022 to the first 6 months of 2023), there were 16,229 road traffic accidents nationwide, killing 9,086 people and injuring 11,235 people. In the first 9 months of 2023 alone, there were 8,335 traffic accidents nationwide, killing 4,765 people and injuring 5,802 people. Traffic order and safety are one of the important issues related to the life and development of the country. According to statistics from the World Health Organization (WHO), each year about 1.35 million people die and 50 million people are injured due to traffic accidents. Some serious traffic accidents, killing and injuring many people, are mainly caused by high speed and violation of the regulations on alcohol concentration. Therefore, implementing safe traffic solutions to minimize loss of life and property is one of the urgent needs. The project develops an IoT system prototype that can reduce the risks of traffic accidents through a continuous monitoring of parameters during participation in traffic by vehicles. The system integrates sensors, including gas sensors (detection of alcohol concentration), vibration sensors (detection of accidents), and infrared sensors (detection of the seat belts). In case of any accident, the system can send warnings and location information to the relevant systems.

Doi: https://doi.org/10.54644/jte.2024.1517

1. Introduction

Technological breakthroughs in recent years have impacted almost every area of human life, especially, the ongoing 4th industrial revolution (also known as the 4.0 industrial revolution), which has integrated and converged industrial production and supply chains with information and communication technology and IoT.

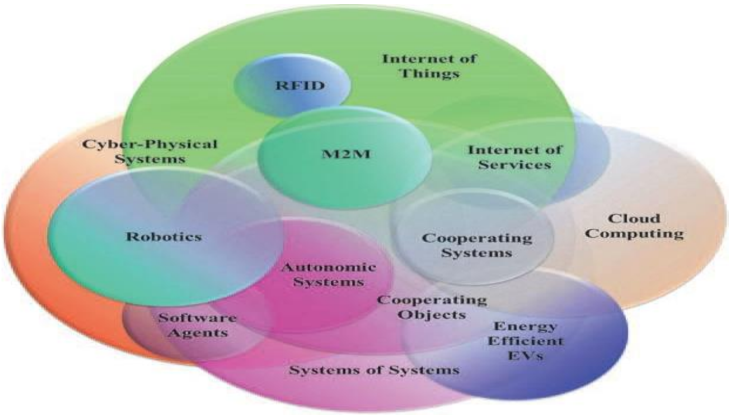

Figure 1. *Convergence of industries [1]*

One of the differences between the 4th industrial revolution and previous ones is that it was predicted in advance and created many opportunities and challenges for developers. The IoT plays a central role in this revolution, specifically, the IoT development promotes the formation of the IoT ecosystem -a network connecting devices, objects, people, and communication processes together to collect and

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exchange data. This ecosystem is created by different components including: IoT devices, sensors, computer networks, cloud computing applications.

Figure 2. *IoT ecosystem* [2]

The IoT ecosystem enables devices to communicate and exchange data in real time. Allow organizations to collect and analyze large amounts of data, automate processes, improve making decisions. For example, the IoT ecosystem can be used to monitor and control energy consumption for smart buildings, or track and manage a fleet of vehicles in real time.

Developing an IoT ecosystem requires a coordination between the relevant parties, including hardware and software manufacturers, service providers, and users. The ecosystem can also benefit from the integration of AI, big data analytics and other advanced technologies to enhance capabilities and foster innovation.

1.1. Researches in our country

In recent years, much attention has been paid to a research into IoT applications in a variety of fields. According to [3] the Internet of Things (IoT) device industry, Vietnam is transforming itself with forecasts that by 2027 there will be about 14.8 million IoT connected devices. According to the data from Statista, revenue from the IoT field in Vietnam is expected to reach a compound annual growth rate of 16.04% in the period 2023 – 2028, estimated to reach a total revenue of 13.11 billion USD in 2028. Among them, the most important market for the IoT sector in Vietnam is automobiles, with the estimated revenue for the IoT sector for this market in 2023 of about 2.18 billion USD. Many industries and fields in Vietnam have potentialities to apply the IoT technology. These are energy, traffic – transportation, logistics, manufacturing and resource exploitation industry, retail industry, health care and even the Government activities. Among them, the energy industry may need to be prioritized because of the quite low complexity of application of the IoT technology and then a group of industries relating to transportation, logistics with an average complexity.

However, according to [4], although some initial achievements have been achieved, the IoT ecosystem in Vietnam still has some shortcomings such as: no IoT application having a strong impact on the social life, foreign hardware and software suppliers in spite of the hot IoT market. The IoT research companies in Vietnam include: DTT, FPT, VNG, MobiFone, Orient Soft, HBLAB, NAL, TMA Solutions, VNPT Technology.

1.2. Researches in the foreign countries

Research and implementation of the IoT applications have been performed in a variety of fields such as healthcare, education, smart buildings, smart agriculture, smart transportation, among others,. According to [5], the IoT in the transportation market is categorized by Types (Hardware, Software, Services), Mode of Transport (Road, Rail, Air), Application (Traffic Congestion Control System, Automotive Telematics, Parking seats, Toll collection and ticketing system) and Geography.

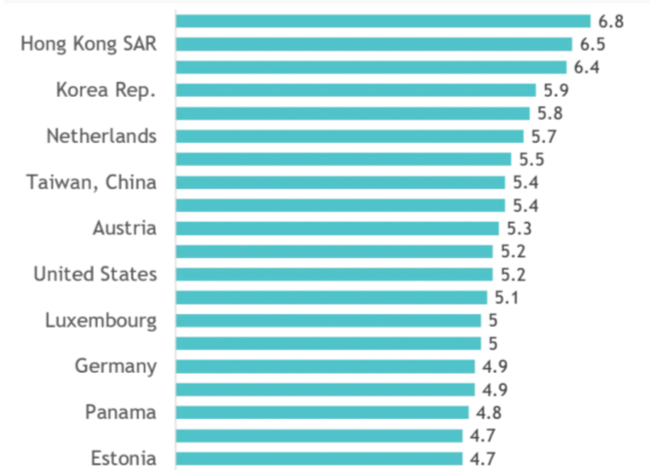

Figure 3. *Ranking of the most efficient Countries in Train Transport Services, valued from 1 to 7 (best), 2019*

Also according to [5], the IoT in transportation market is highly fragmented due to the presence of many global and local industry players who are considering strategic partnerships and acquisitions as a lucrative avenue for their expansion because it helps them leverage the strengths and skills of other companies in the market and enhance their market presence through such strategic collaboration.

Among the traffic-related studies, [6] describes a research on the design and construction of a prototype of an outdoor object location tracking IoT system.

2. Architecture and Process of building and developing the IoT systems

2.1. IoT system architecture

The IoT architecture is the structure enabling the connected devices, cloud services, and protocols to form the IoT ecosystem. It is composed of 3 to 7 layers [7], allowing the devices such as sensors, actuators, transport components and application components to interact with one another through the Internet. The 4-layer architecture is presented as below:

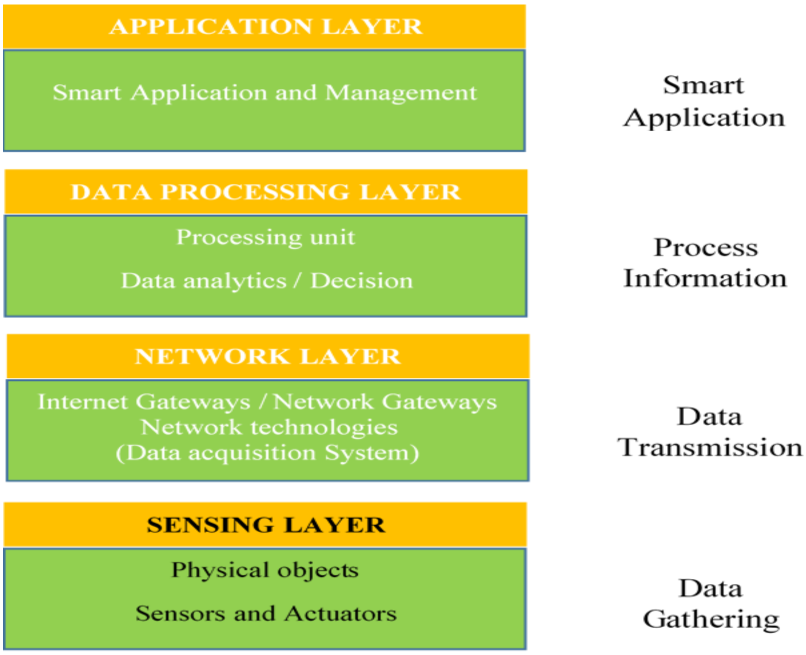

Figure 4. *4-layer IoT architecture*

- Sensing layer (Perception layer): Including the devices collecting and processing information such as: sensors that receive information from the environment and actuators. It can be considered like the eyes, ears and nostrils of human-being.

- Network layer: Being considered as a bridge between the perception layer and the application one. Information transmission is collected via sensors, the transmission medium can be wired or wireless. It will be in-charge of connecting the smart things, network devices and networks together. The current wireless technologies are commonly used such as cellular technology, Wifi, Wimax, Zigbee, Bluetooth [8].

- Data processing layer: Processing the collected data.

- Application layer: Defining all applications that use the IoT technology or those in which the IoT is deployed. Such applications can be smart buildigs, smart cities, smart heath, animal tracking. It will be responsible for providing services to the applications and such services may vary subject to each application.

2.2. Components of the IoT system

The IoT provides many benefits and facilities to users. In orderto use them properly, some components are needed, [9] shows the components of the IoT system as per the Figure 5 below:

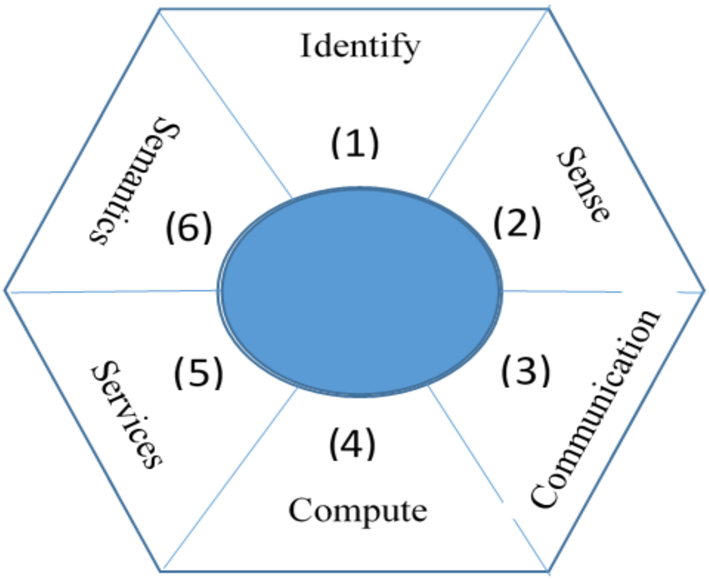

Figure 5. *IoT components*

- Identification: Being needed to provide an identification for each object. There are two processes of such identification: naming and addressing. The Product code, Ucode can be used for the naming and the IPv4 or IPv6 can be for addressing
- Sensing: Being the process of collecting information from the objects, the collected information is transmitted to the storage media. There are lots of types of sensors such as RFID tags, smart sensors, wearable devices, actuators, etc.
- Communication [10], [11], [12]: Being used to provide a connectivity for different devices and transmit information to one another. Many technologies are applied in communication such as: RFID (Radio Frequency Identification), NFC (Near Field Communication), Bluetooth, Wifi, LTE (Long Term Evolution).
- Computation: Being performed on the collected information. Many hardware and software platforms are available. The Hardware platforms include: Arduino, Raspberry Pi, Intel Galileo, Nvidia Jetson Nano, etc. and the Software ones include: Android, Tiny OS, Lite OS, ROS (Robot Operating system), etc.The stream processing platforms include Spark, Storm, S4, Google Cloud IoT, AWS IoT, Azure IoT, etc.
- Services: There are four specific types of services that can be provided by the IoT applications: The identity-related services to be used to obtain the object identities; The services related to collecting information from the objects; The collaborative services to be used to make decisions based on the collected information and transmit responses to the devices; The ubiquitous services to be used to respond to the devices instantly without relying on the time and place.

- Semantics: Being the most important component, it acts like the brain of the IoT in terms of receiving all information and makes appropriate decisions to transmit responses to the devices.

2.3. IoT system building process

The design of the IoT systems is generally based on the design methodology of general embedded systems. The design process according to [13] shown below includes 10 steps:

Figure 6. *Steps in the IoT design methodology*

- Step 1: Determine the purpose and requirements of the system
- Step 2: Process specification, it describes the entire usability of the system based on the objectives and specifications as required.
- Step 3: Domain model specification (determine the domain model), it describes the main concepts, entities and objects in the domain of the designed IoT system. It also defines the properties of the objects and the relationships between them.
- Step 4: Determine the information model. It defines the structure of all information of the IoT system, and describes in detail the method of the information is shown or stored.
- Step 5: Identify the services used in the IoT system such as: service types, inputs and outputs, service endpoints, service efficiency.
- Step 6: Determine the level of IoT deployment.
- Step 7: Identify the functions of the IoT system classified into the different functional groups. Each functional group provides the functions for interacting with the objects in the domain model.
- Step 8: Determine the technical parameters of the working mode. Many different options related to the deployment and operation of the IoT system are identified herein.
- Step 9: Integrate the devices and components.
- Step 10: Develop the IoT applications.

3. System Deployment

3.1. Description

The system focuses on ensuring journey a safety for drivers and passengers through monitoring safety parameters during the trip. It is equipped with the sensors including gas sensor (detecting alcohol concentration), vibration sensor (detecting accidents), infrared sensor (detecting whether seat belts are worn). In the event of a potential hazard, it will take appropriate actions such as preventing the vehicles from starting or sending an alert with location information.

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3.2. Operation principle

The hardware block diagram is shown in the Figure 7

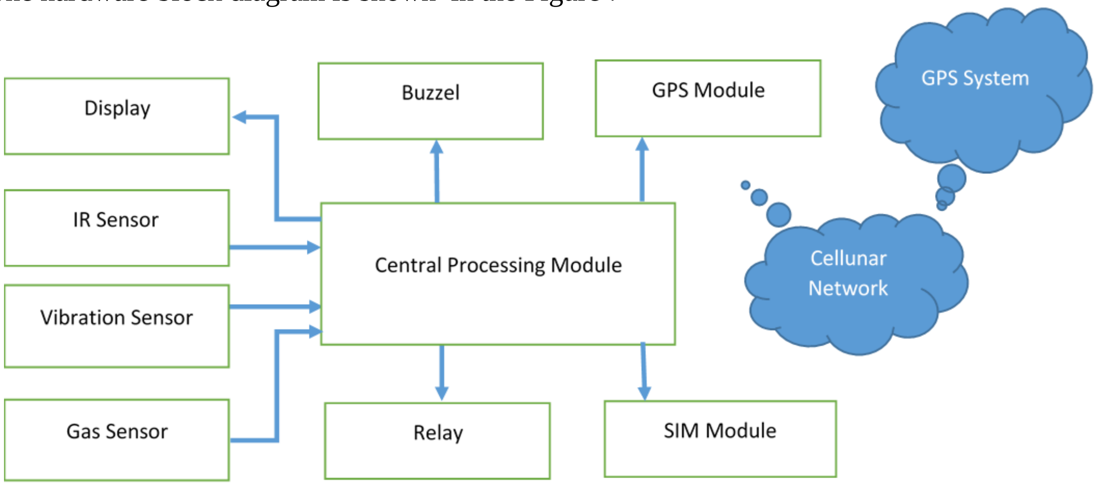

Figure 7. *System hardware block diagram*

- Before starting the vehicles, the driver must be tested for his/her alcohol concentration through a gas sensor. If the concentration exceeds the allowable level, the relay disconnects the power source, making the vehicles unable to start. At the same time, the speaker emits a warning signal and the alcohol concentration is displayed on the screen.
- Then the system checks whether the driver's seat belts have been fastened or not. If not, the relay cuts off the starting power of the vehicles and the speaker emits a warning signal, a message is displayed on the screen.
- The relay only allows the vehicles to start once the alcohol concentration is within the allowable range and the seat belts have been fastened.
- In case of occurrence of any accidents during travel, the vibration sensor will report to the central block and activate the GPS global positioning system to indicate the location of the accident, and the system will make a call to the rescue center's hotline number via the sim module.

3.3. Devices to be used

The use of the IoT devices and programming are based on the documents [14], [15], [16], [17]

- Arduino uno board with the diagram as shown in Figure 8, plays the role of central processing block [14], [15].

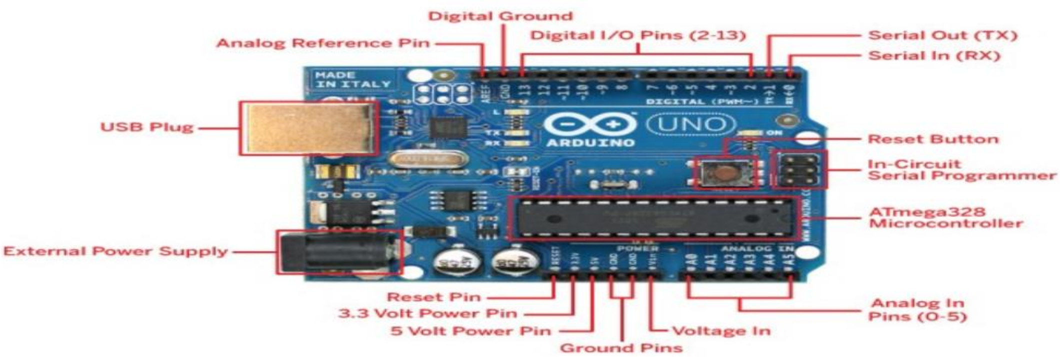

Figure 8. *Arduino Uno board*

- Infrared sensor [18]

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Figure 9. *Infrared Sensors*

Figure 10. *MQ3 alcohol gas sensor*

The infrared sensors are used to emit and detect infrared radiation. According to this principle, infrared sensors can be used as obstacle detectors.

- MQ3 Alcohol gas sensor [19]

The SnO_2 material is the main component of this sensor because the fresh air has less conductivity. The SnO_2 is more conductive when exposed to alcohol gas. The presence of the alcohol can be detected by a microcontroller so that the user can detect differences with the output voltage. The alcohol detection sensor is of a low-cost and suitable for multitasking. It has a good sensitivity and long life. It can be used to perform a number of applications such as breathalyzers, alcohol meters and portable gas alarms.

- Vibration Sensor Module (SW-420)

Figure 11. *Vibration sensor*

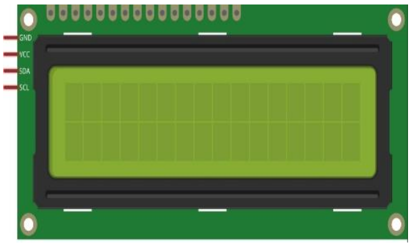

Figure 12. *LCD 16x2 module*

Figure 13. *Buzzer*

It is a versatile sensor that can be used for many different applications such as sensing if someone knocks on the door, identifying problems in machinery, detecting car accidents, or as part of a system alarm. It is compatible with low voltage systems as it operates on a power supply of 3.3 V to 5 V.

- LCD Modul 16x2 (as shown figure 12)
- Buzzer (as shown in figure 13)
- Introducing the GPS (Global Positioning System) and GPS module [20]

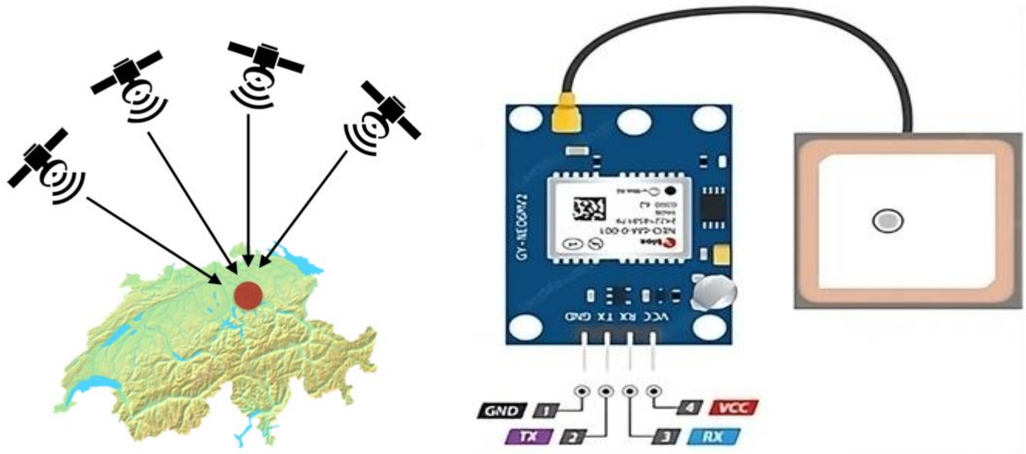

Figure 14. *GPS system and GPS module*

The GPS (global positioning system) uses 24 satellites at an altitude of about 20,200Km, each satellite transmits navigation information containing its location and the exact time of the transmission. GPS receivers measure the arrival time of navigation information and estimate the distance from it to the satellite, the receiver's position and time are calculated based on a three-dimensional space.

A typical GPS module includes: a GPS receiver, an antenna, a number of processing units which performs some tasks such as: decoding satellite signals, calculating position and providing the data to the external control like an Arduino board.

- SIM 900 Module [19]

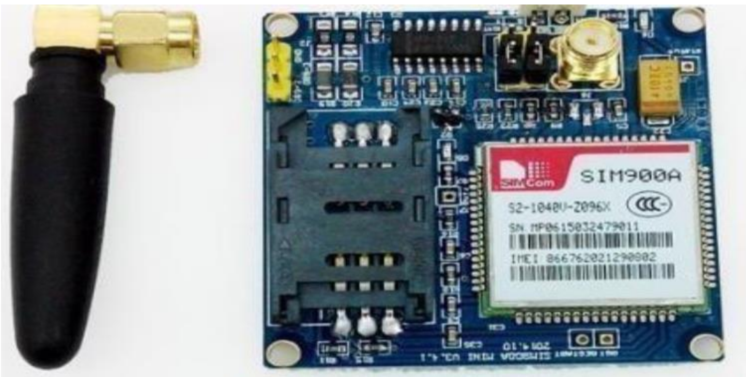

Figure 15. *SIM 900 Module*

This is a very efficient wireless module, SIM900A is a dual-band GSM/GPRS system. It provides GSM/GPRS signals in the 900/1800 MHz band applicable to voice, SMS, Data and Fax at low level and power.

The reasons for choosing the above devices are: popular, cheap, can be easily purchased at electronic component stores.

3.4. Software components implementing the system

- Arduino IDE software: To be used to program and upload code into the embedded board.
- Proteus simulation software: To simulate and test the system.

3.5. Hardware deployment and simulation on Proteus

The system has been deployed and simulated on Proteus as shown in Figure 16

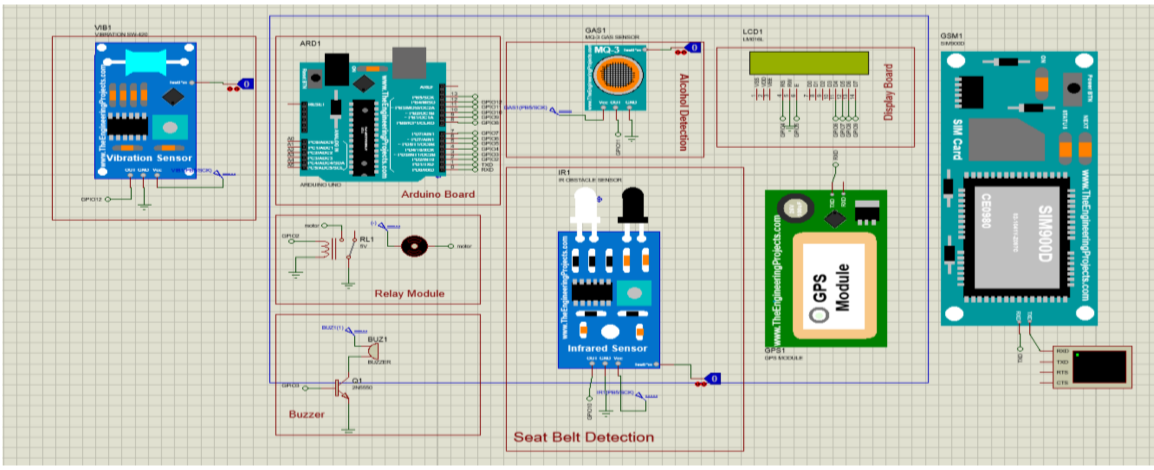

Figure 16. *The system prototype is deployed on Proteus*

3.6. Results

- Situation: Seat belt is not fastened, relay has not been turn on, screen displays notification, speaker sounds as shown on Figure 17

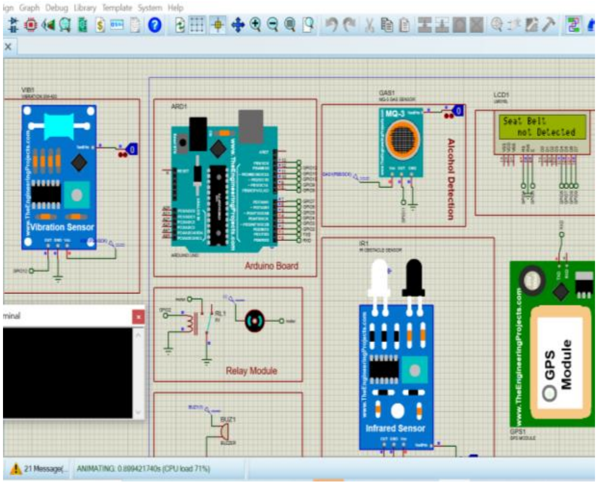

Figure 17. *The seat belt not to be yet fastened*

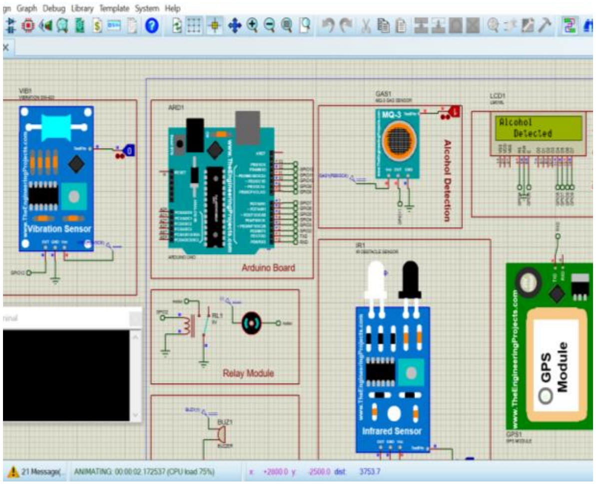

Figure 18. *Alcohol detected*

- After the seat belt has been fastened: The speaker stops ringing, the screen displays the message that the seat belt has been fastened.
- If the alcohol concentration exceeds the allowable threshold: The relay is not connected to the power, that is to say, the engine cannot start, the screen displays a message, and the speaker beeps to notify the driver as shown on Figure 18.
- In case the seat belt has been fastened and no exceeding alcohol concentration is detected, the relay closes and allows the vehicles to be started.

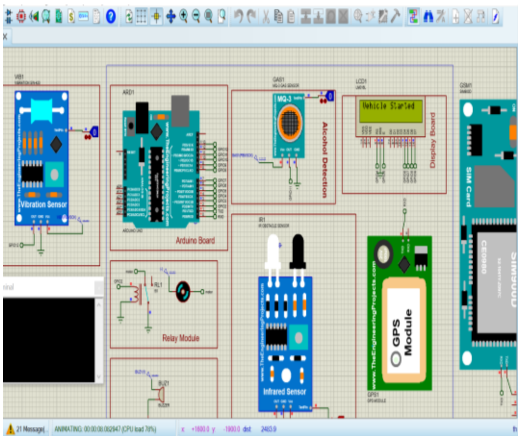

Figure 19. *Vehicles to be started*

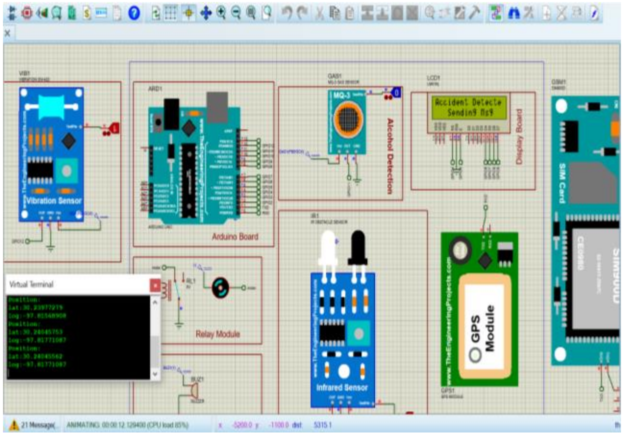

Figure 20. *Accident detection and delivery of position information*

- In the course of travelling of the vehicles, in case of occurrence of any accident, the screen displays a notification and the system sends a location and notification to the designated hotline number.

3.7. Evaluation

Overally, the system has worked in accordance with the requirements as put forward. Through simulation testing, the system works relatively accurately. However, the device positioning speed is not fast, due to the use of mobile telecommunications waves and the distance of satellite signal transmission and reception.

4. Conclusion

The drivers' negligence and carelessness are the cause of accidents, in consequences, the number of traffic accidents is more and more increasing. The Article has proposed a prototype that can be easily manufactured at an affordable cost, helping to partly limit the accidents due to the drivers' carelessness as well as in case of any accidents, provide a timely and promptly rescue. The system will send a location and notification to the competent authorities for a timely rescue.

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- **Advantages:** The system has worked as expected and is feasible in terms of construction and cost, easy to deploy, easy to use, effective in prevention.
- **Disadvantages:** The system uses the Arduino Uno board with ATmega328 microcontroller which is an 8-bit processor with maximum frequency of 20MHz. Although its costs are very competitive, its speed and processing capacity are still slow and its number of pins is low. The connected peripheral is still small, so some other functions cannot be deployed yet.
- **Development direction:** Instead of using the Arduino Uno, we will use the Arduino boards to be equipped with more powerful microcontrollers with more peripherals to speed up and deploy some additional functions such as using the ultrasonic sensors to detect any obstacles ahead, if the distance reaches the specified threshold, it will warn the driver of the risk of collision, or automatically apply the brake pedal to reduce vehicle speed.

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