Complete Microcontroller Based Vehicle Accident Detection System with Case Study for Saudi Arabia

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Abstract: The road accidents problem in Saudi Arabia has become a serious and enormous problem as it was found that Saudi Arabia is recording more than 500 thousand of accidents annually with up to 17 deaths daily. Such large numbers are caused mainly due to the lack or latency of succoring responses to the injured person, which motivated us to research thoroughly to propose a solution that can mitigate the effect of road accidents. In this paper, we propose sensors based on microcontroller solution that utilizes the use of many sensors and modules along with Arduino microcontroller such as the vibration sensor to detect the accident quickly. For better and more accurate results, we have added the Airbag sensor. At the end of this work and the proposed prototype design is manufactured as with enhanced component, it can easily be adapted and it will help the society to have better results (if Allah want) such as: avoiding many of deaths that could happen because of lateness, decreasing the crowding areas which lead to decrease the accidents too, helping the injured people from getting worst as soon as possible, helping the medical staff by providing them more time to help the injured, and saving the time of the Ambulance staff and Najm employees, by adding the buttons to cancel the request in case if they are not needed.

Key-words: Arduino Microcontroller, Vibration Sensor, Airbag Sensor, GPS module, GSM Module, Najm insurance.

1 Introduction

Even though Saudi's government always sets the laws and advices to struggle the car accident calamity but the number of car accidents in Saudi's community is increasing significantly and it needs a serious action to mitigate the failures of accidents especially in terms of human damage (injuries and deaths). According to the Red Crescent Committee, Saudi Arabia recording 526,000 accidents annually with up to 17 deaths daily and a total of SR 21 Billion is spent annually on road accidents. These numbers put Saudi Arabia in the 23rd among world countries and the 2nd among Arab countries in terms of road deaths [1]. These reports motivated us (and many other researchers as well) to be a reason that assist in preserving of people' lives and their families from the risks of the road accidents, as the recently became a significant source of fear and concern for all members of society. The main goal of this work is helping the families who are exposed to incidents in the places and roads that are isolated or far from the residential neighborhoods, and to observe the accidents occurring time and place, and what is the status of the families.

Thus, here we propose a new solution for road accident treatment, which is heavily based on the use of microcontroller, sensory elements, GSM Module, GPS system and Programming. Microcontroller (MC) is considered as a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals [2]. We have chosen Arduino Mega Microcontroller to be the core part of this design. Arduino is open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments [3]. Also, the second core part of the proposed system is the sensory elements, which is a simple and small unit, used to observe some phenomena. Every sensor node is made up of four basic components [4]: a sensing unit, a processing unit, a transceiver unit and a power unit. Also, the third major part of the system is the use of the Global Positioning System (GPS) which is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense [5]. Moreover, the last major component of this work is the use of GSM technology to send the accident related information.

Global System for Mobile communication (GSM) is an architecture used for mobile communication in most of the countries. GSM module consists of a GSM modem assembled together with power supply circuit and communication interfaces (like RS-232, USB, etc.) for

computer. In addition, the programming part is the final stage of design where C-language will be used to program and configure Arduino Microcontroller based system utilizing the serial I/O for Arduino to be connected to PC through the USB port for calibration purposes along with Arduino IDE simulator [3]. Fig.1 illustrates the four core hardware components. Finally, the proposed device will have three buttons: Request both of Najm and Ambulance button (either in case of accident or not, it can be used to call both parties to the location), Cancel Najm only button, that means the person is injured but he/she needs Ambulance to help him/her and Cancel Ambulance only button, which means when the problem just was in the car and needs Najm for Insurance Service to check the situation of the accident. Once the user makes the call (button #1), then, both of Najm and Ambulance will wait for three minutes.

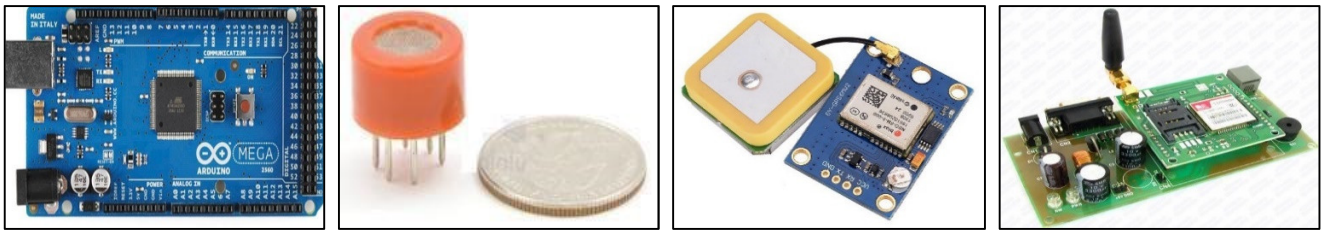

Fig. 1. (a) MEGA Arduino MCU (b) Sample Small Sensor (c) Sample GPS module (d) Sample GSM Module

The final system will combine these components (MC + Sensors + GPS + GSM) along with buttons/ wires/ configurations/ programming and others. The system will function as follow: when an accident occurs (a huge accident will let the airbag to go out) then the system will detect the accident via vibration and airbag sensors [6], determine and specify the location by GPS tracking, send the location coordinates directly to Najm for Insurance Service, and Ambulance through the GSM which finally will follow the GPS signal to arrive and respond to the location as early as possible.

1.1.Problem Statement

The main problem that we face every day in the streets, highways, is the accidents. The percentage of accidents is increasing because of the overcrowding problems, the high speed of the new advanced cars and the use of mobile phones while driving for calling or texting. Most newspapers, news channels and social media talk about the recent accidents happened nearby. This is a very serious and widespread problem as most deaths of the car accidents may be alive now, if there was a faster respond from the emergency facilities. Many people died because they have an accident in a disused highway, so no one helps them! Another case if the person who has the accident cannot call the ambulance because he/she was injured, sometimes he/she is not awake and senseless, or the accident happened in an isolated road or far from the residential neighborhoods. Also, if the accident happened in the city, where there are lots of cars in the street, which will cause crowding if the Najm for Insurance Services was late. We consider that the time is very important factor to protect other's life. We might lose many lives because of lateness. Therefore, the problem in this work concerns with mitigating the considerable number of deaths resulted from the car accidents and caused mainly due to the lack or latency of succoring responses to the injured person. The proposed solution utilizes the use of many sensors and modules along with Arduino microcontroller such as the vibration sensor to detect the accident quickly with more accurate results.

1.2.Analysis of Related Work

The rapid growth of technology and infrastructure has made our lives easier. Searching the related works and ideas will let us learn more about our proposed system, microcontroller devices and how to design/ develop them with their techniques and tools. As a result, we have read many research papers in the literature and then we have summarized the most three related research papers with our targeted system.

Authors in the first research paper entitled "Automatic Vehicle Accident Detection System that is based on ARM & GPS" [7] concerned about the advent of technology that increased the traffic hazards and the road accident take place frequently which causes huge loss of life and property because of the poor emergency facilities. They provided a solution for this drawback using MEMS sensor, GPS & GSM. The system will detect the vehicle accident using MEMS sensor (vibration sensor). After that, the GPS will locate the location of the car accident, and then a message containing the co-ordinates of the position will be sent through the GSM module to the medical rescue team and to the police control room so that the victim

(injured person) will get a faster treatment. Also, the system provides the ability to cancel or refuse the medical treatment if the victim is not injured (or little injuries) to save the efforts and time for the medical rescue team. Moreover, the person can press a switch to call the medical rescue team for other reasons (such as having a heart attack), rather than having an accident that it causes a vibration to call the medical staff automatically. The system hardware consists of a Driver IC (A chip or a microchip consists of many electronic parts that functions as an amplifier or counter or even a computer memory and many), MEMS sensor, GPS module, power supply, GSM modem and the Engine itself (See fig.2. a) [7].

In the second related work, which is a research paper research entitled "The design of the scene of the accident alarm system based on ARM and GPS" [8], the authors proposed a system with a wireless communication method using GSM to transfer the information to the treatment centers when an accident occurs and GPS module. Thereafter, the treatment center will process the information received from the GSM module of the car and determines the location of the car in Google map using the GPS. The system is divided into two major units: information-processing unit and accident sensing unit. In the information-processing unit, when the accident happened or occurred, vehicles state and location (determined by GPS) will be sent to the preset of treatment center through as SMS (Short Message System) through the GSM (Global System Mobile) module (wireless communication technologies). The preset of treatment center involves of the microcontroller and GSM module. By receiving alarm information, the treatment center staffs will notice and decide which branch and the handler who is nearest to the scene of the accident in current time, to arrive the location of the accident happened, for gaining more treatment time for the accident injured, and decrease the percentage of the mortality, that lead to reduce the incidents impacting time on the traffic. In the accident-sensing unit, the hardware circuit is mainly composed of six parts: MCU (Microcontroller Unit), alarm indicating circuit, alarm signal input interface circuit, GSM communication module interface circuit, wireless transmitter and receiver circuit and power supply.

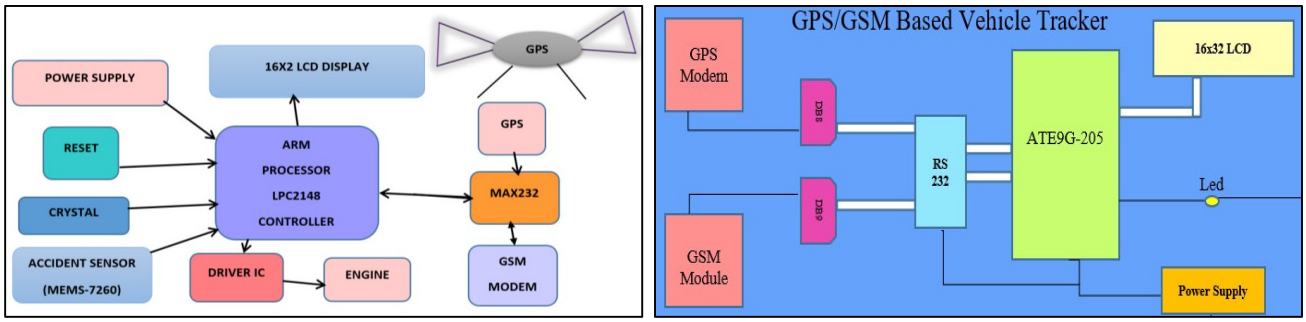

Fig. 2. (a) Automatic Vehicle Accident Detection System [7] (b) Vehicle Tracking System [9]

In the third related work entitled "Vehicle Tracking System using GPS and GSM modem" [9], the researchers proposed a vehicle tracking system that is used in any situations and cases such as like if your car is stolen (theft detection), this system will be very useful, if someone wants to track school bus of their children, it will be helpful to find out the location of kids and to know where exactly they are, because the location is updated directly, and another situation is when a company wants to track the location of the cab/transport bus of employee, in this case this tracking system will be very useful and helpful. The idea of their design is when you want to track the vehicle, you should send an SMS to the device, a certain message which tells the device to send back the location of the vehicle. This message is specified in the programming part, the message will be sent to the device using GSM modem and the device will send the location as link in Google maps (recognized by GPS) which will be sent back to the owner by GSM, (See fig. 2. b). The system hardware includes GSM modem (to send SMS messages of the locations); GPS module to determine the location of vehicle, Microcontroller (Central processing unit), keyboard (used to allow the owner to send SMS to the Microcontroller to have the location back), LCD Display which is used as a monitoring unit, for example the GSM mobile will show the location on LCD after receiving the request from the owner, and power supply to provide the system circuit with the appropriate voltage level. Table 1 summarizes a comparison between the related works and the corresponding enhancement in our proposed system.

Table 1: Related work problem and the enhancement in our proposed system

First related work: Automatic Vehicle Accident Detection System Based	
Related work problem:	***Enhancement in our proposed system***
• This system is not very effective in case of accident of heavy vehicles. They are not using the Airbag sensor.	• Their system is using Vibration sensor only and we enhanced the idea to add Vibration sensor with Airbag sensor too.
Second related work: The design of the scene of the accident alarm system based on ARM and GPS:	
Related work problem:	***Enhancement in our proposed system***:
• Dose not specify the alarms. • It is cannot the specify the type of the helping. • Wasting the time of treatment center. • If the person (in-accident) is fine & want to cancel.	• Specify the alarm (Air bag and vibration sensor). • Specify the destinations of SMS (Najm & Ambulance). • Saving time of Najm & Ambulance via request buttons. • In case, add button to request or cancel.
Third related work: Vehicle Tracking System using GPS and GSM modem	
Related work problem:	***Enhancement in our proposed system***:
• The owner device might be lost so he/she will not be able to send SMS to Vehicle's device. Also, the location will be send only if the SMS is received.	• Our design sends the location directly after sensing Airbag and Vibration sensors without the need of another device that might be lost.

1.3. Alternative Solutions and Justifications

Many alternative solutions were proposed in the literature to address the issues of the accident detection system using different hardware and software implementations such as the works (A, B and C). Table 2 summarizes a comparison between the alternative solutions including the advantages, disadvantages and the features of our proposed design.

Table 2: Advantages/disadvantage of the alternative solutions and features of the proposed system

Solution A: The Car accident detection system using GPS and GSM (Bluetooth-based system). [11]	
Advantages	***Disadvantages***
• The system is using the Bluetooth as all the mobiles have the Bluetooth feature.	• Bluetooth connectivity has limited coverage distance limitations (Not used for far distances)
Features of our proposed system according to Solution A.	
• The microcontroller device that will send the message is connected to the car itself, so it cannot be lost.	
• No limitations since it depends on the base stations existing in the area, because as it uses the GPS directly.	
Solution B: Use Smartphones to detect accidents and provide situational awareness to emergency responders [12]	
Advantages	***Disadvantages***
• Can be available in old cars that has no accident detection. • Cheaper than having an advanced car.	• If the phone is dropped or moved hardly, it senses the motion and consider it as it's an accident. • It has a server, which makes the process slower than sending the request directly. Also, it might be lost.
Features of our proposed system (according to Solution B.	
• Our proposed microcontroller sends the request directly to the ambulance and Najm to have a quick response. • It's connected device, so it'll not be lost.	
Solution C: Najm Application [13]	
Advantages	***Disadvantages***
• Allow the user to request help from Najm in current time. • Uncomplicated way to specify the location. • Available in the market of both IOS and Android.	• Need regular updates to fix bugs of older version. • Battery of the mobile might be empty or not charged. • Has one choice only Najm (no ambulance request). • Need to request it manually.
Features of our proposed system according to Solution C.	
• Its connected as hardware unit (added to the computer system of the vehicle). • The requests (Najm and Ambulance) are done by the buttons. • Have two choices to request Najm and Ambulance and sends the whole information of the accident directly.	

2 System Design Requirements

The system to be designed, it will require both functional and none functional requirements in addition to software and hardware requirements to assure full functionality & goals.

2.1.Functional Requirements

- **Sensing the Airbag with the vibration:** Once the Airbag blow or open, our device will sense the blowing and the vibration.
- **Recording the location:** The location of accident will be recorded using GPS module.
- **Sending the Location:** The location of the accident will be sent immediately for Najm and Ambulance using GSM module.
- **Requesting/Canceling orders by buttons:** Requesting Najm and Ambulance (Button # 1), Cancelling Najm request only (Button # 2), and Cancelling Ambulance request only (Button # 3).

Fig.4 and Fig.5 show the use-case and the flowchart diagrams for the entire process of MCU with other components connected to it. Firstly, the vibration will be initiated from the accident once it happened. Then, the vibration sensor or the airbag sensor or both, will send the analog signals of the vibration to the MCU where it has an embedded ADC functionality that converts the received analog signals to digital signals that can be processed by the microcontroller and other digital components. Thereafter, the Microcontroller will send a request to the GPS module to locate the accident location and send back the Microcontroller. At this moment, Arduino Microcontroller will initiate two parallel processes: will request GSM to send that location with the pre-defined message as "please help" and will request the timer to count for three minutes as a period where it allows the user to do any cancellation or requesting using the buttons within the three minutes timing where if the three minutes passed without pressing any button, then Najm and Ambulance will respond and come to treat the accident as they will assume that the user is unable to press any button. The GSM after the request will send the location and the message to Najm and Ambulance. At the end, the user might be fine and need to cancel the request for Najm or Ambulance so, the user may press one or more of the giving three buttons, one at a time. After pressing the button, the order or the command will go to the Microcontroller, then the Microcontroller will request sending the canceling for the GSM. GSM will send the cancelation to the Najm or Ambulance. Another button is for requesting both of Najm and Ambulance, so the same process of sending the button commands and orders as in canceling will be happen for the requesting both, from the buttons to the Microcontroller the GSM and finally to Najm and Ambulance.

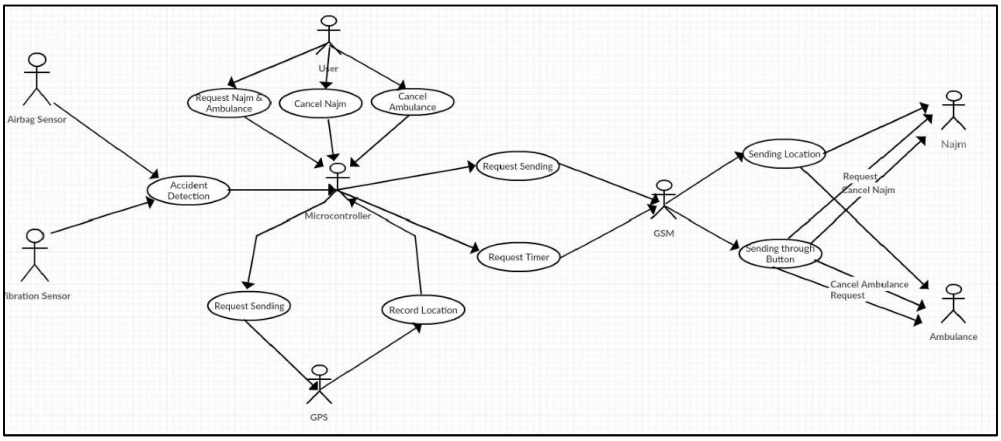

Fig. 4. Use-case diagram for the entire process of the System

2.2. Non -functional Requirements

- ***Performance: Response Time:*** *The time that will take to send the location for the Ambulance or Najm Company is about few seconds because it will automatically send it.*
- ***Throughput:*** *is the amount of material (i.e. the location coordinates) or items passing through our proposed device microcontroller system utilization.*
- ***Availability:*** *The system is available all the time, once the sensor sensed the accident it will immediately make the call and location sending.*
- ***Reliability:*** *Whatever is needed and wanted will happen exactly, i.e. the option selected by the user is exactly what will happen which means that the*

system is reliable. For example, if the user wants to cancel all the calls either for the health center or Najm he will press the first button and that exactly what will happen.

- ***Manageability:*** *As explained earlier, the user can easily manage the system & system device through pressing the buttons that is needed and wanted.*
- ***Usability****: It can be used easily since it can be adapted & integrated to vehicle's computer system to work automatically on accidents & manually on the cancelation process via the given buttons.*

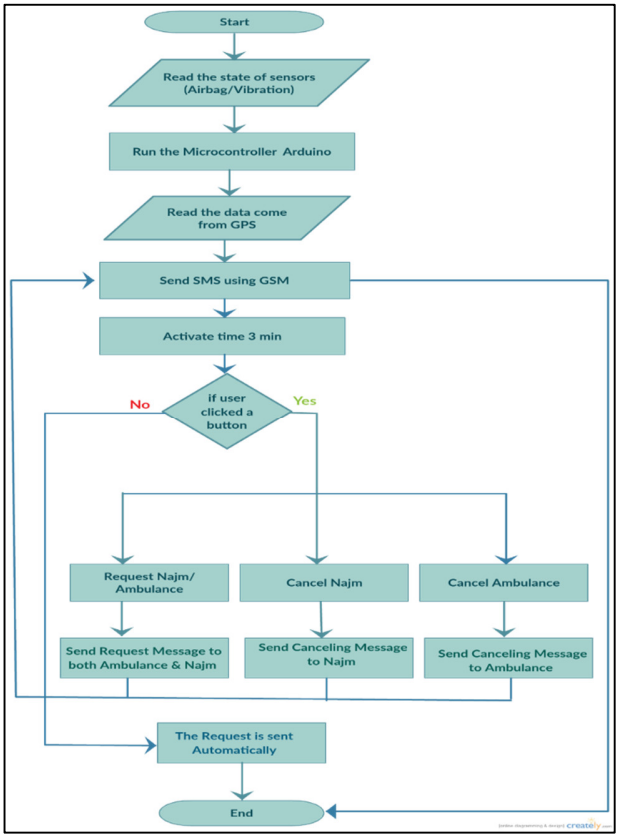

Fig. 5. Flowchart of Car Accident detection

2.3.Software Requirements

On the software level, several tools and applications have been used to help us in building diagrams effectively and to complete the proposed work successfully, listed as follows:

- ***Microsoft Word 2013:*** *It is a word processor program made by Microsoft Company that allows users to type using helpful tools such as spelling & grammar checker, inserting tables, graphs and save document. We use Microsoft word program to help us in writing this report and using tools to create system architecture, system flow chart.*
- ***System Flowchart Diagram:*** *A graphical representation of the data flow to represent how the system work using several symbols used to design specific actions of the system. We used the flowchart to show the data flow through system modules such MCU, GSM, GPS, Sensors and others.*
- ***Creatly.com Online Website:*** *Online application for collaborative diagramming used for drawing diagrams with temple & features. We used it to build up our use-case and sequence diagrams.*
- ***Use Case Diagram:*** *It is used to describe the functionality of the system and showing the interactions among the elements of the system. We use different use case diagrams to show the interaction between the Microcontroller and its components with the user.*
- ***Forum.Arduino Website:*** *It is the special Arduino helpful website. It provided us with many information that helped us in completing most of our system. it helped us in detecting the errors and knowing about them from the others experiments and experience that are recorded on the website. In addition, we knew from it the steps, to download the libraries that are needed to run the code, and how to use these libraries in the code with the hardware pieces and parts of the system. We also knew the different readings of the hardware parts and pieces. Moreover, it provided us with some codes of the other works that are related to our design.*
- ***Arduino IDE:*** *an open source Arduino Software (IDE), it helps in writing codes and compiling them, then uploading these codes into the Arduino board. We can run it on any platform and operating system, on Windows OS, Mac OS, and Linux OS. The environment code written in C language & based on processing & another open source software.*
- ***Autodesk Simulator Online Website:*** *Autodesk and Circuits.io is a powerful online application that supports most Arduino hardware components, such as Uno, Mega, Nano and other common boards. It comes with a range of features that aid rapid sketch prototyping and debugging as well. It helped us in making our electronic circuits and connect the hardware-simulated components together.*
- ***Citation Machine Online Website:*** *Citationmachine.net it is an online website that is used to cite the references in a proper way. It has different type of citations such as the APA, MLA or Chicago. We have used this website to cite our references in an APA citation format.*

2.4. Hardware Requirements:

At the hardware construction phase, the complete system architecture of the proposed system included:

- ***The Airbag sensor:*** *An airbag is a type of vehicle safety device and is an occupant restraint system. It consists of the airbag cushion, a flexible fabric bag, and inflation module and impact sensor. The sensor senses the airbag if it's blow because of an accident. It senses the air bag if it comes out, which means that the accidents happened.*
- ***Vibration sensor:*** *A transducer, such as that incorporating a laser or a piezoelectric crystal, which converts vibrations into an electrical equivalent such as a voltage. Also it's called vibration transducer. It senses the car's vibration which is specified not any small vibration.*
- ***GPS:*** *Which stands for Global Positioning System, is a radio navigation system that allows land, sea, and airborne users to determine their exact location, velocity, and time 24 hours a day, in all weather conditions, anywhere in the world. It will recognize the location of the accident.*
- ***GSM Module:*** *which stands for Global System for Mobile communication is a digital mobile telephony system that is widely used in Europe and other parts of the world.*
- ***Arduino Microcontroller:*** *MCU is the abbreviation for microcontroller unit is a small computer (SoC) on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals.*
- ***Power supply****: Is an electronic device that supplies electric energy to an electrical load. The primary function of a power supply is to convert one form of electrical energy to another and, as a result, power supplies are sometimes referred to as electric power converters.*
- ***16x2 LCD:*** *Liquid Crystal Display screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits.*
- ***Crystal (or 555 timer):*** *an integrated circuit (chip) used in a variety of timer, pulse generation, and oscillator applications.*
- ***MAX232:*** *a dual transmitter/dual receiver used typically to convert RX, TX, CTS, RTS signals. The drivers provide TIA-232 voltage level outputs (about ±7.5 volts) from a single 5-volt supply by on-chip charge pumps & external capacitors.*
- ***Driver IC****: Is an electrical/electronic circuit used to control another circuit or component, such as a high-power transistor, liquid crystal display (LCD), and numerous others.*
- ***Engine:*** *Is a machine with moving parts that converts power into motion.*

3 System Implementation

As alluded earlier, the proposed system is accomplished by using several software packages and hardware modules. Practically, we have used the following hardware modules along with Arduino MCU and used C language for system coding process:

- ***Airbag sensor:*** *We have use a digital Airbag sensor which requires three wires for connection: the ground pin wire (GND), the voltage pin (+ 5 Vcc) to supply the circuit with the required electricity and input pin to communicate with MCU.*
- ***Vibration sensor:*** *Similarly, we have used the digital vibration sensor. The vibration frequency for the sensor when connected with Arduino Uno microcontroller will range from 31 Hz to 65535 Hz. Also, the vibration sensor configured by setting an alarm time for the shock sensitivity to register a shock [14]. It works by shaking the sensor periodically and automatically give us an output as "1" (as an indicator of shaking or movement).*
- ***GPS Module****: NEO6MV2 module as GPS chip for this project. It requires four wires connections which is quite easy to combine with Arduino Uno MCU: GND pin, the voltage pin, the receiver pin (RX) connected to enable GPS module to receive digital signals from Arduino indicating that the GPS has to record a new location, and finally the transmitter pin (TX) that enables GPS module to transmit the location coordinates (latitude and longitude) to Arduino through digital I/O pins. This connection has a minor concern where GPS module uses 3.0 V logic, which is not compatible with the 5V supplied by Arduino. However, adding two resistors as a simple voltage divider concept can solve this issue. The resistors have regulated the flow of electricity in the circuit.*
- ***GSM Module:*** *We have use SIM900A GSM chip. It can be easily connected with Arduino via four wires connections: the GND pin, the voltage pin, the transmitter pin (TX), and finally the receiver pin. The GSM module should be configured with useful communication frequency band to be able access the SIM card (for example Mobily SIM card work in*

the frequency range 900 to 1800 MHz) to send SMS messages (or even do more communication functionalities).

- ***LCD Module:*** *We have used 16x2 LCD module. The circuit can be accomplished by connecting the LCD module with a small resister for voltage regulation along with light editor to control the lightness of LCD and the connection with Arduino MCU is accomplished using six wires connections: 7,8, 9,10,11,12 pins (all are digital I/O pins) in addition to two pins for Vcc and GND.*
- ***LEDs, Buttons and Timer:*** *We have used need 8 pins for LEDs with Arduino and one pin for the button (this button to operate the circuit). With all LEDs, we need eight resistors and one resister for the button. Also, we have used three buttons to perform the requested tasks (mentioned earlier). While the timer module has been added to assign duration times for users to press one of the buttons. If the specified time passed and the user didn't press any button, Najm and Ambulance will automatically be notified to come to the accident location.*

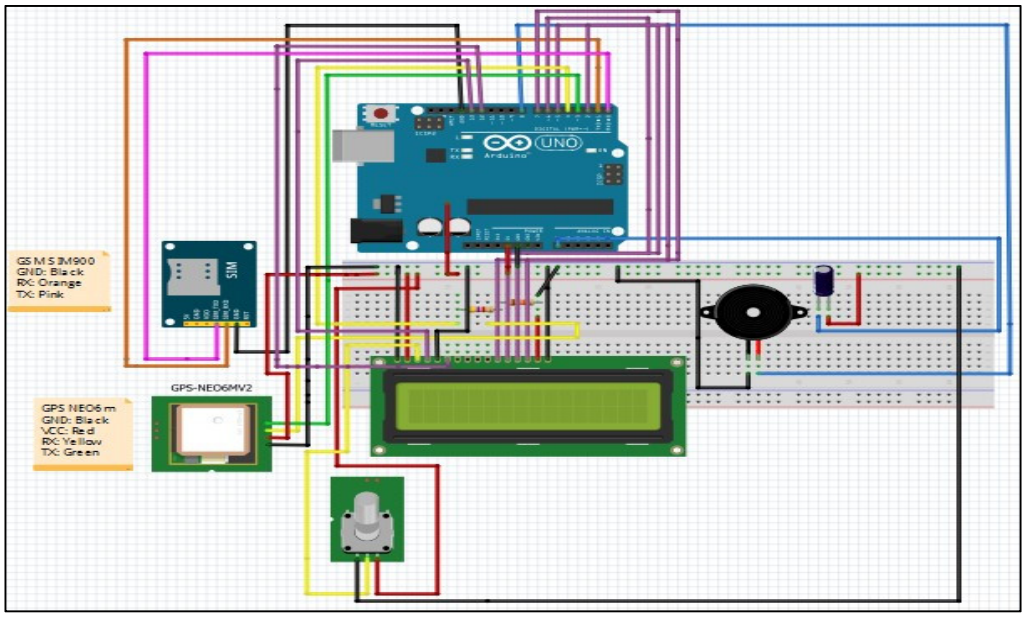

Fig. 6. Simulated diagram for the complete circuit design

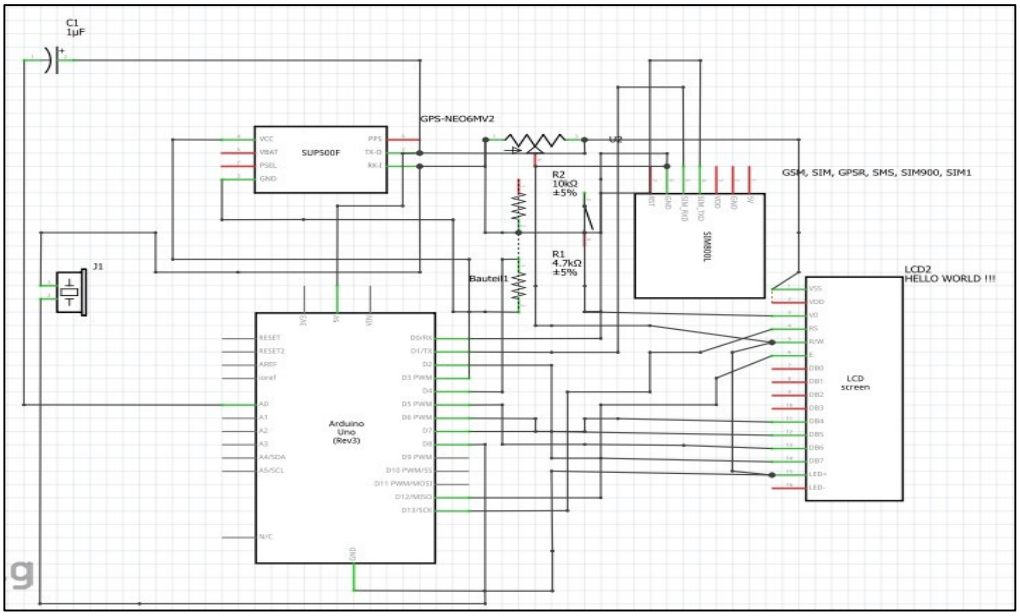

Fig. 7. Schematic diagram for the complete circuit design

As clearly seen, figure 6 shows the complete circuit design with full hardware components (by putting it all together). Arduino microcontroller connects all the components of the circuit together via breadboard and wiring system. Each component should be connected to both GND and VCC to be well operated (otherwise, it will be an open circuit, so the current could not flow through the circuit). Also, the vibration sensor will detect the accident and sends the signals to Arduino through the blue wire and the Buzzer used to make a beep sound when we shake the breadboard. Once the signals processed by Arduino, it will send a request to GPS module to run through the yellow wire, which is connected to RX (Receiver) pin in the GPS chip. Thereafter, the GPS will record the location (longitude and latitude) and send it back to Arduino through the green wire which is connected to TX (Transmit) pin. Moreover, the GSM system will receive the location from Arduino through the orange wire in RX pin that is connected to Arduino Microcontroller. The Message will be sent to Ambulance and Najm via GSM and there will be a message displayed on the LCD display that indicates that the message is sent! The LCD is connected to Arduino by six wires discussed before (the purple wires). In addition, there is a switch connected to LCD display by one pin to control the color of the lights to be displayed. Furthermore, the resisting elements (resistors) are used for limiting and regulating the flow of electricity in the circuit. Finally, for better explanation and understanding, we provide the schematic diagram for proposed system in figure 7. While the physical implemented system is given in figure 8.

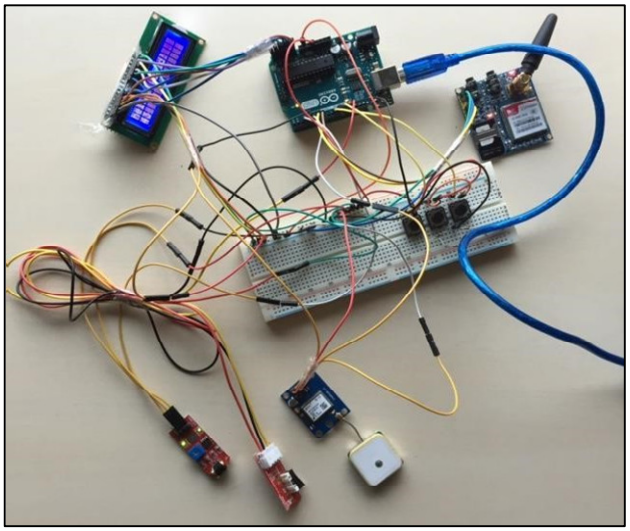

Fig. 8. Internal circuit of the proposed system

4 Overall Outcomes/Results

The overall output of the proposed systems (MBADS) is that the microcontroller will able to detect accidents through the mutual contribution of both vibration and airbag sensors. The resultant prototype of MBADS is given in figure 9. Note that the vibration sensor used here is SW-420 will detect accident by sensing the vibration of the car according to the vibration formula and frequency [14] and then it sends a digital signal (i.e. the value "1") to the MCU. Also, the airbag sensor will detect the accident when the airbag of the car is blowing and then it sends a digital signal (i.e. the value "0") to the MCU to indicate that the sensor detecting an accident. Figure 10 shows the hardware piece of both sensors.

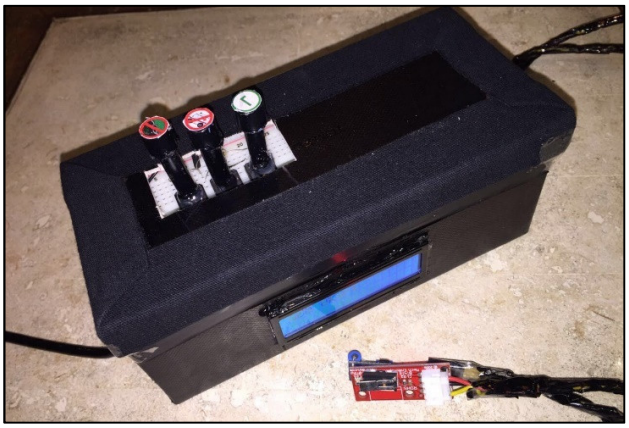

Fig. 9. Microcontroller-Based Accident Detection System

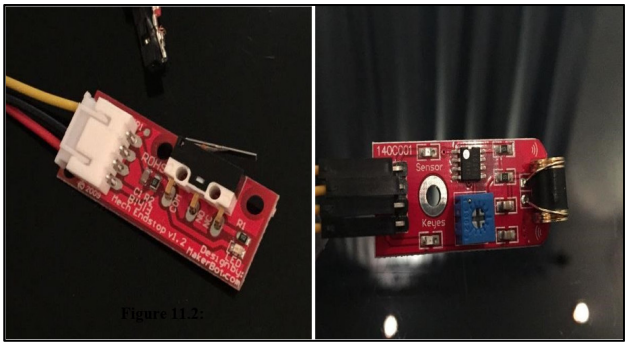

Fig. 10. The airbag sensor and the vibration sensor

Once the microcontroller received any signal from the sensors, it will inform the GPS to record the location, which in turns will directly record the current accident location by determining its longitude and latitude, and then return them back to the MCU. We linked our design to Google Maps which gives us the exact location in the map. Figure 11 a sample output results of the GPS code.

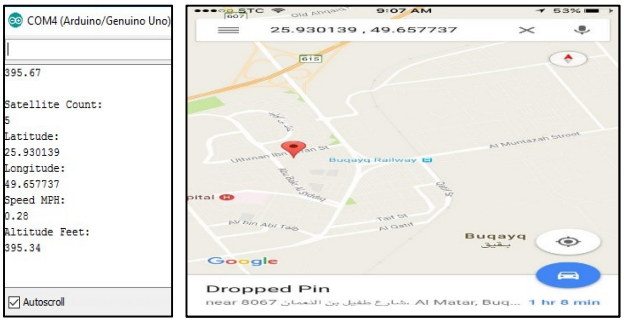

Fig. 11. (a) GPS output in Arduino IDE (b) GPS output in Google map

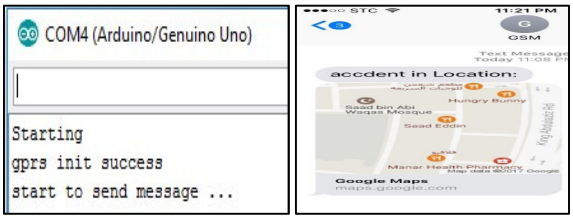

Fig. 12. (a) GSM Sending SMS(b) Received SMS Location by the mobile

Thereafter, MCU will convey the location recorded by GPS module to GSM Module to send the accident location to the Ambulance and Najm. The GSM Module is configured with AT commands [15] using our mobile numbers for sending and receiving SMSs to check for the system functionality. Figure 12 illustrates a sample of sent/received SMS location through GSM to our mobile number.

Fig. 13. The LCD showing the starting message

Finally, the system messages and results can be viewed via LCD (LCD12864 blue screen) such as the messages related to the sensors where the screen will specify which type of sensor is detecting the accident in that situation, the messages related to buttons to specify which button is clicked and many other messages. A sample of LCD messages is given in figure 13. In this sample, LCD message "System Start" is viewed when we power on MBADS.

5 Analysis of Overall Results

We have verified that the system works appropriately in many ways. For instance, table 3 shows test cases for each preliminary result that mentioned in the top section.

Table 3: The Analysis Preliminary Result Details

Functional Requirement	Test to be carried out	Expected	Actual
Airbag Sensor	The sensing of Airbag switch closing	Once the Airbag switch is closed/ pressed, it will send a signal to inform MCU.	We press the Airbag button, after that the Airbag light opened and sent a signal to MCU.
Vibration Sensor	The sensing of any pressure or shake once happening	Once the vibration sensor moved it will send a signal to inform MCU.	We have shacked the Vibration sensor then automatically it sent notification to MCU that there was a vibration that just happened.
GPS module	GPS responding to signals it received and is locating the current accident.	Once the GPS received the signals from MCU, it should locate the current position of the accident.	The GPS located the current position when it receives a request by MCU.
Sending Locations	Sending the location through GPS to GSM.	GPS should send the location to GSM once it locates the current (accident) location through MCU.	GPS has sent the current location coordinates to GSM.

GSM Module	GSM will send the location received from GPS to the prespecified mobile number.	GSM should use the SIM card loaded into the module to send a text message to the number given it in the code, once it received the location from GPS.	Once GSM received the location from GPS, it sent the location coordinates SMS message as Google map link to the mobile number.
LCD Circuit	LCD shows messages	Once the system starts LCD will show us "For Accident Detect" message, to indicate that the system is running. Also, once any message sent from GSM has, LCD will show "message sent".	LCD showed the "For Accident Detect" message when the system ran. After sending the location coordination through GSM to the mobile number, and the mobile received the message, LCD showed the "message sent" message.
Button # 1	Requesting Ambulance & Najm.	Once pressed within the first three minutes, the system will communicate with both Najm and the Ambulance.	When pressed, a message has been sent to both of Najm and Ambulance, the message contains the location of the accident as mentioned before.
Button # 2	Cancelling Najm.	Once pressed within the first three minutes, the system will cancel Najm request and call Ambulance only.	When pressed, a message has been sent to Najm for cancelling the request, the message is "Cancel the request, everything is fine, thank you"
Button # 3	Cancelling Ambulance.	Once pressed within the first three minutes, the system will cancel Ambulance request and call Najm only.	When pressed, a message has been sent to Ambulance to cancel the request "Cancel the request, everything is fine, thank you".

5.1.Detecting Scenarios & System Limitations

Generally, human designed systems can be reliable with precise readings up to a specific threshold, i.e. it will be limited with specific limitations. In this work, the proposed MBCDS can sense collisions with minimum vibration frequency of 4000 Hz (the lower limit of system vibration) to detect an accident occurrence and up to 6000 Hz as the higher limit. In our system testing phase. Also, normal vibration cases can be recorded by the system (starting from 1000 Hz to less than 4000Hz) such as strongly closing the door or car which may cause a small vibration (e.g. 1000 Hz) and it can be detected by our system. We have tried many Scenarios, most of them has been successfully detected and very few have shown right readings with a wrong outcomes and results, as shown in the giving table 4

Table 4: Validation and Verification using different scenarios

SN	The Scenario	Vibration rate	Outcome
1.	The user closed the door of the car, and due to that the vibration sensor detected the vibration rate.	1000 Hz	Normal vibration detection due to closing the door.
2.	The user quickly drove the car where the road was crowded, a car came suddenly in front of him, he went left strongly to avoid accidents. Thus, the vibration sensor detected the vibration rate.	1500 Hz	Normal vibration detection due to changing the road strongly, so it causes a vibration for the car.
3.	The user ridded over a trap, the car has vibrated, Thus, the vibration sensor detected the vibration rate.	2000 Hz	Normal vibration detection due to the tap.
4.	The user in the traffic didn't use the break at the appropriate following time and distance as he gently cracked the car in front of him, therefore, the vibration sensor detected the vibration rate.	4000 Hz	Vibration detection due to the car crash with the back end of front car.
5.	The driver cracked the car gently in front, due to that the vibration sensor detected the vibration rate.	4000 Hz	The vibration sensor did not detect the accident, as it has a rate which is lower than 4000!
6.	The user crashed a car strongly, due to that the vibration sensor detected the vibration rate.	4200 Hz	Accident is detected by the vibration sensor due to strong crash & vibration.

7.	When the car crashed strongly in the left and right sides, which also activate the airbag to be blow as well as the vibration sensor that will detect the vibration rate.	4800 Hz	Accident is detected by both vibration & airbag sensors due to the strong accident in the right and left sides.
8.	When the car crashed strongly in the front, which activate the airbag to blow and vibration sensor to detect the vibration rate.	5000 Hz	Accident is detected by both vibration & airbag sensors due to the strong accident in the front side.
9.	When the car crashed strongly in the front, which activate the airbag to be blow as well as the vibration sensor.	5000 Hz	The airbag sensor did not detect an accident while the vibration sensor does.
10.	When the car crashed strongly in the front, which activate the airbag to be blow as well as the vibration sensor.	5500 Hz	Vibration and Airbag sensors do not detect an accident
11.	The user crashed a car strongly and his car has been flipped, due to that the vibration sensor detected the vibration rate.	6000 Hz	Vibration detection due to the strong accident and car flipping.
12.	When the accident occurs, and the user is awake, and the car is not damaged, the user can press cancel both Najm and Ambulance. If suddenly the car release smoke, the user can request both, then cancel Ambulance to request Najm only.	Button 1, 2 and 3.	Najm will come to the accident location, after pressing Request button & cancelling Ambulance

5.2.Testing the Scenarios

For better prototyping testing, we have installed our MBADS into a small car as shown in the figure 14. We have used two vehicles: a sedan car (equipped with our MBDAS) and a small truck to perform some simulated accidents and to test the accident detection by the sensors. Also, we have used two mobile phones with different numbers to simulate Najm and Ambulance to receive messages from the GSM. Then, we have tried many scenarios (as explained in the previous section).

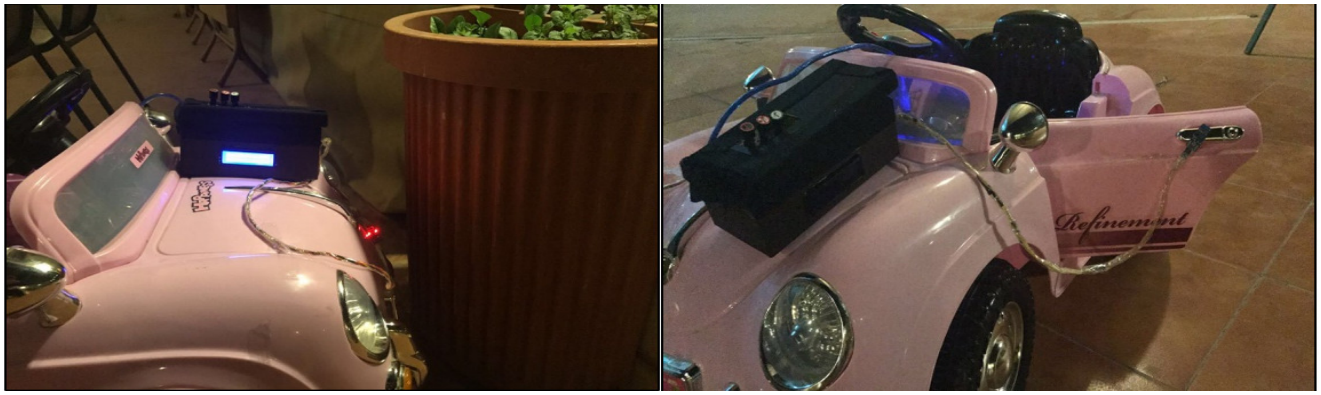

Fig. 14. Testing the System

6 Conclusions and Future Works

It is important that every car has the accident detection system to decrease lots of loss. We understand the significant importance of such system as it helps the whole community and provides an additional safety for driving people. We wish to apply our MBADS into Saudi Arabia which will be an evolution of the mechanics and the car's production. The proposed MBADS can be easily added to any vehicle system (personal/organizational) to operate on response to an accident. It will be connected as an integral part with vehicle's computer unit and in a fixed protected place to avoid damages in case of accident. Many parties will benefit from this technology especially the medical side who will be very thankful due to the lots of time added to relieve the injured. In the future, we are planning to improve our system and having high capabilities to increase the usability. We would like to publish this work all around the world, to benefit others. Also, we are planning to link it to a web-based application which to do statistics of the latest accident

happened nearby, their locations, how many cars are damaged and how many people are died, injured or fine. Moreover, it could help in providing information about the crowded areas and streets to avoid it. It'll give percentages of the benefited people, also it will provide diagrams and graphs to show these statistics. Furthermore, we are planning also to use a Voice Recognition technique as a support for the buttons, instead of clicking the buttons, the user can say the orders by his/her voice. For example, if the user said, "Cancel ambulance" instead of pressing the button, the system will send a canceling message to the ambulance, to make it easier.

7 Acknowledgment

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