Smart Car: An IoT Based Accident Detection System

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***Abstract* - The Internet of Things (IoT) offers limitless possibilities to both the public and private sectors. Automobile manufacturers are interested in IoT applications to increase the safety of their vehicles, to meet customers' demands and ultimately to offer cutting-edge products which maximize profit. The healthcare industry is concerned with how the IoT can improve the speed and accuracy of communication. This paper describes the feasibility of equipping a vehicle with technology that can detect an accident and immediately alert emergency personnel. When there is a car accident someone has to actively seek help such as calling 911 for emergency services. There is no automatic notification to the police, ambulance, friends, or family. The Internet of Things (IoT) can be used to produce an automatic notification and response to the scene. A signal from an accelerometer and a GPS sensor are automatically sent to the cloud and from there, an alert message will be received by whoever is subscribed to that car. The signal will indicate the severity of the accident and the GPS location. The ambulance will use the GPS coordinates to get to the scene quickly.**

Keywords - ThingSpeak, Twilio, accelerometer, GPS sensor, smart accident detection.

I. INTRODUCTION

The Internet of Things (IoT) is the term used to refer to the communication between people to things and things to things. In today's society, technology is improving at an exponential rate. Broadband Internet is more widely available and more cost-efficient than ever before. Technology costs are going down and as of 2018, 36% of the world's population use smartphones. The number of smartphone users worldwide is forecast to grow from 2.1 billion in 2016 to around 2.5 billion in 2019 [1]. IoT is the focus of research, and industries are investing heavily due to the potential benefits of IoT in various fields [2]. All of these things are creating a ripe environment for IoT.

The health-care industry is benefiting from the technological advances that IoT has to offer with improved access to care, increased quality, efficiency, and reduced costs. As the technology for collecting, analyzing and transmitting data in the IoT continues to grow, more IoT-driven healthcare applications, services, and systems emerge [2]. Currently, many vehicles are equipped with an automatic crash response system that can communicate with a server in the Cloud alerting a paid provider of an emergency. Once the provider has been alerted, an operator communicates back with the driver to get further instruction and sends emergency personnel if necessary. This paper proposes a system that can eliminate the need for an operator. When the vehicle is in an accident it communicates directly with emergency services and family members giving the severity of the accident, GPS location, and the car ID. Ambulances are currently capable of sending patient information to the hospital. The uniqueness of this project is that sensors detect an accident and information is sent immediately to the ambulance, thus eliminating the need for an intermediary step.

II. RELATED WORKS

An overview of the relevant literature reveals that IoT has many applications. Communications between Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and the combination of V2V and V2I, commonly known as V2X, is currently gaining momentum as an emerging technology, especially when combined with Internet access and smartphone-based applications in the field of transportation [3]. All of these vehicle networks contribute to Intelligent Transportation Systems (ITS) paradigm by providing applied serves related to traffic, mobility management, and safe driving [3]. One study developed an Android application that displays maps with location information of relevant nearby vehicles. The application was able to warn the user about an approaching ambulance, allowing the driver to make navigation decisions based on that information [3]. Another similar research project collected the GPS location of emergency responders and gave the contact information of the nearest responder to the users requesting the help. A smartphone application was used in this scenario as well [4].

A closely related study proposed a system that controls the speed of a vehicle in school or construction zones, with the intent of reducing reckless accidents. Just before the vehicle is in a transmitter zone, the vehicle speed is controlled by receiving a signal from an RF transmitter [5]. Another relevant work proposed an IoT-based live monitoring system for patients with the risk of heart attack and uneven body temperature [6]. The patient purchases a device that continuously monitors vitals and then alerts the hospital if the patient's condition becomes critical. The hospital then dispatches an ambulance. Similarly, nine faculty members from Qatar University and the Harokopio University of Athens proposed a remote monitoring and diagnosis system for elderly subjects called Remote Elderly Monitoring System (REMS) [1]. They described a progressive Smart Ambulance System (SAS) that enables fast dispatching of ambulances to locations of medical incidents and treatment of a patient on-board with the assistance of remote healthcare personnel (who can make preliminary diagnosis and preparations) [1]. They were interested in real-time diagnosis of medical issues, telecare, and telemedicine, remote monitoring of patients, as well as computer-assisted smart transportation in case of emergencies. Each component in the system has a level of criticality. Systems-of-Systems (SoS), is mainly composed of hardware (e.g., sensors, smartphones) and software (e.g., specialized OSes, Cloud services) that can execute several applications of different criticality [1]. Similar work was done exploring an IoT health-care application involving wearable and implanted devices that alert emergency personnel and/or family members during a medical emergency. Figure 1 illustrates their proposed system to implement a wireless sensor network to form a patient monitoring system and take necessary actions under critical conditions [7].

III. PROPOSED SYSTEM

In this system, there will be an automatic response to an accident. Figure 2 shows the use of sensors and microprocessor to detect an accident and send the location to the Cloud. From the Cloud, the notification is sent to the hospital, ambulance and emergency contacts. The unit involves the use of a Raspberry Pi (Fig. 3(a)) [15] single board computer and GPS (Fig. 3(b)) [16] which takes advantage of data such as position and location. The device is meant to immediately detect a collision involving the vehicle it is installed in. This is done using the ADXL345 accelerometer (Fig. 3(c)) [17]. The ADXL345 has been shown to work with other projects using Raspberry Pi 3B+. It has a triple axis feature and was easy to mount in the vehicle. The x-axis refers to a forward or backward acceleration in order to detect front or rear end collision. The y-axis reading detects an impact from either side of the car. The z-axis reading is used to detect a collision from above or below. The system operational flow chart is presented in fig. 4.

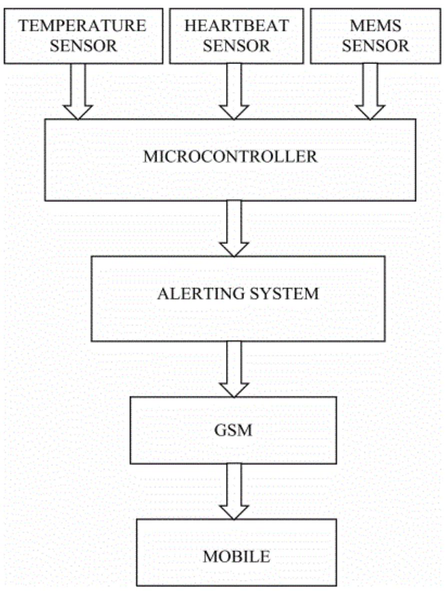

Figure 1: Block diagram of the proposed system [7]

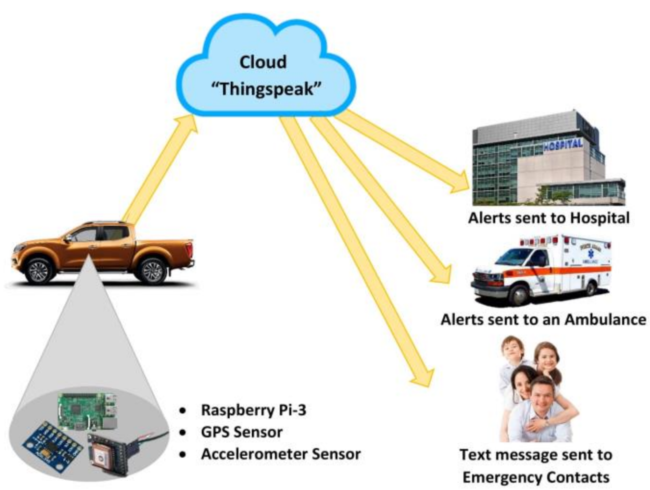

Figure 2: Overview of proposed system

Constantly monitoring the vehicle's velocity and acceleration, this device allows the microcontroller to sense an extremely rapid shift of position. The change in velocity translates to an accident for the Raspberry Pi. The corresponding collision is then rated based on severity. With level 1 being the least severe up to level 3 being the most, the urgency for police and paramedics to arrive at the scene can be assessed. After the impact is recorded and sent to the servers, the device is programmed to then find the GPS coordinates of the vehicle it is installed in. Based off of the coordinates given by the GPS unit, data will be uploaded to the database. This data will be used to aid authorities in quickly locating the accident in order to help whoever is involved. The data will also be used to alert the corresponding emergency contact of the vehicle's owner. It is important to know that the proposed system will only track location in the event of an accident. Until a collision has occurred, the device will maintain the privacy of the motorist and will keep the GPS module in an idle state. When activated, it takes a few milliseconds for the GPS board to wake-up and provides accurate results. The Raspberry Pi will continue to monitor the location every five seconds and upload this data to the database. At the same time, it also looks for a 'clear' variable on the database that is set by the server. In the event that the car has been found, police arrive on the scene, and/or the crash is marked as safe, the server operator then marks that car with the particular unique car identifier 'clear'. The Raspberry Pi then read this value, and clears its local variables, and awaits the next impact.

Figure 3(a): Raspberry Pi 3B+ [15]

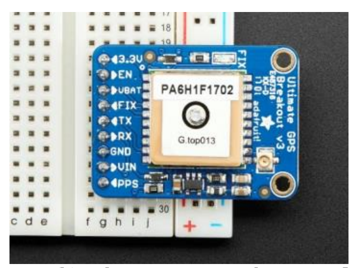

Figure 3(b): Ultimate GPS Breakout - V3 [16]

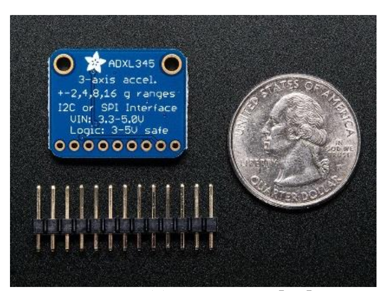

Figure 3(c): ADXL345 [17]

In the event that the felon leaves the scene and tried to escape the location, the system is programmed to circumvent such a scenario. When the felon starts driving, the system will continuously track the GPS coordinates of the car. If the suspect runs, parks the car in their garage, and turns off the ignition, the system will draw power from the battery and continue its cycle until it receives the 'clear' value from the database. As the system operates on very little power, this will not be an issue of draining the car's battery.

Each mobile unit will constantly be in communication with the database. The database server is programmed on Thingspeak [11] API. It will pull the values from the database, use them, and will be able to upload the 'clear' alert that will be registered by the mobile unit in order to dismiss their alerts. As soon as the mobile unit is notified of an accident and has collected the necessary data, the server begins collecting. It receives the values of the initial crash, including the severity level, the crash's longitude, and latitude, as well as the automatic longitude and latitude updates that start filtering in every 5 seconds. The server's responsibility is to pull all of this information. Upon receiving the crash variables, it sends a message to both the family and authorities with the crash level and the location. The location is determined using a Google Maps API. In order to do so, the longitude and latitude of the crash are sent to Google, and the corresponding street number, road name, city, state, zip code, and the country is returned in a string variable. This is then saved and used in alert messages.

The server also updates itself to keep up with the infiltrating longitude and latitude updates every five seconds. If these new coordinates are drastically different than the original crash – determined by the allowed safe radius, then the server goes into what we call "running" mode. This means that until the operator clears the alerts based on that car's particular identification number, the alerts will be processed every five seconds. This internal of alerts allows for a virtually live tracking of the vehicle, while still saving memory, bandwidth, power, and computational resources. The server is the only device that can clear the mobile unit and reset them until the next impact. This assists with tamper-proofing the system in order to keep felons from disabling the device or rendering it unusable.

IV. Implementation & Results

A 2003 Ford Taurus was fitted with the proposed system. The GPS was resting on the back seat along with the Pi. For safety, the parameters that indicate an accident were changed to lower values as in see Table 1. This enabled the test drive to mimic collisions without actually being in a collision. Fig. 5 shows an accident detected because *x = +0.38*. This was tested by speeding up. It mimics a rear collision. When the accident is detected the software collects GPS location as in Fig. 6, and this information was sent to the ThingSpeak cloud server. In addition, the GPS coordinates were sent to the subscriber as a text message via the Twilio [12] messaging service.

The data are summarized in Table 2. The values in bold were sufficient to trigger an accident detection. Under hard braking, the forward rotation of the car achieved a z-axis trigger. Note: The last column in Table 2 shows the magnitude of the acceleration.

Table 1: Testing Parameters

	a_x	a_y	a_z
Safe	$\lvert a_x \rvert < 0.2$ g	$\lvert a_y \rvert < 0.2$ g	$\lvert a_z - 1 \rvert < 0.2$ g
Accident Detected	$a_x \geq +(0.2)$ g Rear collision	$a_y \leq -(0.2)$ g Right side collision	$(a_z - 1) \geq +(0.2)$ g Hit from underneath
	$a_x \leq -(0.2)$ g Front collision	$a_y \leq -(0.2)$ g Left side collision	$(a_z - 1) \leq -(0.2)$ g Hit from above

Table 2: Testing Data

	a_x	a_y	a_z	$\sqrt{a_x^2 + a_y^2 + (a_z - 1)^2}$
Hard Acceleration	**+0.38**	+0.14	+0.90	0.42
Hard Breaking	**-0.71**	+0.16	**+1.24**	0.77
Hard Left Turn	+0.11	**+0.40**	+0.88	0.43
Medium R. Turn	+0.02	**-0.28**	+0.93	0.29

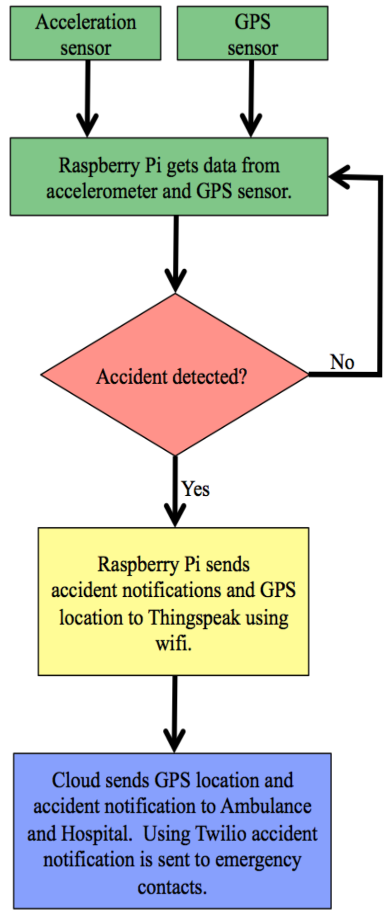

Fig. 4. Block diagram of the proposed system.

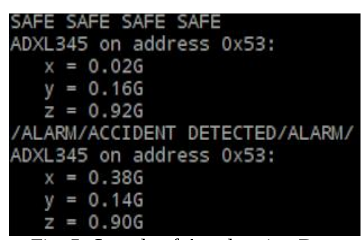

Fig. 5: Sample of Acceleration Data

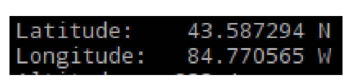

Fig. 6: Sample of GPS Data

V. DISCUSSIONS

Even though the proposed has been designed to be simple, rugged, easy to use, and versatile, there still exist some known challenges. Some of the obstacles that could be overcome are the adaptation of A-GPS technology. This means that the GPS location would be a combination of satellite triangulation, but it will also use cellphone towers as a point of location triangulation. A-GPS augments that by using cell tower data to enhance quality and precision when in poor satellite signal conditions [13]. The reasoning for this is when GPS signal is low, weak, or cannot be established. In cities like New York, Chicago, Detroit, San Francisco, etc. the tall buildings and skyscrapers will provide a struggle to get good reception of satellite GPS location. However, with being able to use the cell phone towers in these areas as well, the location of the vehicles could be a lot more precise. Not only in large cities is this beneficial. For instance, if a runner parks his/her car in the basement of a parking garage, the GPS could be shielded by all of the reinforced concrete above it, however, the A-GPS could still provide an accurate location of the vehicle.

Connection to the internet is becoming easier, faster, and more widespread. By creating a network of these devices, connectivity to the server and authorities can greatly benefit the economy. It is widely believed that the advances of inter-vehicle communications will reshape the future of road transportation systems, where inter-connected vehicles are no longer information- isolated islands [14]. By creating a widespread use of proposed systems, those involved in an accident will be much less tempted to leave the scene. In the event that this still happens, the proposed system will be able to successfully track the felon and hold him or her responsible.

In addition, future work may include providing a network between proposed systems to create an accident alert. In an Intelligent Transport System, interconnected mobile units could communicate together to warn of a unit which has sensed an accident. This could communicate with the vehicle's computer to notify the driver of an accident nearby. Vehicles can exchange traffic congestion and road conditions to construct an up-to-date load conditions database from which the best path to destinations are computed [14].

VI. CONCLUSION

IoT is a rapidly growing area of technology, and it has been successfully deployed in a car and a few tests have been conducted. Upon accident trigger, notification and GPS location were automatically sent to the cloud. The accident notification was immediately sent to cells phones using Twilio and the GPS location was made available on ThingSpeak for anyone with the login credentials to access. The proposed device is designed to save lives by having emergency personnel respond to accident scenes quicker, as well as track the felons who decide to flee the area of an accident in which they were involved.

ACKNOWLEDGMENT

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