IE 407 - Internet of Things (IoT)

Automatic Traffic Accident Detection and Notification

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Declaration

We hereby declare that

1) The thesis comprises of our original work towards the degree of Bachelor of Technology in Information and Communication Technology at Dhirubhai Ambani Institute of Information and Communication Technology and has not been submitted elsewhere for a degree,

2) Due acknowledgment has been made in the text to all the reference material used.

Chirayu Sheth Abhishek Modi

Certificate

This is to certify that the thesis work entitled ***Automatic Traffic Accident Detection and Notification*** has been carried out by Chirayu Sheth and Abhishek Modi for the degree of Bachelor of Technology in Information and Communication Technology at Dhirubhai Ambani Institute of Information and Communication Technology under my supervision.

Dr. Sanjay Srivastava
Thesis Supervisor

Acknowledgement

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Abstract

The Internet of Things-enabled Intelligent Transportation Systems (ITS) are gaining significant attention in academic literature and industry, and are seen as a solution to enhancing road safety in smart cities. Due to the ever increasing number of vehicles, a significant rise in the number of road accidents has been observed. Significant research on the use of Information and Communication Technologies (ICT) for efficient and prompt rescue operations. The majority of such works provide sophisticated solutions that focus on reducing response times. However, such solutions can be expensive. Given this, we present a novel Internet of Things-based accident detection and reporting system for a smart city environment.

One approach to eliminating the delay between accident occurrence and first responder dispatch is to use in-vehicle automatic accident detection and notification systems, which sense when traffic accidents occur and immediately notify emergency personnel which are nearby. This project describes how we can automatically detect traffic accidents using accelerometers and gyroscopes, immediately notify a central emergency dispatch server after an accident, and provide situational awareness through GPS coordinates and communication channels.

Chapter 1
Introduction

1.1 Current Scenario and Observation

Traffic accidents are a major public issue worldwide. The huge number of injuries and deaths as a result of road traffic accidents uncovers the story of the global crisis of road safety. In India, one of the major reasons for premature death is road accidents. Reasons for the increasing number of accidents are increased number of vehicles, unskilled drivers, use of mobile phones while driving, bad road conditions, overloading and poor traffic management.

When an accident takes place, there is this unwillingness of people to call an ambulance, because they have the fear that the hospital authorities and the police might annoy them by asking them to visit the hospital and police station regularly for enquiry. Apart from the fear of being falsely implicated, people also worried about becoming trapped as a witness in a court case - legal proceedings can be notoriously protracted in India. And if they helped the victim get to hospital, they feared coming under pressure to stump up fees for medical treatment. So people resist calling an ambulance in such cases.

The most obvious reason for a person's death during accidents is unavailability of the first aid provision, which is due to the delay in the information of the accident being reached to the ambulance or the hospital. Thus, in the case of incidents involving vehicular accidents, response time is crucial for the timely delivery of emergency medical services to accident victims and is expected to have an impact on fatalities. Moreover, each minute passed while an injured crash victim does not receive emergency medical care can make a large difference in their survival rate, for example, analysis shows that decreasing accident response time by 1 minute correlates to a six percent difference in the number of lives saved. [2]

In hilly regions like Himalayan road, having valleys on one side, and very few barriers to safeguard the vehicle from an accident, it takes around 2-3 days to locate the vehicle itself, which leaves behind no chances of the victim of the accident to come out alive.

An important indicator of survival rates after an accident is the time between the accident and when emergency medical personnel are dispatched to the scene. Eliminating the time between when an accident occurs and when first responders dispatched to the scene decreases mortality rates.

1.2 Related Work

The early experiments with smartphone-based accident detection systems are discussed like, the authors[3] developed a car accident detection and notification system that combines smartphones with vehicles through the second generation of On-Board-Unit (OBD-II) interface to achieve smart vehicle modeling, offering the user new emergency services. The authors have developed an Android application that in case of an accident detection sends an SMS to a pre-specified address with relevant data about the accident and an emergency call is automatically made to the emergency services. The only requirement to achieve the goal of this system is that the vehicle supports the OBD-II standard. The OBD-II standard has been mandatory since 2001 in the U.S and there is also a European version of this standard, thus this solution applies to all vehicles in the U.S and European countries and is not available in all vehicles in other countries. Besides that, the maintenance or upgrading process of this system is an expensive operation.

The current solution that provides help in case of a vehicle accident is concerned with mostly one sensor. Author[4] proposes a system that detects accidents automatically using GPS and notifies all the nearest hospitals and police. This is a hardware-based system and uses only one sensor to detect an accident; if this sensor fails, the whole system fails. Other systems use gravitational force to detect accidents and inform rescue teams. These systems[5] have the same problem that they use only one sensor. Reliance on a single sensor also carries the risk of false positives—the reporting of an accident in the case that one did not occur. Other systems[6] use accelerometer information as a trigger to notify emergency response about an accident.

1.3 Motivation

Road accident records in India say that 16% of the world's road accident deaths happen in India only, while India has only 1% of the world's road vehicles.[7] In Mumbai's 26/11 bomb blast 195 people were killed, but if we checked about the death victims in road accidents in India, then we find that 250 people die in road accidents in India every day. If we discuss the data, then Mumbai's 26/11 type of bomb blast happens every day in India. Now, it is a big question to everybody which one is a big killer, Road accident on Mumbai's 26/11 bomb blast. Other countries are also facing these types of problems.[8] Some statistics show that the main cause of death of the people in road accidents is the delay in providing emergency services.[9] Having known about such types of statistics, it was thought off to make a detection system which can give the information or alert about the accident that occurred to the police control room or family member of the accident victim.[10] This vehicle detection and alert system may help the human by saving the life of accident victims.

The point to focus here is that when an accident occurs, it is not just the victim who suffers. It can be a case that the victim was the only bread-earner of the family. The entire family suffers due to the unfortunate incident, which would have not occurred if there was some proper mechanism. And it takes us immense pleasure to suggest some mechanism to help people.

Chapter 2
Problem Statement

2.1 Definition

Various enquiry reports of road accidents were studied and it was clear that the major reason for road accident death was the delay in providing help to the accident victims. Eliminating the time between when an accident occurs and when first responders are dispatched to the scene decreases mortality rates.

One approach to eliminating the delay between accident occurrence and first responder dispatch is to use in-vehicle automatic accident detection and notification systems, which sense when traffic accidents occur and immediately notify emergency personnel which are nearby.

The MPU6050 based transportation system proposed would inform the police control room or accident victim's family members as well as to the nearby hospital about the accident instantaneously, so that help to the injured in a road accident could be delivered as soon as possible. The medical emergency care unit would dispatch to the accident location without any delay, thereby increasing the victim's chances of survival.

We propose an IoT based system that detects an accident through low-cost devices. Our proposed system consists of two phases:

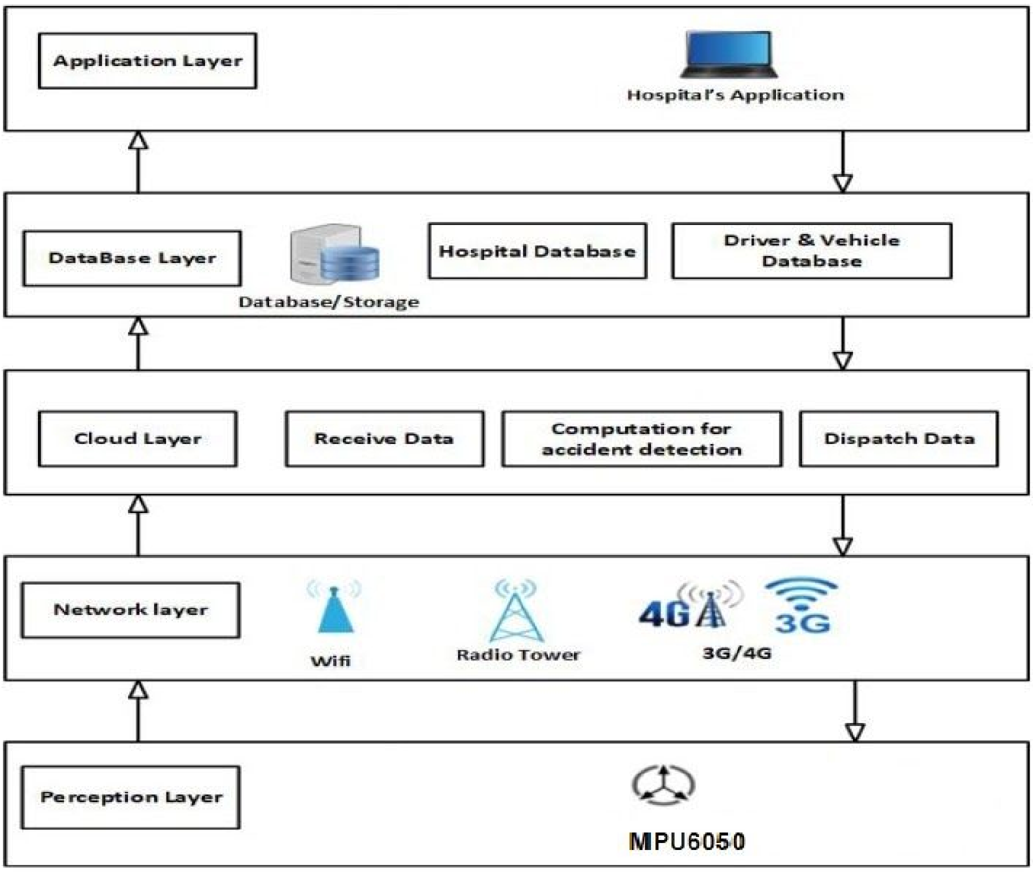
1. Accident detection
2. Notification system

An accident is detected by the threshold analysis. Whenever the readings of data from the sensors exceed the threshold value, it is detected as an accident. Also to avoid false positives we are taking feedback of accidents from users though the false positives will be rare in the proposed system, Upon detecting an accident, the system will inform the nearest hospitals and ambulances. By using two sensory inputs, the system results in fewer false positives and more accurately detects accidents, outperforming earlier methods.

Chapter 3
System Design

3.1 Layered Architecture of ADNS

In order to address the current limitations in accident detection systems, we propose a novel ***Accident Detection and Notification System (ADNS)***.



The architecture of the ADNS is layered architecture as shown in the figure. The system architecture of ADNS comprises five different layers.

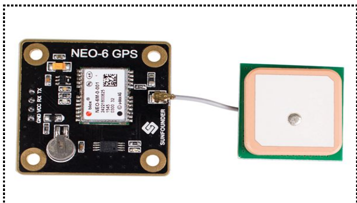
1. Application Layer
2. Database Layer
3. Cloud Layer
4. Network Layer
5. Perception Layer

The main purpose of Perception Layer is to collect data from the different sensors. This data is related to gravitational force (g-force), angle and the location of the vehicle (detected by GPS). Now the Network Layer provides the connection between the Perception Layer and the Cloud Layer. This layer receives data from different sensors and location through sensors available in the Perception layer. The Network layer enables WiFi or cellular communications to transmit the data into the cloud server. The Cloud layer has the algorithm for accident detection through the threshold values of different sensor data. If the Cloud layer identifies the accident detection based on data analysis, then it informs the nearest hospital about an accident with the data of the current location (detected by GPS) of the victim. It uses the data of the Database Layer to determine the nearest hospital. Then, all the information is transferred to the Application Layer.

3.2 Components

3.2.1 GPS Module (NEO-6M)

The NEO-6M GPS module is a well-performing complete GPS receiver with a built-in 25 x 25 x 4mm ceramic antenna, which provides a strong satellite search capability. With the power and signal indicators, we can monitor the status of the module. The module can save the data when the main power is shut down accidentally.



Specifications:

- 5Hz position update rate
- Operating temperature range: -40 to 85°
- The cold start time of 38 s and Hot start time of 1 s
- Supply voltage: 3.6 V max
- Configurable from 4800 Baud to 115200 Baud rates. (default 9600)
- Separated 18X18mm GPS antenna

Pros:

- Comes with backup battery and antenna, nothing additional needed
- Standard UART
- Fast

Cons:

- Antenna comes on a separate PCB, this makes it a bit fragile.

3.2.2 GSM Module (SIM 900A)

Specifications:

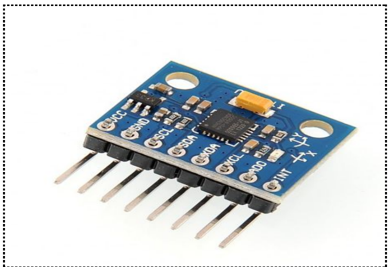
- Single supply voltage: 3.4V – 4.5V in vcc pin
- Power saving mode: Typical power consumption in SLEEP mode is 1.5mA
- Operating Temperature: -30ºC to +80ºC
- Supports CSD, USSD, SMS, FAX
- Supports single SIM card
- Communication by using AT commands

Pin Details:

- **Important pins:** TXD, RXD, GND, MIC_P, MIC_N, SPK_P, SPK_N, VCC, SDA, SCL
- **Mic+ and Mic-:** pins are used to connect the microphone with Modem.
- **Spk+ and Spk-:** pins are used to connect speakers with Modem.
- **Vcc:** is supply voltage, which is necessary for GSM to work.
- **Tx and Rx:** pins are used to connect a microcontroller to GSM. The Microcontroller's Rx pin will be connected to the Tx pin of the GSM module and the Microcontroller Tx pin will be connected to the Rx pin of the GSM module. Such that whenever command from the controller will be sent, GSM will work on that and then it transmits the result to the controller.
- **SDA:** Serial Data
- **SCL:** Serial Clock
- **LEDs:** Network, Status, Power

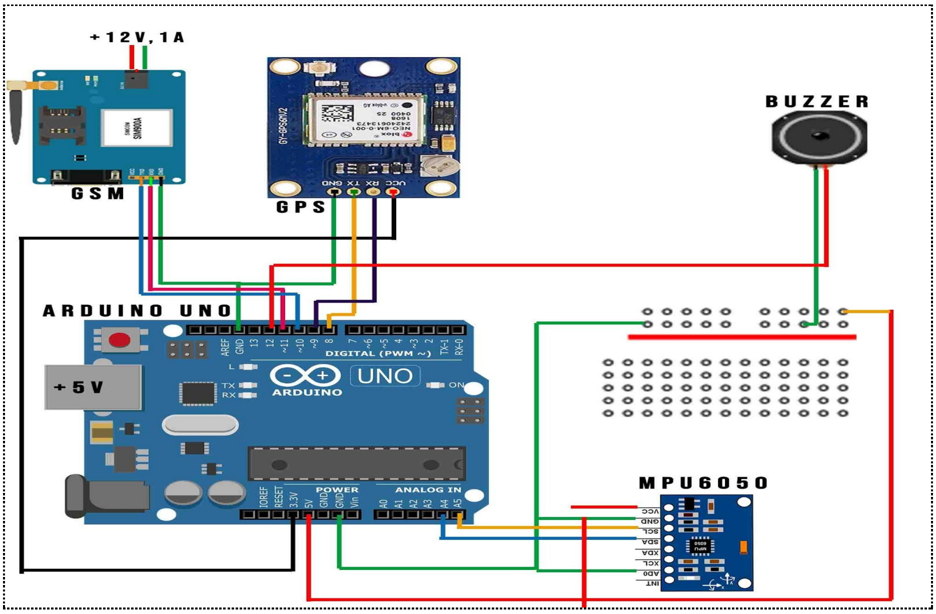
When the modem is powered up, the network LED blinks every second and after network registration it will start to blink after every 3 seconds. This shows that the modem is registered with the network. Status led is indicated by blue led. It will turn on if gsm is detecting the sim card properly.

3.2.3 MPU 6050



- The MPU 6050 to be the most reliable and accurate IMU (Inertial Measurement Unit) sensor. Apart from that it's cheap from the other sensors, the MPU 6050 performs much better too.

❖ The MPU 6050 is a 6 Degrees of Freedom (axis) IMU sensor, which means that it gives six values as output.
❖ Three values from the accelerometer and three from the gyroscope. The MPU 6050 is a sensor based on MEMS (Micro-electro-mechanical Systems) technology.
❖ Both the accelerometer and the gyroscope are embedded inside a single chip. This chip uses I2C (Inter Integrated Circuit) protocol for communication.



**Expected Design*

3.3 Databases

3.1.1 Hospital Database

To inform the hospitals in an emergency, the system must know all the nearby hospitals and forward the message to it.

H_ID	H_Name	H_Address	H_Number
h1	Civil	Gps coordinates	99988 82222
h2	VS	Gps coordinates	98765 43210
h3	Sterling	Gps coordinates	98989 89898

**Here, GPS coordinates include latitude and longitude of Hospital.*

Chapter 4

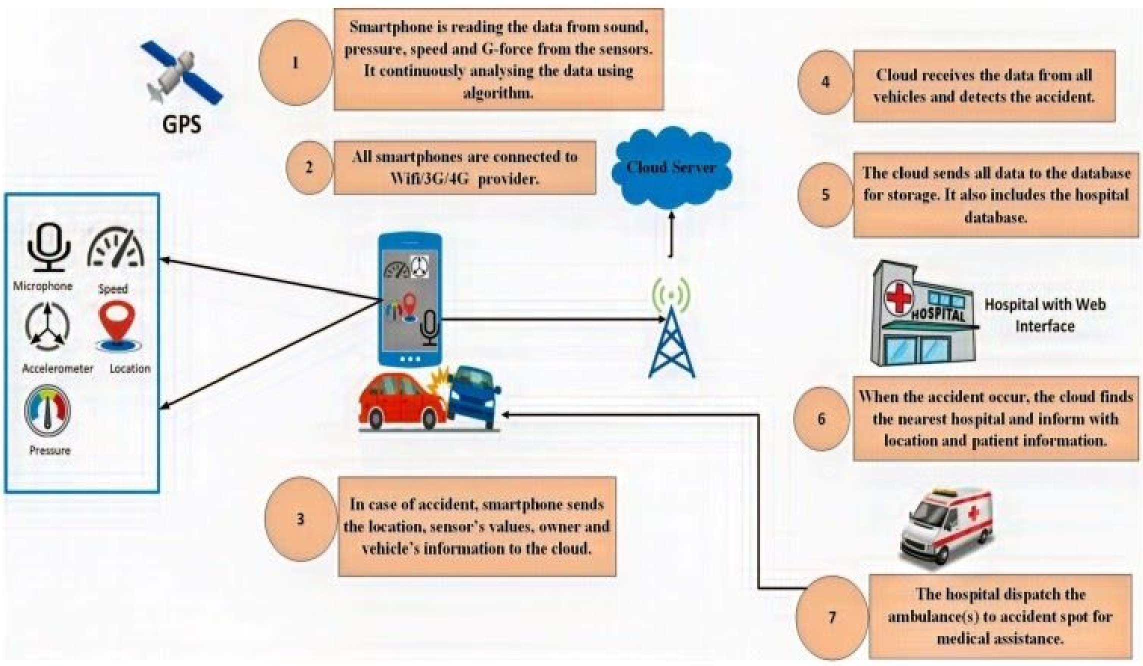
Proposed Methodology

4.1 Overview of ADNS

The main objective of this architecture is to enhance the accuracy of accident detection. This system consists of two phases:

i). Accident Detection Phase

ii). Notification Phase



4.1.1 Accident Detection Phase

Accident detection is used to prevent unfortunate incidents that result in damage or injury and hence reduce death rates from road traffic accidents. An accident might be any of the following three types:

1. Roll-Over
2. Collision
3. Combination of the above two

4.1.1.1 How to Detect Roll-Over

To detect Roll-Over we need to find the angular position of Car. That can be measured using two sensors. Gyroscope and Accelerometer. But both of them have some limitations. So let's see how to detect roll-over using them and limitations of them and solutions to the limitations.

In the case of using gyroscope data, the angular position is calculated by integrating the angular velocity over time.

$$\theta = \theta_0 + \int \omega(t)dt$$

Where,

- θ = angle (deg)
- $\theta 0$ = start angle (deg)
- $\omega(t)$ = angular velocity (deg/sec)
- dt = time (sec)

However, calculating the angular position using the accelerometer data requires determining the position of the gravity vector (i.e. G-force). This can be done by using tan^{-1} function. In both cases, there are some issues making the acquired raw data noisy and very hard to use without filtration.

1) The gyroscope provides accurate measurements that are not subject or susceptible to external forces. However, when the system returns back to its original position, there is a tendency to drift and not return to zero. This is because of the integration over time. Therefore, gyroscope data are reliable only in the short term because it begins to drift in the long term.

$$Roll = Roll + G_x/fs$$
$$Pitch = Pitch - G_y/fs$$
$$Yaw = Yaw + G_z/fs$$

Where,

- $fs = Sampling\ Frequency$

2) To find rollover using an accelerometer we need to eliminate forces applied on the vehicle due to dynamic acceleration. Because every external force will introduce noise in the detected angle. High rotations per second can't be detected accurately because it might be the effect of external forces. So we can only measure low rotation per second accurately. Therefore, a low- pass filter has to be used.

$$Roll = tan^{-1}(A_x / \sqrt{A_x^2 + A_z^2})$$
$$Pitch = tan^{-1}(A_y / \sqrt{A_x^2 + A_z^2})$$

3) To compensate for limitations of both sensors we use both sensors simultaneously. Use accelerometer and gyroscope data together to determine the angular position of the vehicle. This gives more precise angular values.

We have proposed a solution in 3rd point to accurately measure angular position, to do that we need to filter the outputs of both. Kalman filter is a well-known filter that can be used to filter acquired data. However, the complementary filter is used in this research since the Kalman filter is very hard, if not impossible, to implement on certain hardware (e.g. Atmega32U4 microcontroller). The complementary filter facilitates the use of the gyroscope data in the short term because it is very precise and not susceptible to external forces and in the long term, the accelerometer data is used because it does not drift. Equation 1 shows the simplest form of the complementary filter.

Basically, the complementary filter is used to fuse the accelerometer and gyroscope data. This is done by passing the accelerometer data through a 1st-order low pass and the gyroscope data through a 1st-order high pass filter and adding the outputs.

$$Angle = \beta * (Angle_{Gyro} * dt) + (1 - \beta) * Angle_{Acc} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where,

- β is a floating value between 0 and 1. It is typically ranged from 0.9 to almost 1, depending on how much you can trust your gyroscope and accelerometer. It is used to tune the filter.
- $Angle_{gyro}$: Angle calculated using gyroscope data
- $Angle_{Acc}$: Angle calculated using accelerometer data

As shown in equation (1), the calculated angle using gyroscope data is combined with the angle calculated using accelerometer data. In our research, different values of β are used. However, the highest accuracy has been reached by setting these β to 0.98.

After having an angular position, let's use it to detect rollover.

The vehicle usually starts rollover at 46 degrees or more and at -46 degrees or less. The threshold value of roll and pitch angles represents a point from which the weight of the vehicle may contribute to the vehicle rollover. Therefore, if the roll or pitch angle exceeds 45 degrees or is less than -45, then a rollover is detected, the notification system will be activated, and vehicle rollover will be reported to the emergency services.

4.1.1.2 How to Detect Collision

The book named **Transactions on Computational Science XXXV[18]** has described one experiment done for having the correct threshold. And they came to know that the correct threshold value is 4.5g. The experiment shows that for none of the test cases during the normal test drive, the threshold value of 4.5g has been reached, even in the event of sudden braking and driving on uneven surfaces, so **the false positives rate is 0%**. But when the accident was detected then the lowest mean value of the number of experiments was 21.5.

$$M = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

If M >= 4.5 ⇒ accident occurred.

4.1.1.3 Placement of Sensors

- MPU6050 (gyro+accelerometer) near the driver seat.

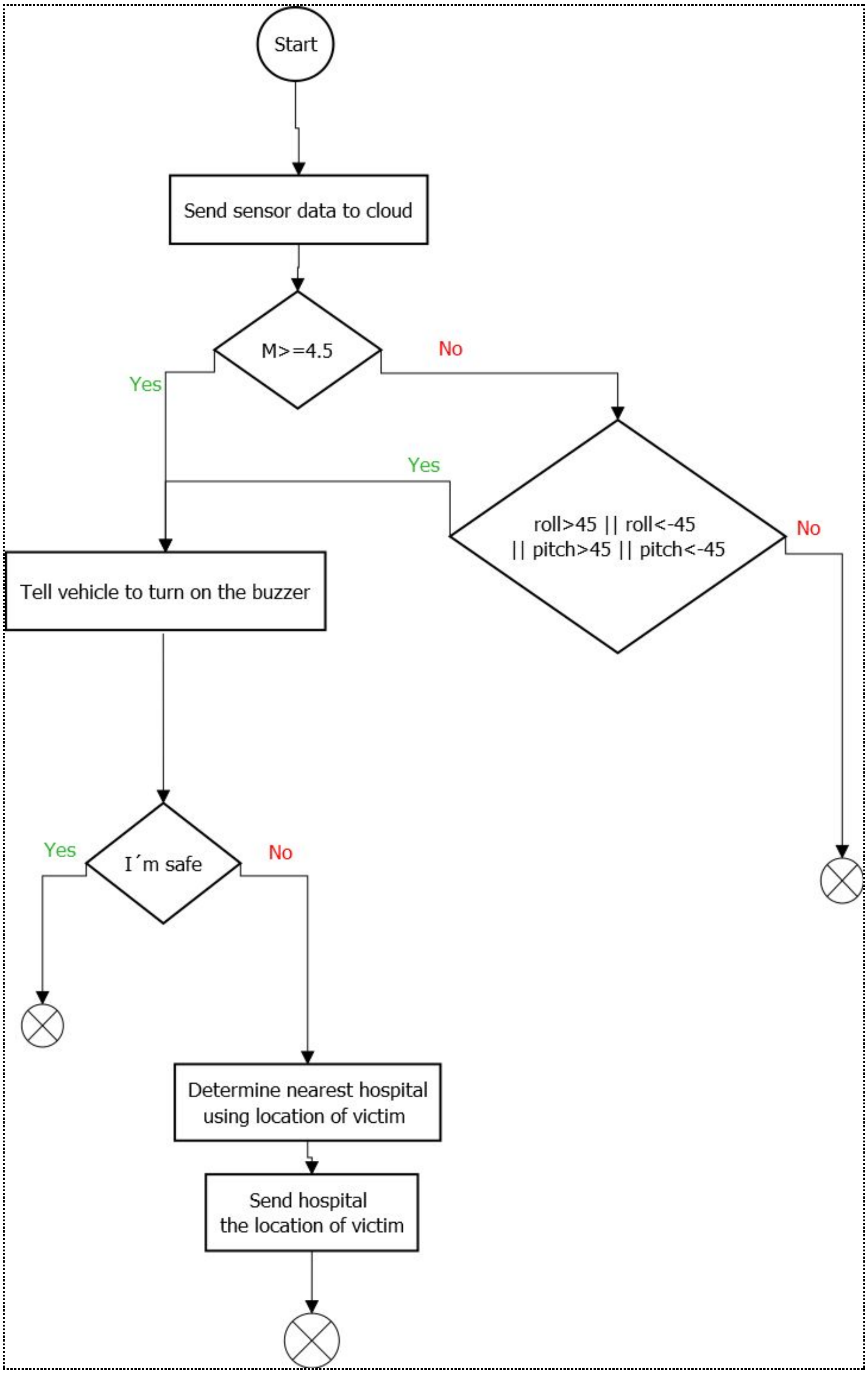
4.1.2 The Notification Phase

After having an accident detected, the next important thing is to inform the nearest hospital about the accident with the location of the victim. The database will have information about all hospitals with their latitude and longitude. Cloud computes the nearest hospital using the hospital's location and location retrieved from the GPS sensor of the victim. After having an accident detected, the nearest hospital will be extracted using this algorithm:

Data:
MESSAGE=(location)

Result: *Ambulance Dispatched;*
Server decode the message;
lat1 = start.lat;
lon1 = start.lng;
lat2 = end.lat;
on2 = end.lng;
dLat = lat2 - lat1;
dLon = lon2 - lon1;
*a= Math.sin(dLat / 2) * Math.sin(dLat / 2);*
*b= Math.cos(this.toRad(lat1)) * Math.cos(this.toRad(lat2));*
*c= Math.sin(dLon / 2) * Math.sin(dLon / 2);*
*d= a+b*c;*
*e= 2 * Math.atan2(Math.sqrt(d), Math.sqrt(1 - d));*
*Dist= R * c;*
Cloud finds the nearest hospital using the ***HAVERSINE****;*
Hospital= nearest_hospital;
Server sends notification to Hospital Web Interface;
Hospital dispatch the ambulance;

4.1.3 Flowchart



Chapter 5
Results

5.1 Result Analysis

Results are taken from Transactions on Computational Science XXXV[18]. They used two accelerometers with one having a higher detecting range and one having smaller along with that one gyroscope. They determined some scenarios and did 5-6 tests for each scenario. Below are results we have taken from Transactions on Computational Science XXXV[18].

5.1.1 When Roll-Over is not detected

Scenario	Test no.	M1	M2	Roll angle	Pitch angle	Acc. det.	Roll. det.
5 ropes no roll	153208	20,63	8,20	15,46	3,40	1	0
	153156	27,16	8,08	13,05	3,12	1	0
	153208	20,63	8,20	15,46	3,40	1	0
	153217	24,47	8,23	9,37	2,32	1	0
	153226	28,28	8,32	12,88	2,87	1	0
	Mean	**24,23**	**8,21**	**13,24**	**3,02**		
9 ropes no roll	152830	48,35	8,10	22,34	4,86	1	0
	152913	47,02	8,09	27,27	6,19	1	0
	152936	49,72	9,13	14,87	3,28	1	0
	152953	33,11	8,08	15,66	3,15	1	0
	153006	32,27	8,32	16,32	3,65	1	0
	Mean	**42,10**	**8,35**	**19,29**	**4,23**		
5 ropes rear hit then front hit no roll	153818	22,77	8,00	12,96	3,20	1	0
	153838	17,99	8,12	13,66	3,86	1	0
	154049	22,95	8,15	9,76	2,84	1	0
	154104	19,00	8,45	8,77	3,64	1	0
	154111	24,78	8,01	10,59	1,37	1	0
	Mean	**21,50**	**8,14**	**11,15**	**2,98**		
9 ropes rear hit then front hit no roll	154855	23,08	9,96	9,87	3,00	1	0
	154941	31,66	8,11	11,77	4,81	1	0
	154953	32,24	9,51	8,33	8,38	1	0
	155005	30,89	11,31	8,65	15,97	1	0
	155022	30,06	11,31	12,39	24,10	1	0
	155051	31,86	10,68	17,10	12,77	1	0
	Mean	**29,96**	**10,15**	**11,35**	**11,50**		

Here,

- ❖ M1 = output from accelerometer with the higher detection range
- ❖ M2 = output from accelerometer with the lower detection range

5.1.2 When Roll-Over is detected

Scenario	Test no.	M1	M2	Roll angle	Pitch angle	Acc. det.	Roll. det.
5 ropes with roll before hit	153346	26,48	10,67	224,61	4,29	1	1
	153432	22,35	9,50	230,55	3,88	1	1
	153456	21,98	8,55	237,21	4,32	1	1
	153521	29,98	11,07	234,00	3,58	1	1
	153544	28,62	8,41	236,63	4,05	1	1
	Mean	**25,88**	**9,64**	**232,60**	**4,03**		
9 ropes with roll after hit	152440	31,24	8,18	206,80	12,64	1	1
	152551	33,90	9,26	196,78	5,55	1	1
	Mean	**32,57**	**8,72**	**201,79**	**9,10**		
5 ropes rear hit then front hit with roll	154153	24,50	10,76	224,48	2,80	1	1
	154213	22,95	8,65	256,01	3,53	1	1
	154325	21,19	10,13	252,35	4,22	1	1
	154433	19,45	10,10	224,65	2,11	1	1
	154447	21,63	8,07	236,63	7,33	1	1
	154515	23,70	10,09	231,25	3,71	1	1
	Mean	**22,24**	**9,63**	**237,56**	**3,95**		
9 ropes rear hit then front hit with roll	154617	23,94	8,00	260,65	5,91	1	1
	154641	31,65	11,31	248,45	3,28	1	1
	154706	28,94	11,31	239,53	5,18	1	1
	154724	29,51	9,26	240,42	3,20	1	1
	154759	30,66	8,04	258,42	6,90	1	1
	Mean	**28,94**	**9,58**	**249,49**	**4,89**		

5.2 Threshold Analysis of 4.5g

They did 12 series of experiments each with different road condition and at different speeds: stop, slow passage through residential streets (30kmph), normal city driving (30kmph), driving out of the city (50kph) driving the car on uneven surface and braking (from 60kmph to 0).

The analysis shows that the threshold value of 4.5g never crossed, even in sudden braking and driving on an uneven surface, so the false positives are 0%.

Series	X max	X min	Y max	Y min	Z max	Z min	Magnitude
1	0.144	−0.144	0.144	−0.144	1.152	0.864	0.161
2	0.504	−0.432	0.648	−0.648	1.800	0.360	0.709
3	0.576	−0.504	0.576	−0.504	1.440	0.576	0.664
4	0.504	−0.504	0.792	−0.720	1.728	0.288	0.805
5	0.432	−0.360	0.504	−0.504	1.656	0.504	0.519
6	0.576	−0.648	0.576	−1.224	2.232	0.000	1.224
7	1.152	−0.144	0.864	−1.008	1.368	0.504	1.207
8	1.152	−0.144	1.080	−1.080	1.368	0.576	1.163
9	0.936	−0.144	1.152	−1.152	1.512	0.288	1.207
10	0.648	−0.648	0.864	−1.080	2.160	−0.144	1.163
11	1.224	−0.504	0.792	−1.008	2.016	0.000	1.239
12	0.864	−0.432	1.800	−0.720	1.800	0.144	1.806

Chapter 6
Conclusions

Our purpose was to detect the accident efficiently and also notify about it so that the first aid reached there as soon as possible. Now we can see our purpose being fulfilled because we are detecting accidents in almost every case, with rare cases of false positives also to avoid that we are using feedback after every detection.

And the notification part is being handled by the cloud efficiently. Whenever it detects an accident it calculates the nearest hospital and sends the hospital the location of the victim. Because of this nearest hospital feature, a person's life is not compromised for just a few seconds of delay.

Chapter 7
Future Work

Our proposed system is bound to work for four wheelers(specifically cars), in future the system can be made so that it can work for two wheelers also.

Our proposed system doesn’t take into account how many people are in the car who have met with an accident. So in the future, using image processing the number of persons can be detected and the precise number can be sent to the hospital so everyone who is affected can have treatment.

Also instead of the complementary filter to calculate angle, we can use the Kalman filter for more accuracy.

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