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Design and development of a smartphone-based application to save lives during accidents and emergencies

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Abstract

A road accident is an unpredictable event that could occur to an individual at any given time. Despite several measures taken to reduce fatalities, accidents continue to claim a large number of lives. The crucial step in saving a victim's life is to provide prompt medical support. In this paper, a smartphone-based application is developed that can observe, record, and take necessary actions for an immediate emergency response to the victims. This application can detect the occurrence of an accident based on the accelerometer data of the victim's smartphone. After the accident is confirmed, the app sends SOS alerts to the emergency medical services, ambulance services, registered contacts, and nearby acquaintances. Synchronisation with ride-hailing services and weather services, warning for dangerous on-road conditions, and natural disasters are further proposed for integration with the app.

Keywords: Road-accidents; emergency medical services; smartphone-app; SOS alerts

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1. Introduction

Worldwide, road accidents claim a staggering 1.35 million lives a year, equivalent to one life lost every 25 seconds (World Health Organization (WHO) 2018). A road accident involves a collision that results in minor or grievous injuries or even death. This collision can occur between a moving vehicle and a geographical obstacle (such as a tree or a human-made structure), between two moving vehicles, between a moving vehicle and a pedestrian or animal (Ruikar 2013). The severity of injury and survivability depends on the instantaneous speed of the vehicles (involved in the collision) at the instant of the accident (Elvik, Christensen, and Amundsen 2004). Majority of the road accidents cause intense human suffering, immense pain and trauma coupled with the loss of productivity and income. The number of injuries due to road accidents are grossly underreported at an estimated 50 million injuries per year (World Health Organization (WHO) 2017). Among these victims, about half the deaths (49%) include cyclists, pedestrians, and motorcyclists (World Health Organization (WHO) 2017). It is an alarming fact that road accidents are the leading cause of death among young people (aged 5-29) (World Health Organization (WHO) 2018). A significant proportion of these deaths (greater than 90%) occur in low-income and middle-income countries where there is a lack of road safety norms, vehicular safety norms, road safety awareness, and adequate emergency response systems. These deaths and injuries account for 1 to 3 % loss to the GDP (Gross domestic product) of these countries (World Health Organization (WHO) 2017). In the Indian context, this loss is higher than the GDP spent on the entire healthcare sector (1.02% of total GDP) (National Health Profile 2018).

The major roadblocks to receiving timely emergency care include lack of robust emergency care systems and public apathy. Public apathy towards the affected victims could be attributed to:- a) psychological conditions such as bystander effect (Latané and M Darley 1970); b) fear of being involved in medico-legal cases as a consequence of helping the victims (Beck 2003); c) slow and inefficient judicial systems leading to delays in timely delivery of justice (Doshi; 2016); d) lack of appreciation to those helping the accident victims; e) inadequate infrastructural facilities to handle emergency cases in rural hospitals along the highways (Bhandari and Dutta 2007); f) non-availability of ambulance facilities and basic first aid; g) lack of public awareness in handling emergencies; and h) economic issues such as lack of affordable accident-related health insurance facilities (Kumar, Avneesh, Gupta 2012). The 2030 agenda for sustainable development by the World Health Organization (WHO) has set an ambitious target to reduce the number of accident-related deaths and injuries to 50% by the year 2020. Moreover, WHO has issued a document called ‘Save Lives’ that can act as a guideline (in the form of a technical package), which if adopted by the low-income and middle-income countries, can reduce the number of road accident related deaths and injuries (World Health Organization (WHO) 2017). One of the five pillars of the global strategy for road safety is ‘post-crash response’ (World Health Organization (WHO) 2017), which is crucial in saving lives during accidents. The prompt post-crash response is critical and should ideally happen within the *Golden hour* (Martinez et al. 2010). *Golden hour* is a time-frame within the first hour following an accident, where providing prompt medical treatment is critical for the survival of the victim.

There are several apps available for download that help a user in case of emergencies such as Medical ID, Life360, First Aid by American Red Cross, SirenGPS, Disaster alert and others alike. These apps attempt to store the medical records of the user and help to connect its users with concerned persons (family and friends) or with various emergency response services such as (911 in the USA) or with other disaster response task forces. The features they lack are an automated response customised for a road accident and prevention strategies without the need for manual intervention from the user.

This paper attempts to develop a smartphone-based application (*LifeSaver*) as an emergency response aid to detect accidents and facilitate the provision of medical care to the victim at the accident spot, within the golden hour. Once the accident is confirmed with the help of onboard smartphone sensors (primarily accelerometer and GPS), the user’s smartphone responds by sending alert messages (multimedia) to the user’s family and friends, and nearest emergency medical services (EMS) based on the GPS location of the accident spot. The app also attempts to save lives with preventive measures being incorporated to avoid an emergency scenario (accidents or causalities) while traversing on roads. Preventive measures are realised with the use of real-time predictive warnings on the app for impending natural disasters, calamities and other human-induced roadblocks (such as barricades and potholes) by collating real-time information from weather forecasting channels and other relevant publicly available databases.

The paper is organised as follows; the second section describes the methodology adopted in designing the app which includes design methodology with the aid of cross-impact matrix and morphological analysis, followed by technical methodology that includes flowchart illustrating the process flow of the app. It is followed by section three with results and discussions.

2. Methodology

2.1. Design methodology

The design methodology adopted in this paper is based on *systems thinking* approach (figure 1). The functional requirements are obtained by group brainstorming sessions, various case studies and author's prior observations. It is then prioritised based on the cross-impact matrix (table 1). The list prioritises '*SOS to ambulance services'* or emergency medical services as the highest rank. Based on this ranking, app development is initiated.

Each functionality has multiple subsystems. These subsystems are possible solutions to achieve functionalities being incorporated into the *LifeSaver* app. Therefore, morphological analysis is carried out, and concepts are generated (table 2). Based on morphological analysis, three designs are generated, namely Design-A, Design-B, and Design-C. These three designs are evaluated based on the weighted mean method. Evaluation factors with their respective weights used in the weighted mean method are: - ease of use (w=0.2); functionality (w=0.3); reliability (w=0.2); technical feasibility (w=0.2); and flexibility (w=0.1). The best possible design (design-C) is chosen for the app development.

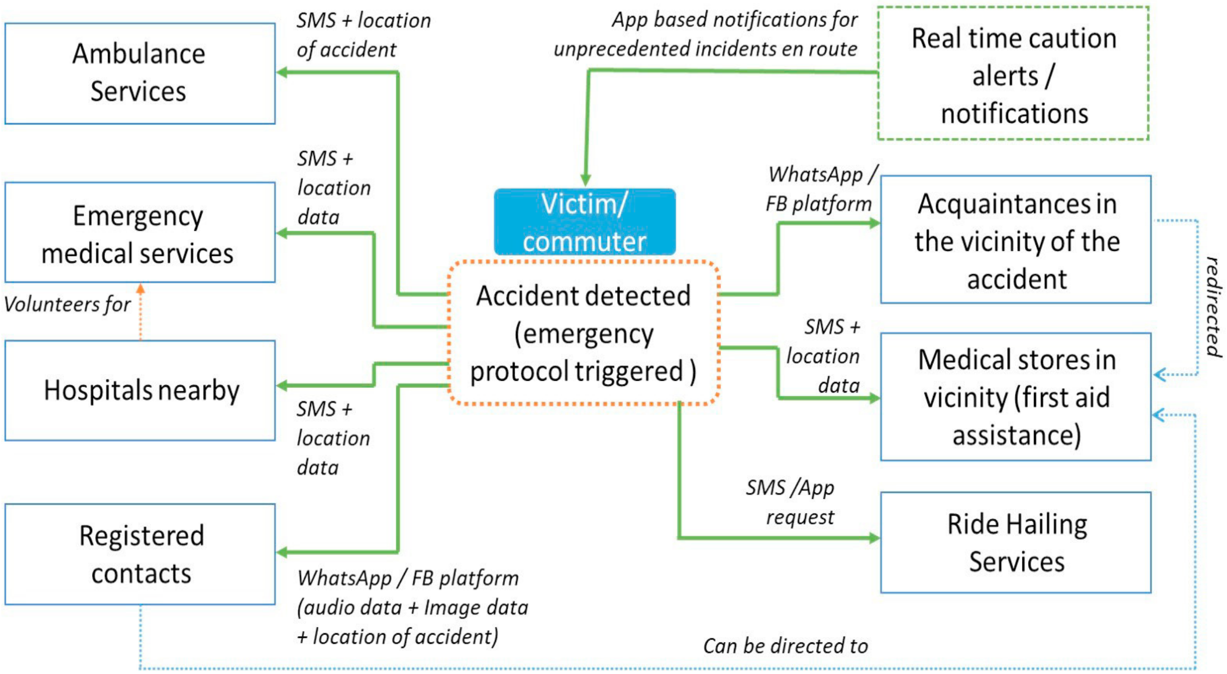

Fig. 1. A system thinking diagram describing the processes and interactions during an accident.

Table 1. Cross-impact matrix for prioritisation of functionalities of the application.

Functionalities	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***Total***
SOS ambulance services **(1)**	-	1	1	1	1	1	1	1	1	1	9
Alerting emergency medical services **(2)**	0	-	1	1	1	1	1	1	1	1	8
Alerting registered contacts (GPS location) **(3)**	0	0	-	1	1	0.5	1	0.5	1	1	6
Turn on mic and record audio **(4)**	0	0	0	-	0.5	0.5	1	1	1	1	5
Auto capture and send pictures **(5)**	0	0	0	0.5	-	0.5	1	1	1	1	5
Alerting nearby acquaintances via social media **(6)**	0	0	0.5	0.5	0.5	-	1	0.5	1	1	5
Integration with ride hailing services **(7)**	0	0	0	0	0	0	-	1	1	1	3
Alerting nearby medical stores for first aid **(8)**	0	0	0.5	0	0	0.5	0	-	1	1	3
Caution the user to dangers during the journey **(9)**	0	0	0	0	0	0	0	0	-	0.5	0.5
Caution the user about natural disasters **(10)**	0	0	0	0	0	0	0	0	0.5	-	0.5

Table 2. Morphological analysis (concept generation)

Functional Attributes	**Alternate sub-systems/assemblies**				
SOS Ambulance services	Dial from app database ▲	Dial from online database	Dial to specific ambulance services ●	Dial Govt. ambulance services	SMS ambulance services ◆
Alert hospital/mobile clinics nearby	SMS with GPS location ◆	Call via google maps data ●	Call via data from website	Calls via data from online database	Calls from app database ▲
Turn on mic and record audio	Manual ▲	Automatic after prompt ◆	Predictive analysis ●	Voice command	Gesture based
Auto capture and send pictures	Automatic on impact ◆	Gesture based ▲	Voice command	Heartbeat sensor ●	Face recognition
Alerts to nearby acquaintances	SMS (custom msg /default) ◆	Push message ▲	WhatsApp	Messenger/other social media ●	Automated Call From database
Integration with ride hailing services	Integrate with ride hailing app ◆	Trigger to open ride hailing app	Voice command for booking	Send SMS to ride hailing service ▲	Heartbeat sensor trigger ●
Medical stores for first aid	SMS custom text ◆	Push message ▲	WhatsApp	Messenger/other social media	Automated Call ●
Caution the user to dangers through the journey	Integrate with Waze app ●	Fetch real-time data ◆	Link with free weather portals	Integrate with google maps ▲	Integrate with Met. Dept.
Alert to registered contacts	SMS (custom msg set by user/default) ◆	MMS ▲	WhatsApp ●	Messenger/other social media	Automated Call
Caution the user about natural disasters	Integrate with NASA disasters mapping portal ●	Fetch real-time data	Link with free weather portals	Integrate with Facebook ▲	Integrate with Met. Dept. ◆
● - Design A		▲ - Design B		◆ - Design C	

2.2. Technical methodology

The sequence of actions performed by the app is described in the flowchart (figure 2). The smartphone accelerometer provides acceleration in Cartesian (a_x, a_y, a_z) coordinate system. For comparison with the reference acceleration values, the magnitude of acceleration (a_{mag}) is calculated in real-time using the triangle law of vector addition. The resultant calculation is necessary due to the difference in the *inertial frame of reference* for the smartphone accelerometer sensor (local coordinate) and the vehicle driven by the user (global coordinate). Although *LifeSaver* app can work equally well for pedestrians, it is assumed here that the smartphone is held inside the vehicle driven by the user of the *LifeSaver* app. The emergency timer is incorporated in the app to avoid false positives, which is set to 10 seconds by default and is user customizable. The phone's alarm will get triggered, overriding the smartphones default volume settings for the duration when the emergency timer is operational. *Timer stop functionality* is executed once the false positive is confirmed by the user, or if the user fails to respond. If the user establishes a false positive, the app resets to its default mode of operation, else the emergency protocol begins execution. The sequence of execution begins by sending SOS alerts to ambulance services or emergency response teams. Then an SMS is sent to registered contacts. The front and back camera of the smartphone is turned on to capture images in intervals of 10 seconds. Availability of mobile telecommunications network is necessary for the app to function. The primary functionalities and the minimum requirements for specific functionalities to work optimally are listed (table 3). Continuous data monitoring is performed for acceleration values for rapid changes. The collected data is correlated and compared with preset data values (stored in the app database within the smartphone memory) that correspond to acceleration/deceleration data from real crash tests. The reference data is obtained from actual crash tests performed for scientific research, which is open-source and available in the public domain (NHTSA n.d.). GPS sensor data is used to locate the site of the accident. This functionality is beneficial for the ambulance and emergency response teams. The GPS location, along with user's necessary information such as name, social security number (Aadhar number in the Indian context) is sent to ambulance services/emergency medical services.

The emergency services information is fetched from the online database concerning the location of the accident. Further, information related to the nearby hospital is obtained from *Google Maps* API. Alerts are then sent to registered contacts via SMS services available on the user's smartphone network. Registered contacts are telephone numbers of friends and family members, sourced from the smartphone's contact list or entered manually by the user during the app installation and its initial set-up.

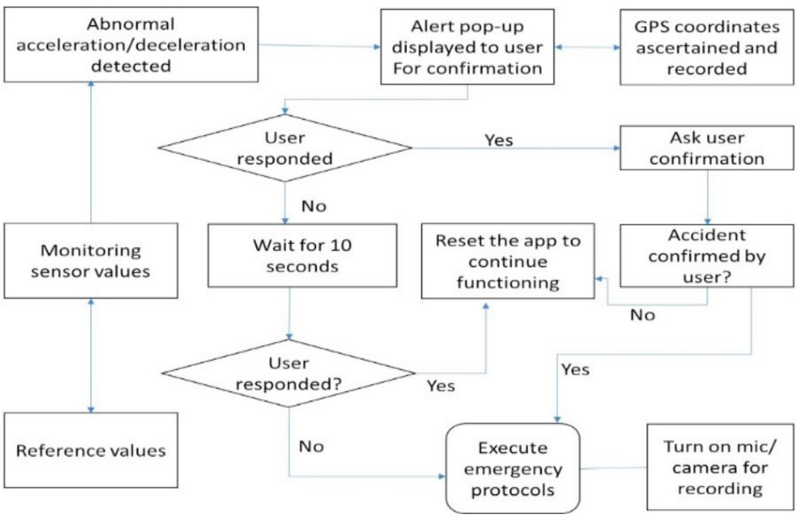

Fig. 2. Flowchart describing the process flow of the *LifeSaver* app

Table 3. Functionalities and system requirements.

Basic functionalities	**Minimum system requirements**
Sending SOS, SMS, placing an automatic distress call	Active Network connection (2G, 3G, 4G or 5G); Available main balance (prepaid connections); Active subscription to services (prepaid or postpaid plans)
Record audio, Audio format	Minimum storage space 10 MB; onboard microphone, Mp3; or AMR
Capture and send images	Working camera on smartphone (front or rear), Active Network connection preferably 3G, 4G or higher generation; Wi-Fi; mobile internet data connection;
Alerting nearby acquaintances via social media	Social media server integration; other users of *LifeSaver* app; basic access to user's profile on social media platforms
First aid from nearby medical stores	Installed *Google Maps* app; active internet connection
Receive help from ride-hailing services	Active Network connection (3G, 4G or higher); Installed app of ride-hailing services; GPS access/ other location services
Warning alerts on the journey	Installed *Waze* app; plugins installed for weather services

3. Results and discussion

3.1. System description

A smartphone-based mobile application (*LifeSaver*) is developed on Android Studio, which is a standalone app that can collect data from the user's smartphone sensors. After analysing the data, necessary actions are undertaken to help the user receive timely medical treatment after an accident. Additionally, it helps to prevent accidents via warnings and alerts. The basic functionality of the app is achieved by alerting the ambulance services through their service numbers (via SMS). The SMS sent to EMS is a formatted message; decoding the same helps the EMS to reach the accident's location. Parallelly, SOS alerts are sent via SMS to contacts saved in the app database. The camera and microphone (mic) of the smartphone is turned on; data is recorded and sent to the listed contacts on the app, as well as to the EMS near the accident spot. The recorded audio-visual data could help the EMS to assess the type and severity of the accident better. Contacting nearby acquaintances needs integration of the app with Facebook, Google, WhatsApp and other social media platforms that agree to share the details of people connected with the user of *LifeSaver* app. Integration with ride-hailing services (e.g., Uber, Lyft, Ola, etc.) for urgent help in case of non-availability of other medical facilities is proposed. This functionality requires active participation from these ride-hailing services' to form a collaborative business model with the *Lifesaver* app.

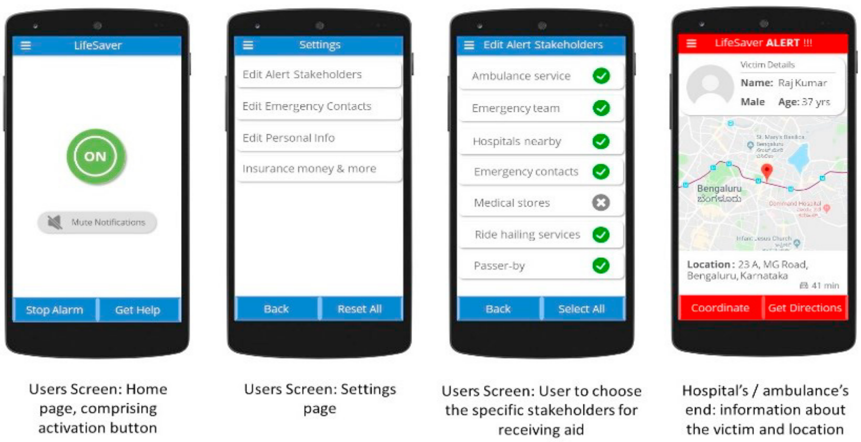

Fig. 3. Screenshots of the *LifeSaver app* (prototype stage)

Table 4. Functionality and corresponding Java code snippet.

Functions	Code Snippet (in Java)

Resultant acceleration calculation	public void onSensorChanged(SensorEvent event)
	{if (event.sensor.getType() == 1)
	{this.ax = (double) event.values[0];
	this.ay = (double) event.values[1];
	this.az = (double) event.values[2];
	this.a = Math.sqrt(((this.ax * this.ax) + (this.ay * this.ay)) + (this.az * this.az));}}
	if (this.number[i] != " " && this.number[i] != null) {
	this.owner = getSharedPreferences("state", 0).getString("owner", "Me");

Sending SMS and location data	smsManager.sendTextMessage(this.number[i], null, "Hi, This is " + this.owner + ".I am in an emergency.Please help. http://maps.google.com/?q=" + this.latitude + "," + this.longitude, null, null); Toast.makeText(getApplicationContext(), "SMS sent.", 1).show();

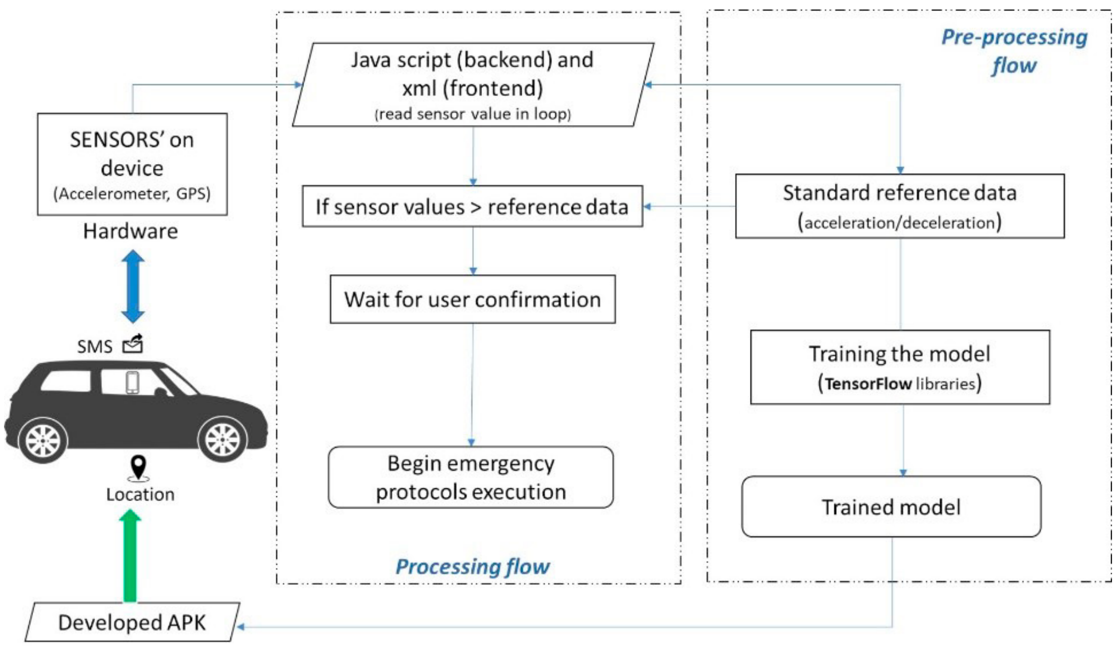

Fig. 4. Process flow of the *LifeSaver* app

3.2. App development

The application is developed for the Android platform using the *Android studio*. *Java* is the programming language used in the back end while *XML* is used for front end development. A reference dataset is collected from crash test database of *www.nhtsa.gov*, which is a trusted repository for vehicle crash test data. The app has a reference value (resultant threshold acceleration), which is obtained from analysing the crash test data. The reference value is continuously compared with the accelerometer sensor values on the smartphone in real-time. When the data read from the sensors are matching the reference values, the app enters the primary functionality mode. The emergency detection protocol begins with a pop-up message displayed (with a loud alarm sound) to the user for final confirmation to avoid false positives. After the waiting period is complete, and no response is received from the user, an automated course of actions begins (figure 1). The app runs the emergency protocols such as sending SMS to emergency response teams, registered contacts and other stakeholders in the designed sequence so that the user receives medical aid in the least possible time (preferably *golden hour)*.

The application records sound using the microphone inbuilt in the smartphone, turns on the camera to capture images, which gets stored on the device memory. At intervals of 10 seconds, this process repeats and simultaneously sends the sound and image data to persons concerned, and to the EMS. According to the position and orientation of the smartphone (inside the driven vehicle) after the accident, captured images and recorded audio have a probability of containing crucial information about the status of the victim. The code snippets for executing primary functions of the app in the Java programming language is listed in Table 3. The user interface is minimal and easy to use (Fig 3). At the systemic level, the application connects the victims to various stakeholders – the ambulance services, EMS, hospitals, medical stores, known contacts, ride-hailing services and acquaintances in the vicinity. The primary objective of the EMS is to arrive at the victim's location within a stipulated time with an adequate number of medical staffs, supplies, and emergency medical equipment. On reaching the accident spot, they provide basic first aid and transfer the victim to the nearest healthcare centre if necessary. Specialised ride-hailing services to transport the victim to the nearest hospitals or healthcare centres can be availed in collaboration with the prevalent cab-aggregator organisations. The contacts registered (in the app for emergency aid), and the acquaintances near the accident spot, will be alerted through prevalent social media platforms; and can either be directed to the victim's location for added assistance or specific medical stores in the vicinity for procuring necessary first-aid medications.

3.3. Discussion

A smartphone-based application for detection and response to an accident is considered in this paper rather than building a standalone device. Android is the preferred platform due to its open source access feature, flexibility in programming and widespread usage around the world.

The medical emergency response time post-accident is significantly reduced by using this application. The app also provides self-reliance in alerting the EMS. In case of delays in the arrival of the EMS, the nearest medical stores can be contacted for requesting basic first aid. '*Alerting friends and family members'* functionality is facilitated without the need for external intervention. Furthermore, alerting acquaintances nearest to the site of the accident is explored with the use of social media integration with the app. Also, the possibility of ride-hailing services to help the victim get transported to the nearest medical facility is proposed. This functionality is of high impact when EMS support is delayed due to traffic congestion in urban and semi-urban areas. In the case of remote locations where EMS support is not readily available, the victim can be provided with basic first aid from the nearby medical stores (which are alerted by the app).

Prevention of an emergency is of great importance; therefore, this app includes features that warn the user for adverse road conditions (such as potholes, barricades and speed breakers). This functionality is achieved with the aid of real-time data sourced from open-source platforms such as *WAZE* and *Google Maps*. Natural disasters and calamities such as tsunami, hailstorms, snow-storms, floods, hurricanes or cyclones, which have real-time data available in the public domain can be integrated into the app. Thus, *LifeSaver* app helps the user avoid accidents or encounter an emergency.

4. Conclusion

Accidents are unpredictable events which are stochastic, making the prevention of the same a significant challenge until the implementation of an intelligent transport system. Immediate medical support becomes a critical factor for the survival of a victim in the case of an accident. This smartphone application (LifeSaver) is an attempt to provide a solution for prompt EMS support. The app also helps in avoiding an emergency scenario with the help of warnings and notifications. In case of lack of EMS facilities, the nearest healthcare centres or hospitals are located with the help of data sourced from Google Maps and GPS. In the context of developing nations where the EMS system is not fully functional or improved yet, the ambulance or mobile clinics dispatched from hospitals nearest to the accident spot can benefit the victim. In cases where the accident location is at desolate places along interstate highways, help might arrive delayed to the victim, in such instances, nearest medical stores or mobile clinics can provide the basic first aid to the victim. Alerts to registered contacts offer a means to the concerned family members and friends to provide medical treatment support to the victim at the site of the accident via human intervention. The audio-visual data recorded on the smartphone after the confirmation of the crash is sent to registered contacts and EMS, which can contain critical information regarding the physical condition of the victim.

The scope of this app is limited to smartphones with active subscription services for SMS and calls. Availability of an active and stable mobile telecommunications network is also necessary at the site of the crash. Further validation with field testing and real-world trials is necessary for improving the accuracy in detection for an accident. Reference acceleration needs modifications to suit different usage scenarios based on the type of vehicle driven and the region where the app is being used.

In future, smart-wearables such as smartwatches, health bands, or fitness trackers can sense heartbeat and blood pressure and can also help in confirmation of the accident (avoiding false positives). Also, this app can help pedestrians and bike users when customised. This application can be retrained and remodelled to suit different spatial scenarios and road safety norms in different countries. An optional alert could be sent to health insurance providers of the victim to get assistance in receiving necessary treatment. An alarm could be sent to the nearby police stations to help the victim get better care and security at the accident spot as well as get clearance with regards to legal proceedings. This app has the potential to save millions of lives by providing prompt medical support within the golden hour, thereby bringing a revolution in road safety and emergency care for accident victims.

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