Vehicle Accident Detection on Highway and Communication to the Closest Rescue Service

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Abstract

The hazard information and the timely rescue performance are considered as the main elements to reduce the risk of road traffic accidents since the rate of highway accidents significantly increased. In this paper, it is aiming to detect the highway accident victims by using the data received from Sensor Fusion-Based algorithm while Ray Casting algorithm will assist the users to receive the assistance of rescue services in timely manner. With the purpose of user friendliness, these algorithms are intended to apply in the smartphones built-in high technology sensors, which are connected with the GIS, GPS and Geofence technologies.

Keywords: *Highway, Accident Detection, sensors, Rescue Alert, GPS, GIS, Geofence, Dataset*

I. INTRODUCTION

In Myanmar, road collisions are the major cause of death among the young adults and mid-aged people. Most of the precious lives are lost during the road accidents because it is not able to identify the correct location of accident occurred as well as inform the rescue services to save the victims on time. A highway is the main road in which connects the urban and rural areas. Due to its wide structure and possesses the high-speed thresholds, it can reduce the travelling time of the users. In Myanmar, there are forty- nine (49) roads, which connect from Eastern Regions to Western Areas, while the total of thirty-six (36) roads are used as highway to link from Northern States to Southern Provinces. The total length of these roads is more than twenty thousand (20,000) kilometers. All of the matters related to the usage and maintenance of these roads are monitored and managed by the Department of Highways, which is under the Ministry of Construction in Myanmar. Recently, it is noticed that the rate of fatality and injury on Highways in Myanmar has been an upsurge. According to the statistical results stated in "Road Safety in Myanmar 2017" by Federation Internationale de l'Automobile (FIA), the number of deaths related to road accidents received from Myanmar Police Force was 1,853 in 2008 and, this number was increased to 4,688 in 2016. Within eight years, the numbers of reported road deaths were doubled.

Even though the economy and development of Myanmar is still in growth, the vehicle ownerships of the citizens are increasing all the time. It is expected that the number of accidents related to automobiles are likely to be raised and, is estimated that 9,000 people may be killed in road accidents in 2020. Apparently, there is a linkage between a person's death during the above accidents and the absence of the first aid provision due to the delay in informing to the rescue services. Thus, in the case of road accidents, response time is vital for saving the precious lives of accident victims and considered the certain level of impact on death rate. In Myanmar, the smartphones embedded with strong detection sensors to identify the information of accidents and send this to the responsible teams in timely manner are not available yet.

With the intention of overcoming the weaknesses in the Rescue Alert System via Geofence technology, this research aims to validate the status of accident occurred by using the values received from accelerometers and gyroscope sensors, identify the accurate location of accident by using GIS and GPS technologies, maintain and update the rescue service information such as contact points, and search for the nearest rescue units with the usage of Geofence Technology. In this way, the fatality rate due to the vehicle accidents will be reduced to the certain level as the prompt response is received from the emergency services such as Medical emergency services. Once the location of the accident is confirmed, the Ray Casting Algorithm is applied to search for the closest rescue services within the shortest time duration. The similar experiments related to the vehicle accident detection and communication to the rescue services are also as followed:

Chris T., White J., Dougherty B., Albright A. and Schmidt DC.[1] have developed a prototype smartphone-based client/server application "WreckWatch", which operates together with the embedded smartphone sensors and communication interfaces to detect the causes of accidents and deliver the notifications to the respective organizations. The vulnerability of this application is the speed limitation and, the smartphone application does not detect the possibility of accident in low speed condition when the speed of the car is lower than the configured speed threshold in application. Sneha R.S. and Gawande A.D [2] invented the accident notification system called "E-call" for smart phones. This "E-call" uses the cellular network to transfer the data between smartphones and the Server Center. Since "E-call" system accessed the built-in accelerometer sensor of smartphone as an accident detection sensor, it is possible to produce the false positive alarms although the user is not inside the car. In 2015, Dipesh Suwal, Suresh Manandhar, Shashish Maharjan and Ganesh Dhakal, [3] “D-Fencing Application”, which notified the Geo-fencing Post Disaster Scenario using Android App. The users will receive the alert messages from the system admin whenever they are approaching or entering to the regions affected by disaster.

However, the information in database may not be updated because only the system administrator, a person who has knowledge of Geofence, can manage the disaster information as well as send the alert message to the requestors. If the system administrator is not available when the incident occurs, the users may not receive the updated information. Hence, the application is not reliable since it does not have the automated features of receiving disaster information, updating the database promptly and sending the precise rescue alerts to the users.

In 2013, Danish karim and Jaspal Singh [4] proposed the “Development of Automatic Geo-Fencing and Accidental Monitoring System based on GPS Technology”. By operating a single shock sensor embedded in a proposed system, an accident can be detected as well as the vehicle can also be prevented from the theft as it is operated as security control. However, there is no predefined database and datasets to record the user information and the variables of incident occurred. Although it was mentioned that the system should send the alert automatically to the rescue services, it was not mentioned how and where the contact information of rescue services is maintained. Thus, the recipients were likely to receive the limited information of sender via SMS. The remainder of the paper is organized as follows.

In section 2, explain the methodology of this research study. In section 3, we discuss the incident prediction of sensor and driver prediction by using sensor fusion-based algorithm used together Ray Casting algorithm and the elements of Geofencing Technology. In section 4, explain the technical usage of this proposed system. In section 5, the experiments and results are explained. Finally, section 6 presents the conclusion.

II. METHODOLOGY OF RESEARCH STUDY

The performance of an accident detection system is determined levels: data collection with data processing and communication to the closest rescue service is illustrated in Figure 1. Firstly, the values received from Accelerometer, Gyroscope and GPS are maintained in the accident detection dataset. Secondly, the system predicts as an accident and the accident validation message will be triggered to the user when these values are exceeding the accident threshold value. Thirdly, the system starts to search for the accident location by using the GPS values received from the accident detection dataset when the accident is confirmed. Fourthly, the Geofence technology creates the polygon in which the accident location is marked as the center point. Fifthly, the system accesses the rescue service dataset to retrieve the contacts of rescue services located in the polygon and, search for the closest rescue service from the accident location.

The Geofence will create another polygon with wider boundaries if none of the rescue service contacts is identified in the first polygon. Finally, the system will send the alert message including the user and vehicle information as well as the location of the accident to the rescue service if it finds the closest one from the accident location.

The server side’s workflows are emphasized to collect and process the data including the users’ information, incident information and the contact of rescue services. And then decide the relevant action while user side workflows act as the projection of the prediction. To make more accurate prediction, sensor projected data such as false alarm rate; fatalities of accidents, fixed data are stored in centralized system and communication differences parties, smartphones are play as sensor roles to make prediction.

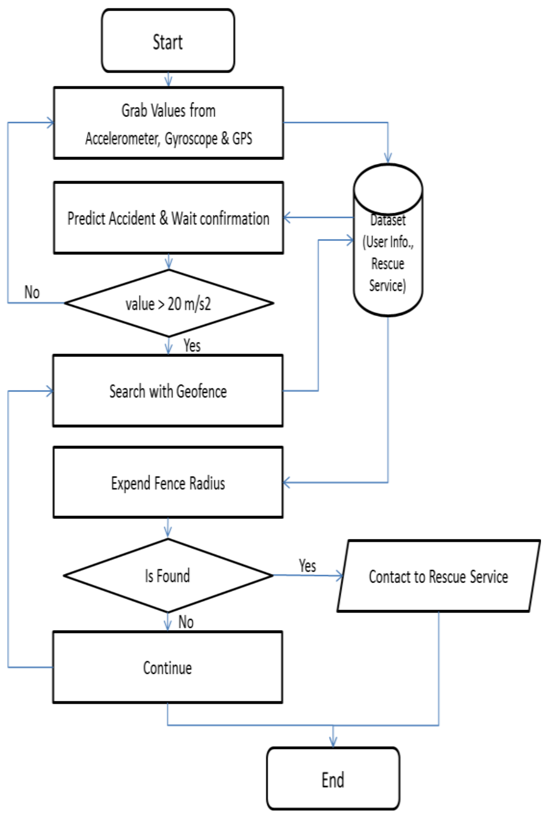

Figure 1. System Architecture

III. DETECT AND SEARCH ALGORITHMS

A. Sensor Fusion - Based Algorithms

Since the data deficiency issue occurs among the individual sensors, Sensor Fusion-Based algorithm is considered as a compensating method to enhance the data reliability by merging the data from various sensors. According to the previous similar experiments, the information produced from the automated sensors might be unreliable to some extent. In Sensor Fusion-Based algorithm, the information can be retrieved not only from automated sensors but also from historical sensor data stored in the centralized database as well as the non-automated sources. Then, the data received from multiple sensors will be refined and evaluated to achieve the optimal result. In this accident detection and rescue alert system, it is crucial to obtain the high-quality input data.

The most favorable result to detect an accident can be obtained by using the following Sensor Fusion - Based algorithm:

$$X_i(t) = A_i x_i(t) + B_i u_i(t) + W_i(t),$$
$$y_i(t) = C_i X_i(t) - v_i(t), (i= 1, 2, n)$$

Where i indicates the number of subsystems (i.e. accelerometers, gyroscopes and so on) in which data is produced and t indicates the time period.

The present value of the subsystem Xi(t) can be expressed by combing the current condition of the source xi(t), the signal value transmitted at the particular time ui(t) and, the noise value at the time period Wi(t). When the value of Xi(t) is received, the output of the subsystem or source yi(t) can be determined by filtering the unwanted noise value vi(t) included in present value of Xi(t).

By using an MLF-type neural network, the most favorable result to detect the accident will be predicted upon the individual output values as well as the integrated result of those individual output values.

B. Ray Casting Algorithms

When the status of accident is confirmed, a polygon fence with the range of 1,000 square meters will be created and the accident location is marked as the center point in that range. In this fence, the contacts of rescue services near the accident location will be searched with Ray Casting Algorithm. If the rescue services cannot be found, the Geofence will re-create the new polygon fence with wider boundaries and search for the contact points of rescue services with Ray Casting Algorithm until the closest rescue service is identified. When the closest rescue service is found, the accident alert message including user and vehicle information as well as the location of the accident will be triggered to the closest rescue services. The intention of applying Ray Casting Algorithm in this paper is that the closest rescue services from the accident location can be found and contacted with a minimum time interval.

In the Ray Casting algorithm, there are three input values, P, Q and R. P defines the point in which the place of accident occurred while Q states the polygon created to encircle P. R indicates the locations of rescue services marked in Google Map. Although the initial value of inside is set as ‘False’ at the beginning of every search, the final value of inside will be shown as ‘True’ if R falls in Q and, ‘False’ if R is out of the edges of Q.

Initially, the system sets the count as ‘0’ before starting the looping of every edge from point P. S indicates the ray that is originated at point P and transmitted to +y direction and, this ray will be only in the edges of y direction. When the accident is detected, the infinite rays or S will be transmitted in +y direction from its point of origin or P. To verify the target point of interest or nearest rescue service (R), there will be a looping between P and the edges of polygon, Q. Once the point of interest (R) is identified in Q, the value is marked as ‘True’ and then, the searching process is ended. If the point of interest (R) is not fallen inside the Q, the value is marked as ‘False’ and the looping will be stopped. Then, another polygon with larger diameter will be created to start the looping until the nearest rescue service (R) is found.

Algorithm:

Input: Points as P, Polygon as Q, Rescue Service as R
P is the position of interest
buf is a buffer distance.
Output: true if R contains Q, otherwise false
1: count = 0
2: s is an infinite ray in the +y direction, originating at P
3: for all edges e in Q do
4:     if R is within buf of ex then
5:         ex,buf = ex -2 * buf
6:     else if R is within buf of e or ebuf then
7:         return false

C. Geofence

Geofence creates the virtual geographic boundary of an area where the accident occurs. To mark a location of interest, the user needs not only to specify its latitude and longitude but also add the adjustment of radius. Once the latitude, longitude, and radius are provided, it is defined a geofence (a circular area or fence) around the location of interest. This feature is to use for hazard area detection. In this paper, geofence is applied to send the information to the closest rescue team from the geographical location where the accident occurs.

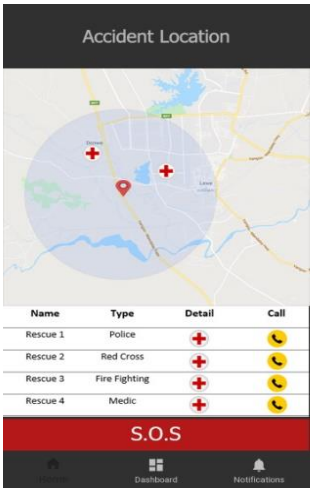

Figure 2. Information of Rescue Services Location and Accident place

D. User Information

Users are required to input information to process for faster and, receive efficient rescue procedure. Before starting the trip on highway, the users including driver and passengers must provide their personal information such as name, gender, blood type, date of birth, contact number and emergency contact number. This information is collected upon installing the one-time input. For example, when fatal accident occurs, the victim might need blood, so the rescue team can prepare for the required blood type of victim.

E. Vehicle Information

After providing the personal information of the users, it is also required to insert the information of the vehicle that the user drives on the highway. Once the accident occurs, the information such as the accurate position is provided upon the selected route of the trip when the user activates the accident detection system. Then, the system will be able to access the below data before informing the rescue teams.

- Car Type (Sedan, SUV, Truck, Wagon, etc.)
- Vehicle Registration Number
- Color of Vehicle
- Number of Passengers

F. Accident Detection Dataset

These datasets are early stages as the built-in sensors of the system need to retrieve and evaluate the status of the accident. Once the status is confirmed, the latest calibration sensors data is delivered to the main system to create the updated dataset automatically. The accident detection datasets decide upon the values received from the smartphones' built-in sensors such as the accelerometer, gyroscope and linear acceleration whether the accident may occur or not.

G. Rescue Service Dataset

With the connection of Geofence, Rescue Service Dataset maintains the data about the rescue services such as the contacts of ambulance service, fire stations, and police stations and so on. In figure 3, the sample of rescue datasets are illustrated. Once the accident is confirmed, then the nearby rescue services will be informed after automatically adding the details of last GPS. These datasets are constantly updated in the servers, thus Geofence can access whenever it is required.

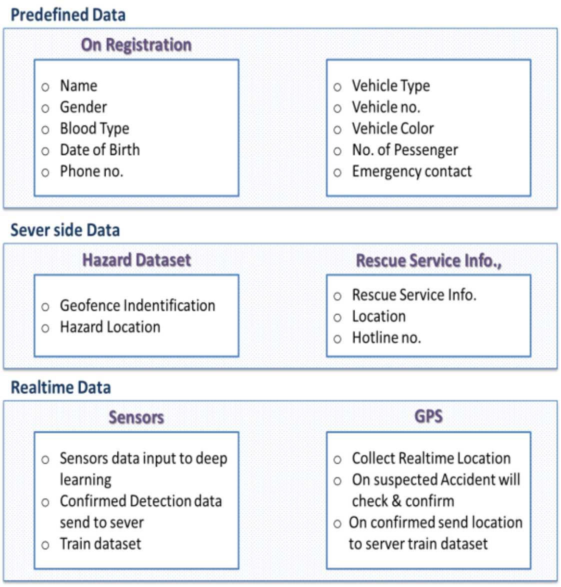

Figure 3. Sample of Sever side Dataset

IV. TECHNOLOGIES USAGE

The following technologies are intended to use for detecting the accidents and sending the alert to rescue teams.

Smartphones are chosen as the major subject of this research as they are the affordable and effective portable machines embedding with powerful technologies. Being an open-source mobile operating system, the Android source code is free to access with only one restriction, which is not allowed to use for personal interest or any other financial benefits. Being the primary Android IDE (Integrated Development Environment), Android Studio supports an Android developer all the required tools when the Android applications are developed. Hence, the developers can write the codes with auto-completion tools.

It is more productive for developers to use Java than any other languages as Java has the large set of class libraries that comprise the multiple functions such as connectivity, sensors and so on. These libraries are reusable by most of the embedded applications, so the developers do not need to rewrite the codes, and this could not only save the developing time but also prevent the unexpected errors.

Geo-fencing creates the virtual boundaries for the actual geographic locations. The virtual boundaries could be fixed or changeable. In a comparison with the conventional framework API, Google Location API delivers the more powerful, high-level framework that can select a suitable location provider and power management without the assistance of manpower. One of the prominent features of this API is the activity detection which is not available in the framework API.

The Google Maps Android API is opted for this research as it is a service allowed to access the Google Maps Server automatically to present Maps, record the response in the target location and retrieve the required information for the user. With the usage of HTTP request, this service provides the information about the geographical locations and, adds the noticeable points of interest along the driving route. Unlike Google Places API Web Service, Google Directions API calculates the distance between the starting point and the destination and, presents the most efficient routes based on travel time, number of turns, distance, etc.

Elements in Geo-fencing

GPS: It can pinpoint the location accurateness within 5 meters from the user's location. Besides, GPS is accessible to all users without burdening on carrier infrastructure.

A-GPS: Assisted GPS (A-GPS) supports to obtain the most accurate result of mobile positon by evaluating the GPS satellite information with the data received from mobile tower sites.

Cell-ID (COO/CID): Mobile device can be easily detected by pinpointing the connected cellular network tower. Since, Cell-ID is uncomplicated way, and it is not necessary to improve network location infrastructure and mobile phones.

Wi-Fi: Wi-Fi is suitable for both indoor and outdoor environments as it decreases time-to-first-fix (TTFF) as well as is highly accessible in urban regions.

V. EXPERIMENTS AND RESULT

The lack of treatment in the proper time is the major reason for many deaths. The major causes may be the late arrival of ambulance or no person at the place of accident to give information to the ambulance or family members. This paper is intended to reduce these factors and save the lives of victims by delivering the required medical assistances to accident location on time.

The possibility of accident can be predicted immediately based on the values received from the accelerometers and gyroscopes by accident detection system. If these values exceed the predetermined accident threshold in the system, the validation message will be sent to the users whether accident is occurred or not. In general, the system will wait for maximum twenty (20) seconds to receive the confirmation from the user. Whether the confirmation from the user is received or not within twenty (20) seconds, the system starts to create the visualized polygon near the accident spot by using Geo-Fencing technology. With the visualization facility of Geo-Fencing Technology, not only the accident spots can be discovered for timely response but also can be assisted to verify the nearest locations for the rescue service facilities. Then, the system access to rescue service dataset and retrieves all the contact spots of rescue units within the Polygon.

By using the Sensor Fusion-Based Algorithm and the Ray Casting Algorithm, received values from the sensors are accident can be predicted and then the closest rescue service spot from the accident location is searched with minimum time interval as it is crucial to deliver the rescue team to the accident victim in timely manner. Once the closest rescue contact is spotted, the system sends the alert message including the list of accidents happened around that selected rescue service location.

To improve the performance of the sensors and obtain the accurate results, the phone must be docked in the vehicle. It is essential to record the movement values, which is standardized as 5 g, on a timely manner. In general, the accident will be identified when the value of X axis becomes greater or smaller than the values of Y axis and Z axis within 0.6 second. It can be deemed as a fatal accident if the value of X is significantly greater than the two other values, Y and Z, after one second.

In Figure 4, the 3-Axis accelerometer is applied to measure the accelerations of the sensors while the car is out of control and is rolling. In this case, the acceleration value of X-axis exceeds the range of -5g and +5g.

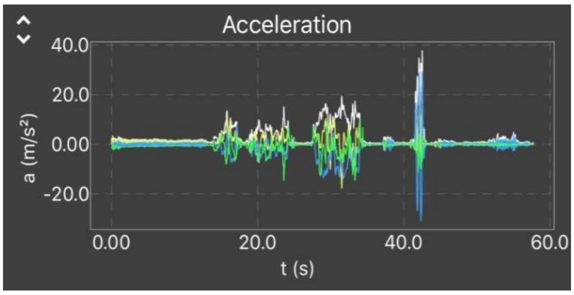

Figure 4. The car rolls as it exceeds the speed threshold and out of control

Moreover, it is also required to maintain the unique client-server architecture to collect and retain the updated data regarding about the real-time situations occurred on highway. Thus, the users from different sectors can access and verify the information effectively and efficiently. This system is planned to implement as a user-friendly version for the users to share their information before starting the trips.

In figure 5(a) and 5(b), the users require registering about user's personal data as well as the general information of the vehicle using for this trip. The requested data indicated in these figures are needed because the required procedures can be prepared such as the correct blood types for the accident victim.

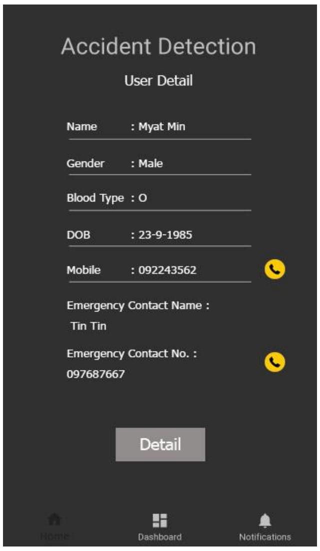

Figure 5(a). Registration of Personal Data

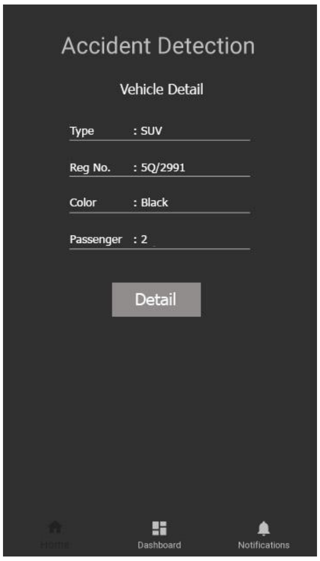

Figure 5(b). Registration of the desired trip

All information of users and vehicles will be maintained in the Database, and the system will obtain them whenever it is required. In figure 5(c), the rescue service, which is the closest to the accident location, will receive the alert message from the system. In this message, the data of user including emergency contact as well as the notification of other accidents received from database will be observed. The latest accident will be shown on top of the list.

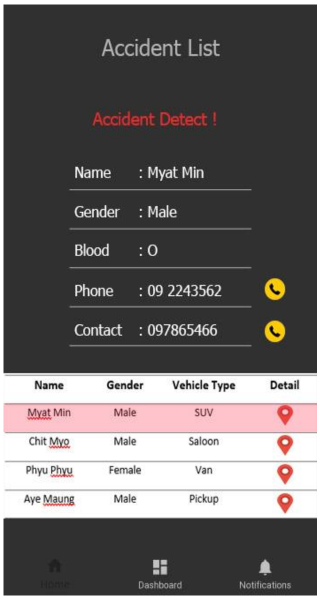

Figure 5(c). Accident Information

VI. CONCLUSION

When the rescue procedures presently used are verified, it is noticed that the current accident detection solutions including smartphone systems still have some weaknesses such as the speed threshold limitation, the higher false alarm rate, the manual controls upon updating the database information, and the lack of predefined dataset to analyze the accident data.

In this paper, the proposed system will be compatible with the various trained dataset as well as operating with Google application programming interfaces (APIs), and thus, the weaknesses mentioned above will be solved. Once the well-trained datasets are maintained in the systems, the user's conditions while using the highways are tracked and updated in the database perpetually. Thus, the system can obtain those data to validate the status of accident whenever it is needed. Moreover, with the usage of Geo-fencing and the Google APIs, the location of accident can be accurately identified within a short time and, the closest rescue services from the accident spot will be pinpointed and informed to save the victims of accidents.

Since this system is implemented as the user-friendly version, the user can simply reply by pressing the verification message whether he or she needs the assistance of rescue team or not. Even the user is unconscious; the system will wait for certain time duration before contacting to the nearest rescue unit via Geo-Fencing Technology to prepare the required procedures. Moreover, the system always synchronizes with user's device and even the device is switched off, the last information of users is still captured in the system to verify the data of accident.

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