Context Aware Wireless Sensor System Integrated with Participatory Sensing for Real Time Road Accident Detection

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***Abstract*—According to World Health Organization, worldwide, every year, more than 12 million people are killed in accidents and more than 500 million people are injured. In this research work, we have designed a context aware wireless sensor system to detect and locate road accidents in real-time. Context acquisition is performed using onboard sensors such as accelerometer, gyroscope, flex sensor and sensors from Smartphone such as accelerometer, microphone, GPS etc. A learning algorithm is proposed to perform context modeling, inference, and context-based action initiation. Participatory sensing techniques are integrated with the proposed system to ensure system enhancement and reduce false alarms.**

Keywords—context aware system, decision support system, onboard sensor system, participatory sensing.

I. Introduction

In India, 1, 20, 000 people die and 12, 70,000 sustain serious injuries every year in Road Traffic Accidents (RTA). 90 percentage of accident cases are such that the victims can be saved if they are treated within few hours of accident. Hence real time monitoring became a necessary factor. For vehicular networks we afford wireless communication for real time monitoring of road accidents, where coverage and connectivity of the networks are scalable. Our system mainly emphasis on saving the life of victims.

Context of the accident scenario is examined with the aid of a set of sensors. Electronic sensors like accelerometer, gyroscope and flex sensor are the set of sensors placed inside the vehicle and GPS is used for deriving the location information. For reducing false alarms, onboard sensors of smartphone like accelerometer, compass etc are also used. Context aware sensing is necessary for the system as real time data monitoring depends on the autonomous decision from a sensor subsystem.

Participatory sensing is a technique which allows people to become a part of any system. It can improve the credibility of the gathered information. Our system demands fast and reliable data propagation, where participatory sensing plays a vital role.

The remaining portion the paper is organized into different sections. Section II explains related work, while section III describes the proposed system architecture. Section IV discuss the algorithm developed, and section V discusses the experimental results. Conclusions have been illustrated in section VI.

II. Related Work

With the rapid urbanization there is a tremendous increase in the number of vehicular users. This eventually results in the increased number of vehicular accidents these days. Smartphone based accident detection is a new research area.

Jules et al proposed a Wreck Watch server and the Wreck Watch client model [1] approach using smart phones where the Wreck Watch client is the smartphone with associated sensors. Accelerometer values are detected and analysed in real time, if needed a warning message is passed to the Wreck-Watch server where data aggregation and message passing to the emergency responders is done.GPS on the phone is used for identifying location information. The main flaws of this system is that its false alarm rate is high, since they are depending only on the smartphone values and if the smartphone gets damaged due to the accident there would not be any message passing or if the phone fell down then there will be false message generation and the entire system will get useless and are using only 3G for connectivity and if there is no 3G connectivity, no media for the message passing. Hence we could not rely completely on this system.

Another method for real time accident monitoring is the use of in vehicular sensors [2]. Here sensors are embedded in the vehicle in such a way that every change in vehicular values like acceleration, force etc experienced also by the set of on board sensors in the vehicle. Messages are passed through GSM. The main flaw of this system is that, if the sensor systems get damaged due to the accident, no message passing will be done and if there is no GSM availability then the system will become useless.

Cano et al [4] proposed an application for android that estimates the G force experienced by the passengers in case of a frontal collision. If it exceeds their threshold value then the

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application will send an e-mail or SMS to pre-defined destinations, immediately followed by an automatic phone call to the emergency services. This also is not a fool proof system and they are not assuring any seamless connectivity.

The main drawbacks of the current systems are that they would not assure a fool proof decision and seamless connectivity to the end users.

III. System Architecture

Our system mainly focuses on reducing false alarms and giving seamless communication to the end users from the spot of accident. Our system shown in Fig 1, mainly aims to detect and locate road accidents in real time and send the information to end users without any fail. The whole system can be divided into three modules, onboard sensor system, a participatory sensing part and a decision support system placed within the monitoring centre. Onboard sensor system is composed of a set of electronic sensors, smartphone sensors, microcontroller and a Wi-Fi module. Electronic sensors are connected directly to the microcontroller while smartphone sensors are connected through the Wi-Fi module. Participatory sensing part includes both vehicles and people's smartphones. At this point, we assume that, Wi-Fi hot spot of atleast one of the smartphone is enabled and all smartphones are monitoring their audio sensor for an abnormal huge sound intensity produced during a vehicular crash. Vehicles with our system are used for rerouting of data to the monitoring centre while smartphones can do vital sensing processes and sending that additional informations to the monitoring centre for credibility of the informations received at the server. Context aware DMU (decision making unit), placed within the onboard sensor system, along with this participatory sensing part can reduce the false alarms. At the monitoring centre a second level of decision making is done depending on the messages received from DMU and participatory systems. Depending on the decision, type of accident and severity of the accident, messages are passed to the end users like police station, hospitals, fire force and relatives.

A. Context aware wireless sensor system

There are different types of vehicular accidents. Out of the different vehicular accident types, context aware DMU can identify most types of vehicular accidents like head-on collision, rear-end collision, side collision, vehicle rollover and rollover with head-on or rear end or side end collision. Context aware DMU is equipped with a microcontroller where set of electronic sensors like accelerometer, gyroscope, flex senor, GPS and smartphone sensors like accelerometer, compass, GPS are giving real time values to the DMU. The electronic sensors are connected directly to a PIC microcontroller. A Wi-Fi module is connected to the microcontroller through UART and smartphone sensors communicate with the microcontroller through this Wi-Fi module. Fig 3 shows system inside the vehicle which includes the DMU. Accelerometer readings are used for detecting a sudden retardation, gyroscope readings detects a tilt or change in the orientation of the vehicle, flex senor detects whether any forced is imparted in the vehicle. GPS gives the location information of the vehicle.

Algorithm 1 explains the first level of decision made at the DMU level. Here, if the decision is an accident then DMU will send the location information along with the type of accident and the vehicle number through GSM. If GSM is not available, then this decision is send through Wi-Fi module. Participants (vehicles or smartphones) intercepting these messages can reroute these messages through ad-hoc networking to the server for a second level of decision making.

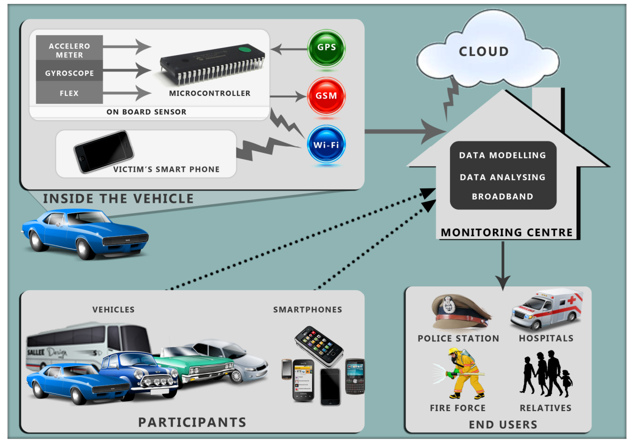


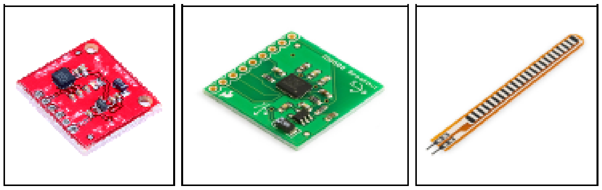
Fig. 1. System Architecture

B. Spatial distribution of sensors

Impacts of accidents in different parts of a vehicle [7, 11] are described in various papers. Accidents can be due to front end collisions, rear end collisions, side end collisions, sideswipe collisions, vehicle rollover, head-on collisions, single car accidents and multi-vehicle collisions. Sudden deceleration experienced by the vehicle is same wherever in its body, but it differs in the entire three axis. So here we are using a single 3-axis accelerometer for detecting the retardation along the 3 axis of the vehicle. Force experienced by different parts of the vehicle differs depending upon the type of collision it experienced. Force experienced by front end collision is more in the front side than on any other sides. Similarly force experienced by the sides will be higher compared to another side, when it is a side collision. So placement of flex sensor should be in such a way that, we should be able to decide upon correct values from all the four sides. Hence four flex sensors are needed to place at front end, sides and rear end of the vehicle. Gyroscope gives the value of orientation rate of the vehicle. It comes into play when the road is no straight. Hence it will be having a change in the entire 3 axis while the journey is not through a straight road. So needs a 3 axis gyroscope for detecting a rollover of the vehicle. Rollover of the vehicle will result in the parameter changes in all the 3axis but will be same for everywhere on the same vehicle. Hence we need only one 3 axis gyroscope.

C. Participatory sensing architecture

Participatory sensing helps in a fast, reliable, flexible and robust data transmission as it incorporates human intervention. Primary assumption is that there is minimum number of participants and audio sensor of smartphones is switched on. Here privacy of the users like location is not taking into consideration. Participants can either be other vehicles equipped with this system or smartphones in that area. Other vehicles are used only for rerouting of the data when there is no GSM availability on DMU. If the vehicles too haven't GSM availability, it can reroute through smartphones.



a. Accelerometer b. Gyroscope c. Flex sensor

Fig. 2. Sensor Used

Participant smartphone's audio sensor will be scanning for any abnormal huge sound accompanied by a vehicular crash. Whenever it detects such a sound, our application will get started. There the user will be providing with a set of questions. They have to just answer those questions say, landmark of the accident, number of vehicles imparted in the collision, number of people died, number of people injured, presence of fire, presence of lethal gas etc and while pressing an OK button, this message is send to the server along with the location information. If it receives the message from DMU, it will stamp that message also while sending to the server. Message is sent through GSM and if there is no GSM availability it is sent through Wi-Fi till it intercepts a GSM available system. It can either be a vehicle or any other smartphone.

D. Decision support system

At the server, the second level of decision making unit, messages are received from different locations and through different means like GSM, Wi-Fi etc. Based on the location information we are grouping the messages. Messages with location information which are far close with respect to their latitude and longitude values are taken and will find the variance in the location information. Then while taking the mean variance, if it falls within a threshold then we can conclude that all those messages are from the same accident spot. Let there are m participants each giving 'n' informations. Thus a maximum of (m* n + 1) informations will arrive at the server including the message from the DMU. Here if we are getting a GSM message and 25% favorable information from participants or more than 50% of favorable information from the participants., then we will send location information with type of collision to nearest police station, hospitals and to the relatives of victims. Relative's number can be collected using vehicle number. If participatory sensing agrees on the presence of fire, then information is sent to fire force also.

IV. ALGORITHM

Algorithm1 explains first level of decision making at the context aware model level. Accelerometer_ reading refers to the analog value from the accelerometer, gyroscope_ reading refers to the analog value from the gyroscope, and flex_ reading refers to the flex sensor reading. Threshold values for each of these sensors vary depending upon the weight of the vehicle. For each vehicle the threshold value for accelerometer, gyroscope and flex sensor varies. In this algorithm continuous monitoring of the sensor values are monitored.

Threshold values for each of the sensors, accelerometer, gyroscope etc are setting dynamically depending on the mass of the individual vehicle. Flex sensor threshold depends upon the bending of the sensor. When it is in normal case, there would not be any bending, then output voltage will be zero and it will keep on increasing depending on the increase of bending on the flex sensor. Fig 2 shows accelerometer, gyroscope and flex sensor used in our system.

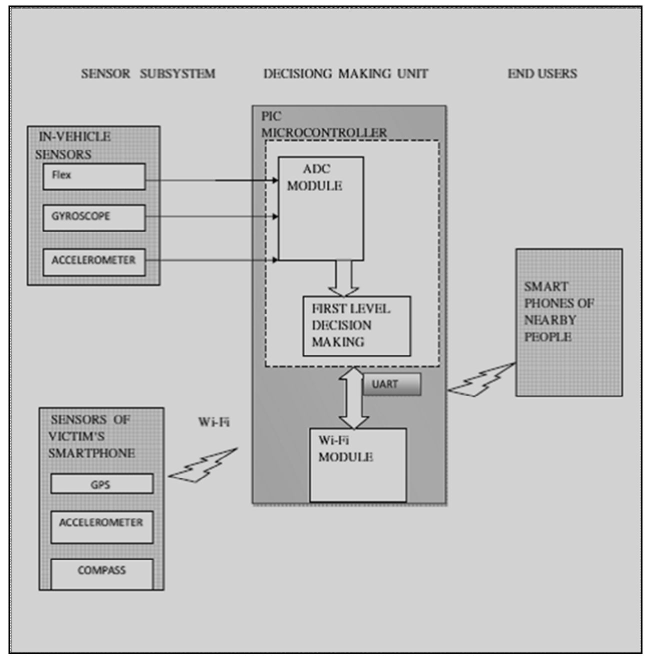


Fig. 3. Block diagram of the System inside the Vehicle

V. SIMULATION

Experimental set up is shown in Fig 4. We simulated our system for different accident scenarios explained in the algorithm. Due to limitation in simulating real sensors in proteus, we use interactive real time potentiometers for these sensors. Since our sensors shown in Fig 2 produces analog voltage value corresponding to the respective sensed values, we can assume these potentiometers as those sensors, as both give analog voltage values. ACCELEROMETER, FLEX and GYROSCOPE are three potentiometers assumed for sensors accelerometer, flex and gyroscope respectively. Threshold value for each sensor has set as 150,100 and 100 respectively for simulation. In real case this has to be found using dynamic threshold setting algorithm depending on the mass and acceleration of the vehicle. We have simulated each type of accident scenarios and the corresponding output messages are shown in a virtual terminal. In the real implementation this message is send through a Wi-Fi module to the Smartphone in its range, Fig 5 shows the scenario of vehicle rollover, both accelerometer and gyroscope exceeded their threshold values. And the expected scenario is an accident due to a Rollover and it is detected and the simulated result is a "rollover" message.

Fig 6 shows the scenario of headon or rear end collision, both accelerometer and flex sensor exceeded its threshold values, i.e. sudden retardation followed with a high force. This can be either Headon collision or a Rear end collision. Hence there is detection of an accident. And our simulated output is a “headon or rear end collision” message. Fig 7 shows the scenario of headon or rear end collision with rollover, here accelerometer, gyroscope and flex sensor exceeded their thresholds and the expected scenario is a “headon or rear end collision with rollover

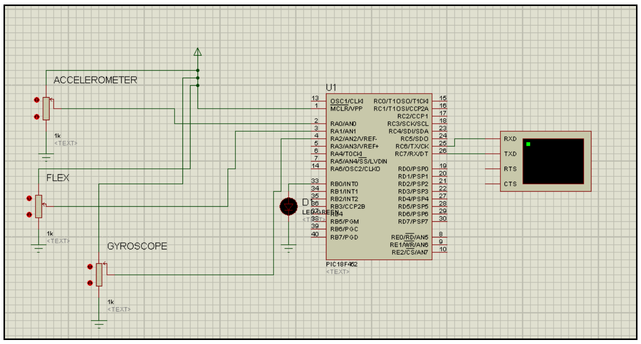


Fig. 4. Simulation setup

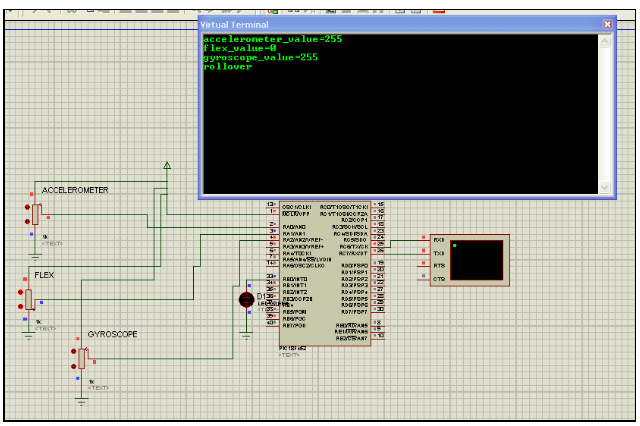


Fig. 5. Simulations for vehicle roll over

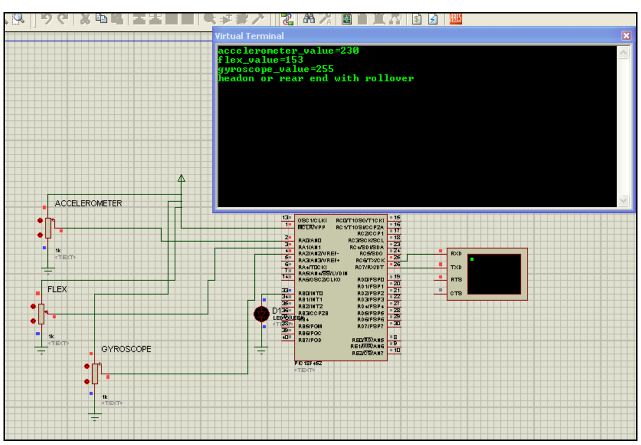


Fig. 6. Simulation for head-on or rear end collision

VI. Conclusion

We presented a context aware accident detection system, with reduced rate of false alarms with the aid of participatory sensing. . Context aware accident detection ensures the credibility of context of the accident and hence interpreting the number of vehicles involved. We have also presented techniques for different means of communication from the DMU to the monitoring centre and also designed a participatory system for increasing the reliability, fastness and scalability of the entire system. We have tested the correctness of our algorithm for context awareness.

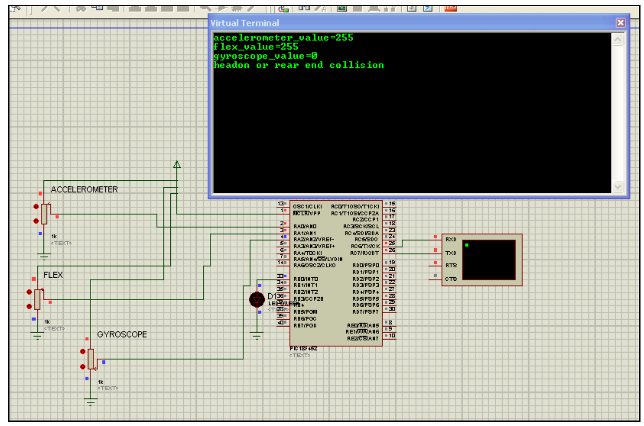


Fig. 7. Simulation for head-on or rear end collision with rollover

Algorithm 1 First level Decision Making Algorithm

```
START
while (TRUE) do
  if (accelerometer_reading > threshold) then
    Set flag_ accelerometer=TRUE;
    Set flagcheck =TRUE;
  else
    Set flag_ accelerometer=FALSE;
    Set flagcheck =FALSE;
  end if
  if (gyroscope_reading > threshold) then
    Set flag_ gyroscope=TRUE;
    Set flagcheck =TRUE;
  else
    Set flag_ gyroscope=FALSE;
    Set flagcheck =FALSE;
  end if
  if (flex_reading > threshold) then
    Set flag _flex=TRUE;
    Set flag_check =TRUE;
  else
    Set flag _flex=FALSE;
    Set flag_check =FALSE;
  end if
  if (flag_gyroscope == TRUE&flag_flex == TRUE) then
    Set flag =TRUE;
  end if
  while (flag_check == TRUE) do
    if (flag_accelerometer == TRUE&flag == TRUE) then
      Send ("head on or rear end collision with rollover");
    end if
  else
    if ((flag_accelerometer == TRUE&flag_gyroscope == TRUE)||(flag_flex == TRUE&flag_gyroscope == TRUE)) then
      Send ("vehicle roll over");
    end if
  else
    if (flag_accelerometer == TRUE&flag_flex == TRUE) then
      Send ("head on or rear end collision");
    end if
    Set flag_check = FALSE;
  end while
end while
END
```

Algorithm 1 First level decision making

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