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Automatic accident detection algorithm

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Abstract
60% of motor vehicle crash fatalities took place because crashes are not reported within the golden hour which is a deciding factor of weather a person will survive the crash or not. An accident can take place through a number of external factors like road rage, poor infrastructure etc. This paper proposes a crash detection algorithm through which a motor vehicle crash can be detected irrespective of the reason of the crash. GPS co-ordinates, gyroscope, magnetometer, accelerometer data is used by the algorithm, which combines the data to identify a crash. This algorithm will be able to accurately detect a crash and save millions of precious human lives.

Keywords: Crash detection, GPS, accelerometer, gyroscope, magnetometer

Introduction
Over the past few decades, there have been a lot of advancements in the transportation and automobile sector which has empowered human beings to do a lot of work in a small amount of time. But along with the advancements, the safety procedures also need an upgrade so that safety is not compromised. There have been major advancements in safety protocols especially in the airways and waterways but safety protocols lag behind when it comes to roadways. In India, every minute and motor accident takes place and every 3 minute one fatal accident takes place on Indian roads. In order to decrease such crash, there have been major advancements in the safety protocols but none are being able to bring down the fatalities. The algorithms which are capable to change the scenario are very costly thus cannot be deployed the budget vehicles which comprises the major part of such crashes.
GPS, accelerometers, gyroscope and various other sensors, can be used to derive the information about the vehicles. Through these sensors, one can accurately identify various factors like current speed, global location, accelerations, instantaneous accelerations, orientations, rate of change of orientations etc. All this data can be used to identify weather a crash has taken place or not. This data can not only identify the occurrence of a crash can also provide the intensity/seniority of a crash.
This paper proposes an algorithm which uses data like speed, instantaneous accelerations, orientations and various other data points to identify the severity of the crash. The algorithm splits an event into 3 types:
1. No crash
2. Non-fatal Crash
3. Fatal Crash

The algorithm is designed uses as minimum data as possible without compromising on the accuracy of the algorithm. As the algorithm uses data which can be easily derived using few sensor, the proposed algorithm can be deployed uses cheap logic boards/system possibly on android phones as android phones are easily available the driver can run the algorithm on the phone.

Related Work
There have been multiple attempts in the past to detect motor vehicle crashes so that the crashes can be reported on time and precious lives could be saved.
Some of the available solutions are as follows:
1. NAIC Home inventory: Is an android application which provides a check list that the user should follow post-crash. The app uses various sensors like microphone, camera to record vital information but fails to detect any accident.

2. Automatic accident detection with multi-modal alert system implementation for ITS [1]: Is hardware unit, specifically prepared for European roads and uses sensors like tri-axial accelerometers, gyroscopes, e-call hardware etc. To detect a crash but is very costly and requires a lot of road infrastructures for ITS [1].
3. Avertinoo [1]: Avertinoo uses pre-marked locations and alerts the user of any upcoming danger zone. It serves the purpose of alerting the user of upcoming accidental/danger zones and is also used to report accident through user input.
4. Accident Detection and Reporting System using GPS, GPRS and GSM Technology [2]: In this system, the author is using kinetic energy to detect a crash. The author has proposed a hardware unit which uses GPS sensors to detect current location and derive speed. The system has multiple threshold values to identify a crash or a non-crash event. The system is able to identify crash but is very inaccurate, and works best in case of an extreme crash [2].
5. Traffic Monitoring and Accident Detection at Intersections: In this, the author has proposed a system through which crashes can be identified on intersections. The system uses road infrastructure like camera and then uses Deductive process tracking algorithm to detect crash. Though the system can identify crashes, but is limited to intersections, and depends on camera which may not be found in majority of roads in countries like India [3].
6. Vehicle Positioning System with accident detection using acceleration sensor and Android technology: In this the user proposes a system which combine a hardware unit for vehicle and an android app for communication. In order to detect an accident, the system uses accelerometers, GPS sensors, dc motors to detect crash which makes the system expensive [4].

Equipments and Proposed Methodology

GPS

GPS sensor is used to detect the current location of the object. Using GPS locations we can accurately identify the speed, veclocity and can track the object.The data from the GPS sensor will be fed to the algorithm which then will be converted to speed and will be used as a threshhold to wheather an event can be an accident or not.

Tri axial Accelerometers

Tri-axial accelerometers provide the instantaneous acceleration of three axis: X, Y and the Z-axis. Orientation, instantaneous acceleration can be used to determine accidents, and this can be easily derived using tri-axial accelerometers.

Tri-axial Gyroscopes

Tri-axial Gyroscopes can provide the rate of change of degree along the tri-axis formally gyroscopes can be used to identify pitch, yaw, and azimuth. Once the raw data is fetched it can be combined with other sensor data to get the current orientation of the device. Improved accuracy of data from accelerometer, detecting a roll-over can be achieved using gyroscope.

Accident Detection Algorithm

In order to detect any crash, GPS sensor, accelerometer and gyroscope data is fed. Once given the data, the GPS location is used to derive the current speed. The accelerometer data is converted to the instantaneous acceleration on the tri-axis. The gyroscopic data is then converted to the orientation data so that the orientation of the device can be correctly identified and then subsequent correction operations can be applied to data form accelerometer in-order to make it independent of current device orientation.

Equation to derive speed

Speed = $\sqrt{((xp-xc)^2 + (yp-yc)^2 + (zp+zc)^2)}$
Where: kp : previous co-ordinate along the k^{th} axis
kc: current co-ordinates along the k^{th} axis

To get orientation of the device

$R_x = x*\sin(\boldsymbol{\theta}/2)$
$R_y = y*\sin(\boldsymbol{\theta}/2)$
$R_z = z*\sin(\boldsymbol{\theta}/2)$

Where R_k is the rotation vector along the k^{th} axis
$\boldsymbol{\theta}$ is the angle along the respective axis

Once speed is calculated, a threshold is defined for 20km/h which will be imposed over accelerometer events and any crash detected when the speed is less that 20Km/h will be downgraded to priority 0.
Over the complete journey the orientation will be monitored continuously and if the angle along x or y axis become greater that 45^o or is less than 45^o, then event will be classified and priority 3 as it will be a case of a roll over.
Along with this, the accelerations will also be monitored over the complete journey and events will be classified based on the table below:

Min absolute acceleration in degree	Max absolute acceleration in degree	Priority
0	1.5	1
1.5	2.5	2
2.5	Above	3

As there are three axis, the axis having the maximum priority will be considered.
In order to make the algorithm more efficient, we will also consider cases of false positives which arise due to poor road infrastructures like potholes and bumps.
In order to detect such inequalities, we will use the values provided by the authors in [8] and limit the maximum priority.
When speed is greater than 45Km/h

Table 1: Potholes

Z_{th}	Max Priority
$-0.5<Z_{th}<0$	1
$-g<Z_{th}<-0.5$	2
$-1.5<Z_{th}<g$	3

Table 2: Speed breakers:

Z_{th}	Max Priority
$2g<Z_{th}<2.5g$	1
$2.5<Z_{th}<3g$	2
$3g<Z_{th}<3.5g$	3

When speed is less than 45Km/h

Table 3: Potholes

Z_{th}	Max Priority
$0<Z_{th}<0.5g$	1
$-0.5g<Z_{th}<0$	2
$-g<Z_{th}<-0.5g$	3

Table 4: Speed breakers

Z_{th}	Max Priority
$1.5g<Z_{th}<2g$	1
$2g<Z_{th}<2.5g$	2
$2.5g<Z_{th}<3g$	3

Here Z_{th} refers to the acceleration along the Z-axis

Based on the priority, subsequent actions like alerting the Emergency contacts and alerting the emergency services can be taken in order to minimize the number of fatalities.

Result

Upon testing the above algorithm over a sample of 60 events, which comprises of 20 severe accident case, 20 non severe accident case fetched from NHTSA research database and 20 non crashes case [8]. The algorithm performance is shown in the table below:

Type of Sample	Total cases	Accurate prediction by the algorithm	accuracy
Severe accident	20	20	100%
Non severe accidents	20	17	85%
Non accidental cases	20	18	90%
Overall	60	55	91.6%

Conclusion

The algorithm is accurately able to identify all three types of crashes, but still the algorithm has 8.4% overall error and 15% error in case of non-severe cases which shows that the algorithm is quite accurate and is capable to save a lot of priceless lives but has a room for improvement especially in-case of non-severe accidents. Also as the algorithm uses data which is easily available, the algorithm can be deployed to cheap system having just enough hardware to get required data and is can also be deployed over android devices.

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