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CHAPTER I

1.Introduction

Different techniques for driver safety are being used in Intelligent Transportation Systems (ITS) area. Also, the smartphone industry is advancing quickly. Mobile smartphones are embedded with numerous sensors that can help to aid in the safety enhancements for drivers on the road[3]. The project has been developed under the Research and Innovation team at IGATE Global solutions. The focus of the project is to introduce different mobile applications that offer new features for safe driving. By combining smartphone applications for existing vehicles, we can offer the user new functionalities and services while driving.

Smartphone applications can be used to increase the safety of the drivers. They can also be used to analyze the various driver behaviors. Such analysis can help to detect and correct the driving styles. Smartphone applications such as Vision Test and different sensor applications can be used for analysis e.g. driver's vision, identifying driving events, driver behavior, etc. This can be applied to various sectors such as Insurance sectors, fleet owners, driving assistance systems etc. Insurance companies can use the data obtained from the applications to provide different claims and schemes to the customers. Fleet owners can check the driver's behavior and analyze it. Various driver assistance systems can be designed based on the data and analysis obtained by the smartphone applications.

Telematics is defined as the integrated use of telecommunication and informatics for application in vehicles and with the control of vehicles on the move [1]. Vehicle Telematics can be referred to as a combination of I.T, instrumentation and advanced communication technologies to assist the drivers. Advanced driver assistance systems include different features such as lane departures warning systems[2] , lane drifting systems[2] etc. The emergence of Telematic systems have also helped in improving driver and vehicle safety. The key features are:

- Pay-as-you-drive and Pay-how-you-drive tracking and reporting unit
- Vehicle diagnostic unit
- Diagnostic data recorders
- Smartphone applications

Smartphone Applications for Vision Tests and Safe driving

The tremendous advancements in the field of technology and research have resulted in the innovation of various mobile applications. The applications made are user-friendly and can be used by the people in their everyday life. They can be used for monitoring the drivers as well as assessing their performance. Such applications and analysis can be used for training sessions of the drivers which can help to improve the overall safety.

Our application includes a Vision Test application that helps to test an individual's vision. It consists of various tests that can be used for further driver behavior analysis. Another set of applications includes the sensor application. It obtains the readings from various sensors such as accelerometer, gyroscope and GPS. The readings help us to understand the driver behavior for different critical events.

CHAPTER II

2.Literature survey and problem definition

Current smartphone applications are able to check an individual's vision using different tests. However the results provided by them can be used as an input for checking the driver's vision. The results provided by our Vision Test application can be used for analysis.

Mobile applications such as Vision Eye Tests can be used easily in order to check an individual's vision. Vision tests check many different functions of the eye. These tests measure the ability to see details at near and far distances, check for gaps or defects in the field of vision, and evaluate one's ability to see different colors. Machine to machine technology (M2M) and wireless connectivity between machines has gained profile in European and North American Insurance sector. Motor insurers are discovering that telematics can serve more accident prone, high risk and young drivers. Advances in application development are pushing some insurers towards GPS enabled smart phones as the data collection devices. The scope of sensor networks has expanded into domains like Intelligent Transportation systems which consist of On Board Diagnostic devices and sensors for collection of data. The emergence of Telematic systems have helped in improving the driver and vehicle safety.

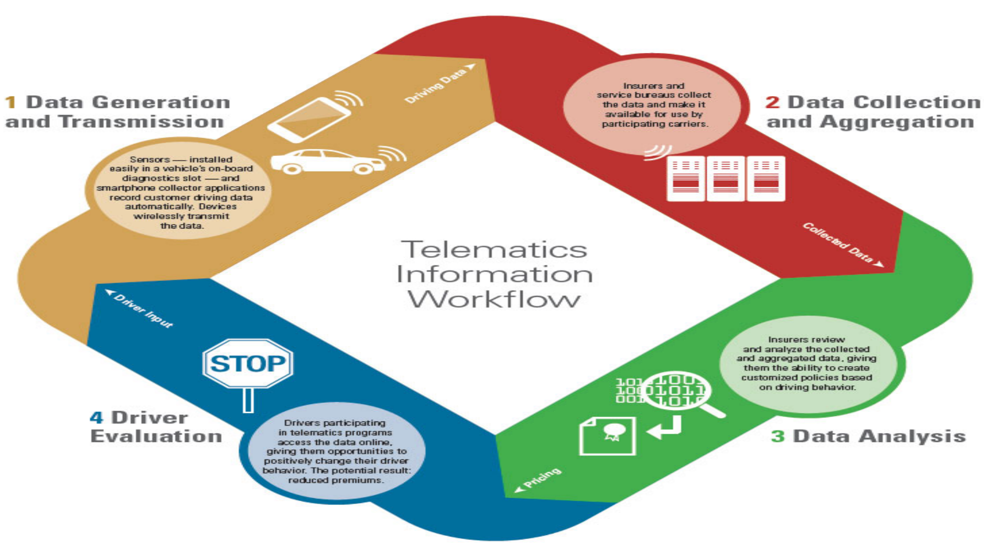

Figure 1 Telematics Information workflow

Source: http://www.propertycasualty360.com/2014/07/25/dazzled-by-telematics-but-dont-know-where-to-start

Smartphone Applications for Vision Tests and Safe driving

The telematics information workflow is shown in fig.1. Research includes towards developing systems that make driving safer [1],[2],[3]. DriveSafe[2] and Carsafe[10] alerts the drivers using dual cameras-one for detecting driver state and other for tracking road conditions. In[4], a recognition system of the driver aggressiveness based on sensor fusion is presented. Other works include connecting smartphone sensors to OBD devices for driver classification. Nericell[7] is a system developed by Microsoft that helps in the detection of bumps, vehicle braking etc. Pothole Patrol[5] is a system which is used for monitoring the various road conditions. It also uses the sensors such as accelerometers and GPS(Global Positioning System). The paper [3] has mentioned various factors that can account to unsafe driving. It has provided various applications which help to analyze the vehicle's condition based on these factors.

The paper 'Traffic sense' [7] provides various methods for monitoring road and traffic conditions. 'Wolverine'[8] is a system designed to provide the traffic and road condition estimations with the help of smartphone sensors. Various systems also make use of the On Board devices for obtaining the data of the vehicle and provide feedback on the drivers' behavior. [11] makes use of smartphone embedded sensors such as accelerometers for providing real time pothole detection. The system in [12] gives assistance to the drivers by using accelerometers and GPS. With portability and sensing capabilities of smartphone sensors such as accelerometer, gyrometers,GPS etc. we can built apps on the smartphones for assessing driver behavior. Driving coach [16] is an application to detect driving behavior using fuzzy logic. Its results show that there is potential for significant energy savings and detection of driving behavior and patterns. A Mobile Sensor Platform for Intelligent Recognition of Aggressive Driving (MIROAD)[6] uses a dynamic time warping algorithm(DTW) along with sensor fusion. [10] evaluates a mobile application that assess the driving behavior based on in-vehicle acceleration measurements and gives corresponding feedback to the drivers. In [2] and [6] the critical events such as acceleration, braking are modeled using Hidden Markov Models (HMM) for driver behavior analysis and route recognition. There has been significant work done in the field of road safety using portable devices such as mobile phones in recent times. Different pattern recognition algorithms can be used for detecting the driving patterns. The paper[3] has also mentioned various factors that account to unsafe driving and different applications for evaluating the driving patterns. The various approaches that have been used for evaluation are:

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1] Fuzzy interpretation system

It enables us to consider every factor while evaluating the driver condition. It follows a holistic approach. It is process of formulating the mapping from given input to an output using fuzzy logic.

2] Neural Networks

This network tries to analyze the input pattern and gives the expected output. Neural networks act as pattern recognition system. One powerful feature of the neural network is that it can give an output even if the input pattern has no associated output for which the network was trained

3] Hidden Markov Model (HMM)

These models are probabilistic tools for studying the time series data. HMM consist of a number of states and transitions between them. At discrete time intervals the Markov process moves from one state to another according to the set of transition probabilities. It can also be used for pattern recognition. Using one of the above approaches a model can be built for event prediction.

Problem Definition

The current applications make use of On-Board diagnostic devices for analysis and results. This requires installation and maintenance of expensive hardware. These On board sensors add to the cost of a vehicle and cannot be affordably upgraded. These devices do not provide privacy to the customer. Hence our target is a mobile smartphone which acts as an alternative for assisting the driver. The main idea of our project is to assess the driver's vision and behavior using smartphone applications.

Our project includes two smartphone applications: (1) Vision Eye Test application and (2) Sensor applications that can be independently used by the customer in order to check their vision as well as driver behavior. The features of the application are explained in the next sections. The applications are built using the Android operating system[28]. The Vision test application can be used as a prerequisite for checking the driver's vision. It includes various tests for checking the driver's vision. The Sensor applications are used to obtain the necessary data that can be used for analyzing the driver behavior.

CHAPTER III

3.Sensor based applications for safe driving

The focus of our project is to provide smartphone applications that can be used for analyzing the driver behavior and patterns. For this we have introduced two sets of smartphone applications: (1) Vision Test application and (2) Sensor applications. These applications provide enough data which can be analyzed using different approaches to obtain safe driving.

Vision test is an important application in the field of ophthalmology required for the people with poor vision. This test can be used to check the vision of an individual. However it provides the basic features. In case of poor results the individual should consult the doctor. The application does not in any way replace a regular eye exam done by a licensed optician. Data from the application can be used for providing information about the drivers' behavior. Similarly data about critical events such as speed, braking, acceleration etc. can also be obtained from the sensors built in the smartphone. Such data is indicative of accident risk and may be utilized for risk-minimizing behaviors among drivers. This can contribute to the overall traffic safety. We can provide feedback of the recorded driving actions to drivers. This encourages them to change their behavior and reduce their individual accident risk.

Mobile smartphones are equipped with different sensors that can help to aid in safety enhancements for drivers on the road[3]. The sensors such as accelerometers and gyroscopes can be used to record and analyze various driver behaviors and road conditions to prevent accidents. Real time analysis can increase a driver's overall awareness to maximize safety[3]. Different axes of the accelerometers are used to identify the sudden changes in acceleration or jerks experienced by the vehicle. The orientation of the phone can be obtained using gyroscopes in the smartphones. In the motor insurance sector, such data can be used to improve the assessment, communication and mitigation of insured risk, thereby creating value for insurers and policy holders.

Our application makes use of sensors such as Three axis accelerometers, gyro meters and GPS for obtaining data based on the driving events. It measures the parameters such as acceleration, deceleration, speed, latitude, longitude etc. The smartphone sensors experience the same forces as those experienced by the vehicle. Thus, with these values we can detect and predict various driving events such as sharp turns, braking, increase or decrease in speeds etc. These events are obtained with the help of the sensors embedded in the smartphone. The data of the different events can be used for analyzing the various driver behaviors.

The sensor application was created using the Android platform to obtain data from accelerometer, gyro meter and GPS. The accelerometer provides readings in m/s^2 for the three axes : x,y and z. The x-axis corresponds to the lane changes. Y-axis corresponds to the increase and decrease of speed. The z-axis corresponds to the jerks or vibrations experienced by the vehicle.

The gyro meter shows the orientation of the phone in the vehicle. GPS provides the latitude, longitude, and speed values. The application was tested on various roads for collection of the training data. A total of six test routes were taken for obtaining the readings.

3.1 Architecture

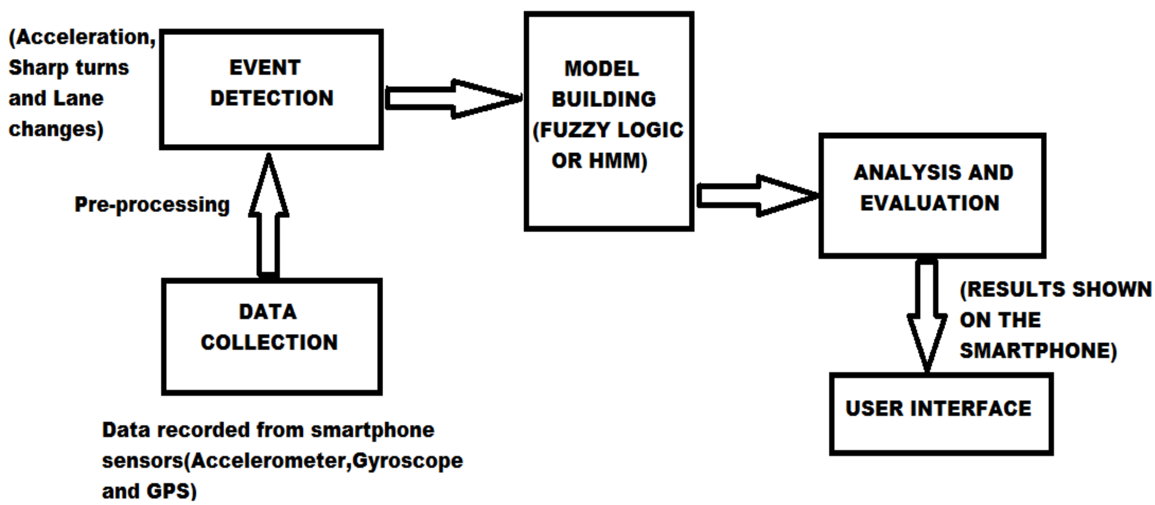


Figure 2 Model for detecting driving events

The figure 2 provides a model that has been used for obtaining data from the smartphone sensors and the approaches that are used for detecting the critical events. The training data is collected from the sensors embedded in the smartphone. The data is recorded from sensors- accelerometer, gyrometer, and GPS. The data is filtered and used for detection of events. The critical events consist of acceleration, deceleration, sharp turns, sudden braking and lane changes. Fuzzy logic and an HMM model were used for detection of the events.

3.2 Methodologies used

The applications were built on the Android platform. The Android operating system [28] offers a custom plug-in for the Eclipse IDE called the Android Development Tools (ADT). This plug-in helps in developing different Android applications. The user interface was designed using the xml layouts. The different tests were built using activity files with Java codes.

For analyzing the data obtained from the sensors embedded in the smartphone, two methods have been used – Hidden Markov Model (HMM) and Fuzzy logic. The HMM model was used for identifying the driving patterns. The model was used to identify critical events- Right turn(RT), Left Turn(LT) and Straight Forward(SF). For Fuzzy logic the Mamdani model was used for evaluation of the driving events.

3.3 Design

3.3.1 Vision Test application:

The Graphical User interface for the Vision Test applications has been designed on Eclipse IDE. The application includes the following four tests:

1. Visual Acuity Test (regular vision test)
2. Astigmatism Test (checks for astigmatism)
3. Duo-chrome Test (tests your ability to focus)
4. Ishihara Color Test (checks for color-blindness)

Other tests which can be included are: Refraction, Amsler Grids, Glaucoma Tests etc. The fig. 3 shows the tests included in the application and their features.

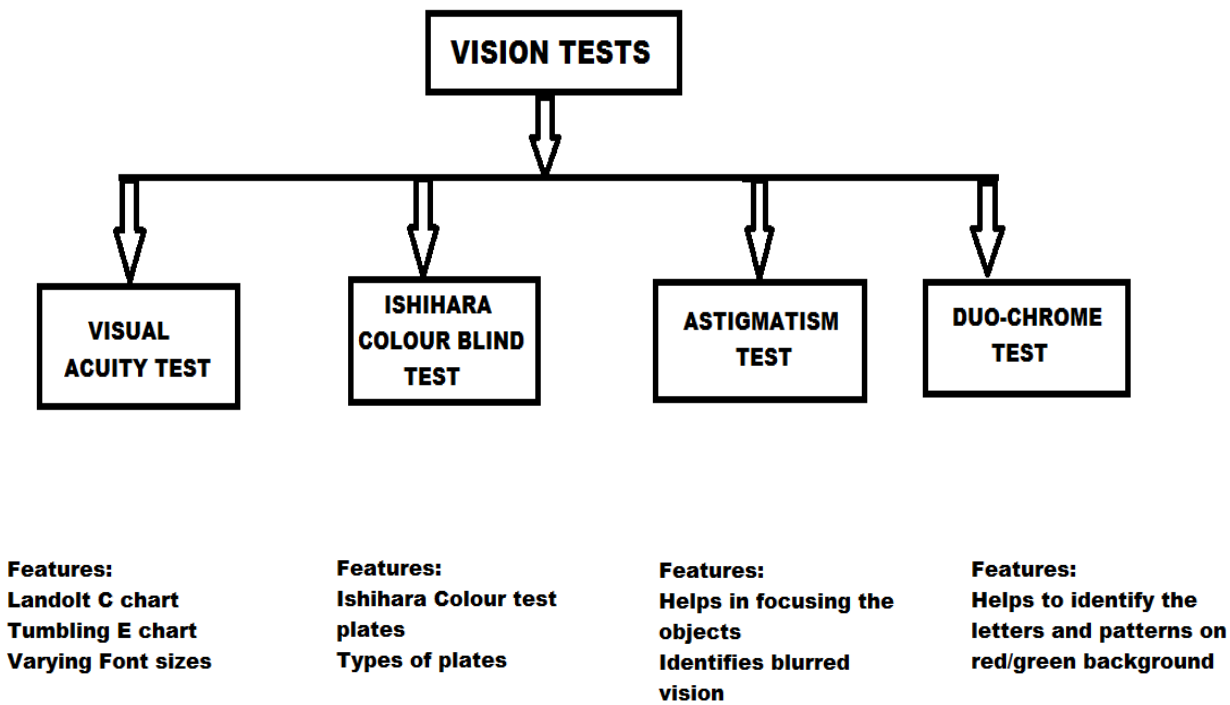


Figure 3 Tests included in the Vision Test application

The fig. 4 describes the flowchart of the Visual acuity test of the application.

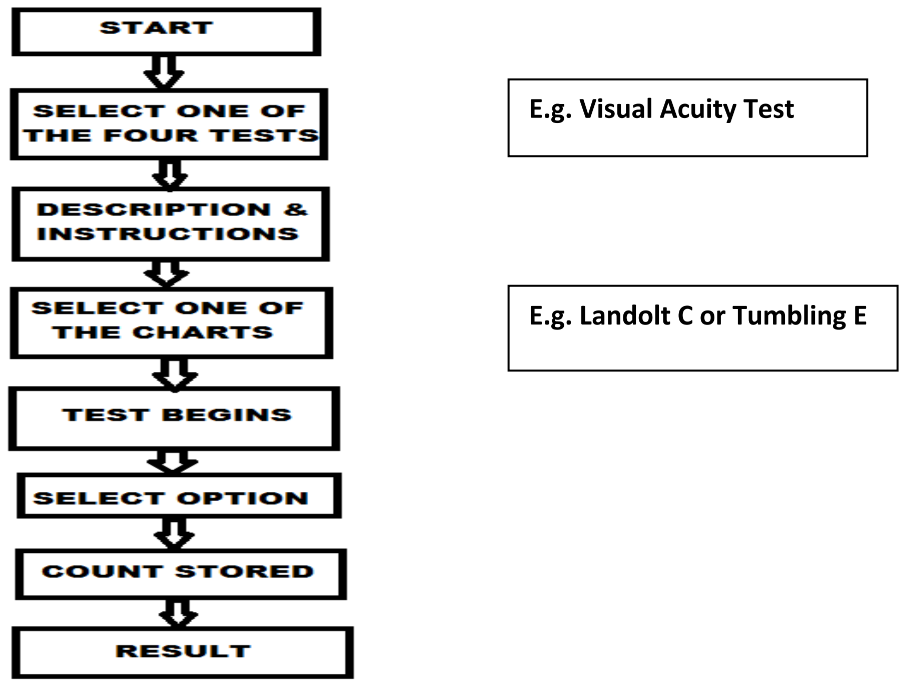


Figure 4 Flowchart of the Visual Acuity test

In the beginning, the user can select any one of the four tests-Visual acuity, Astigmatism, Ishihara Color blindness, and Duo-chrome test. After selection the application provides a brief description of the current test. For e.g. the user selects a Visual Acuity test. In it the user can select any one of the charts for testing- Landolt C or Tumbling E chart. The test then begins. Depending upon the various questions the user selects the appropriate answer. The count of all the answers is stored. The application then provides the corresponding results. These results can be used as a pre-requisite before driving. These results can also be used as the data for analysis of the driver behavior. The different tests included in the application are as follows:

3.3.2 Visual acuity test:

Visual acuity tests are the most common tests used to evaluate eyesight. They measure the eye's ability to see details at near and far distances. The tests usually involve reading letters or looking at symbols of different sizes on an eye chart. Usually, each eye is tested by itself. Several types of visual acuity tests may be used.

Smartphone Applications for Vision Tests and Safe driving

Near Visual Acuity is the measurement of how well an individual can see close objects. It is usually measured at about 16 inches away from the eyes. Single or multiple characters and symbols can be used to check the vision.

Distance Visual Acuity is the measurement of one's degree of vision loss. It is measured by testing the smallest object that one can recognize usually at a distance of 20 feet. The charts that are used for measurement are Sneller and its mirror image, Tumbling E charts, and Landolt charts. The application uses these charts along with different font sizes for vision testing.

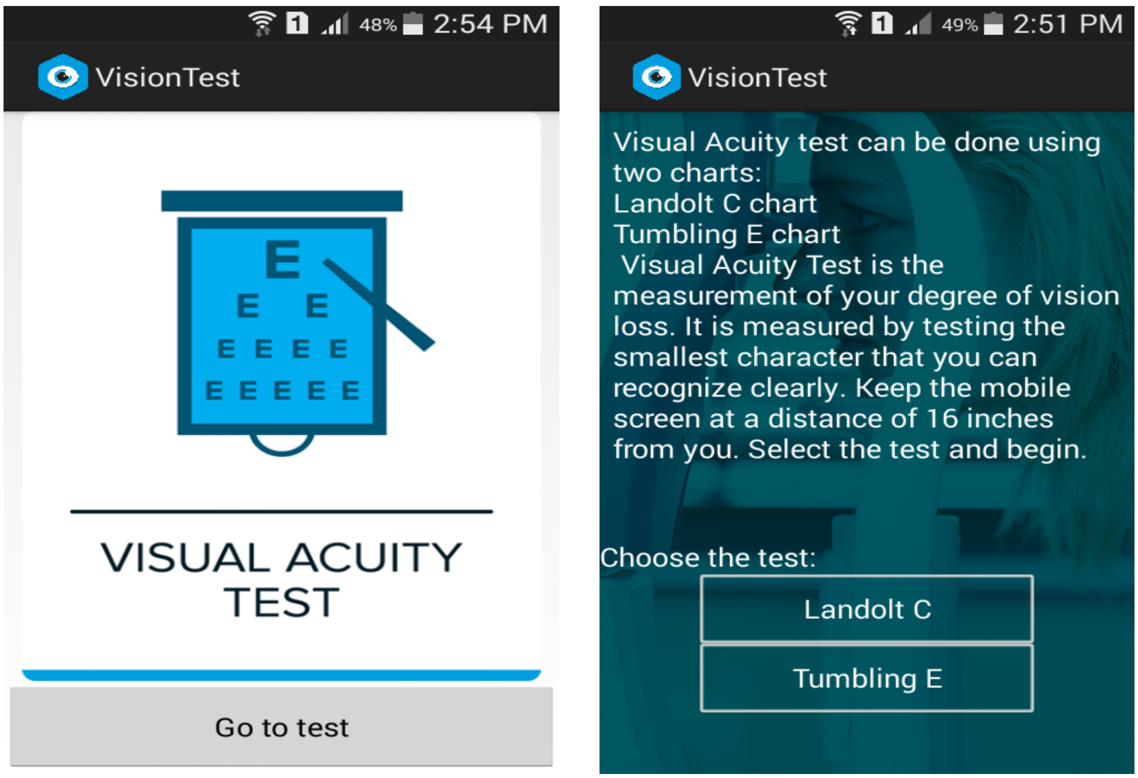


Figure 5 Screenshots of Visual Acuity test

The figure 5 shows the screen of the selected Visual Acuity test. After pressing 'Go to Test' the user can see the next screen. The application provides a brief description of the test. It also provides a few directions which are to be noted during the test. The user can select any one of the charts Landolt C or Tumbling E chart. The test then begins. Figure 6 describes the screen of the Visual Acuity test. It shows a letter C. The user has to select the direction of the circle or the direction of the gap shown on the screen. The four options are given. For e.g. the correct option for the above letter is 'right'. The screens ahead will show different directions of the letter C. Also the corresponding font sizes will decrease and the score will be provided. Depending on the score the application provides the user's range of vision: mild, moderate or normal.

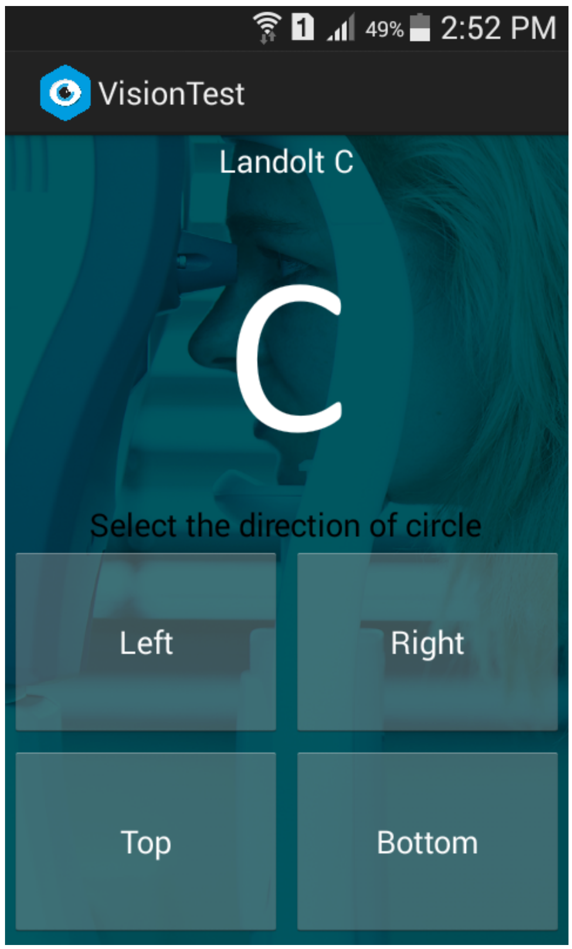


Figure 6 Screenshot of Visual acuity test

3.3.3 Astigmatism Test:

Astigmatism is a condition in which the cornea, the transparent layer that covers the front part of the eyeball, is not symmetrical. The cornea bends or refracts light rays to focus the light onto the retina in the back of the eye, but when it doesn't cover the eyeball evenly, the light rays are not focused on a single point. The result can be blurry vision. However, small amounts of astigmatism usually don't lead to vision problems, as blinking helps maintain the cornea's symmetrical curve. Infants can be born with astigmatism, or it can be caused by heavy eyelids, blunt trauma to the eyeball, scarring of the cornea from lacerations, and infection. Astigmatism is measured in diopters. A measurement of 1 diopter often requires correction with eyeglasses or contact lenses.

For testing the vision using the mobile application, different shapes and patterns are used. These shapes compose of lines and circles of different intensities and thickness.

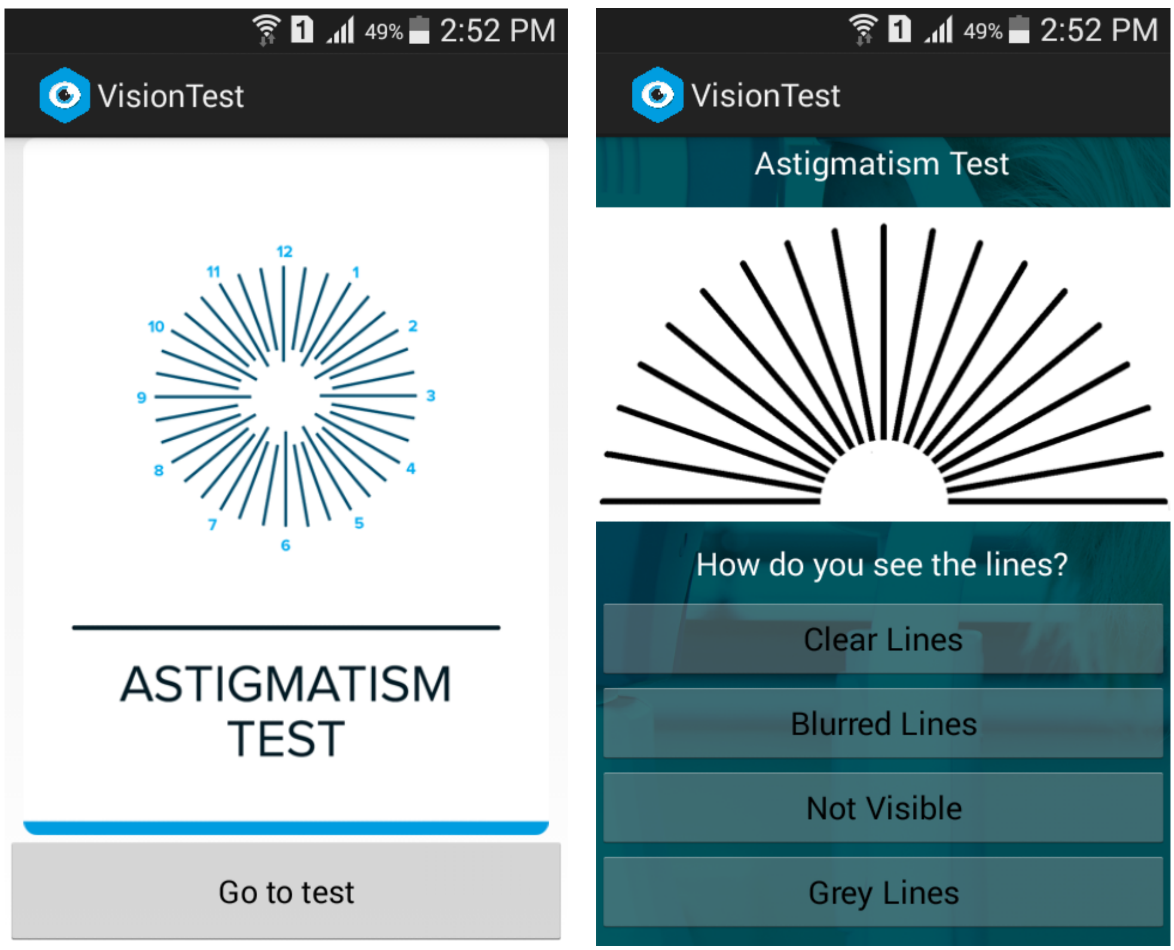


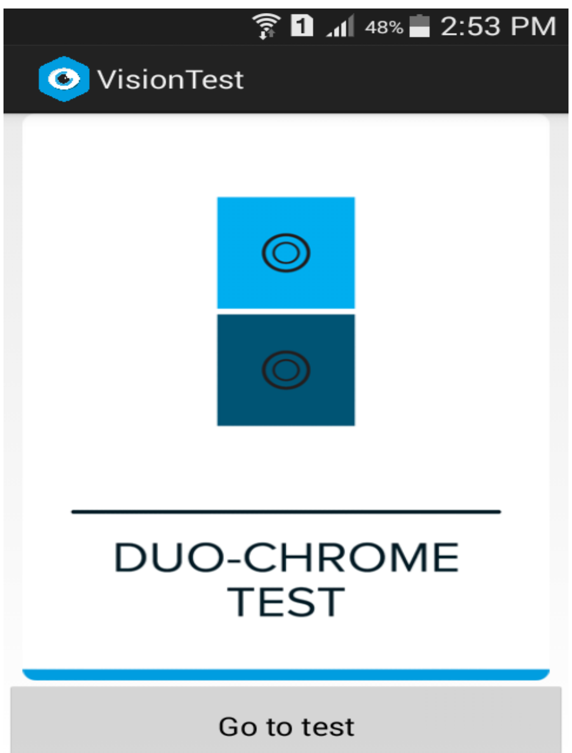
Figure 7 Screenshot of Astigmatism Test

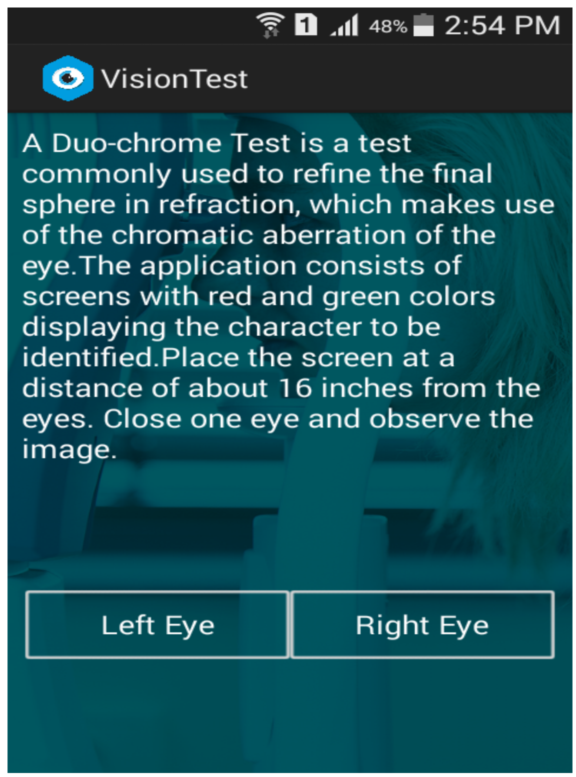
Figure 7 shows the beginning screen of the Astigmatism test. The next screen consists of the questions that are used in the application. This is used to identify the whether the user has blurred vision or not. The count for all answers is stored. Depending on the score, the result is obtained. The next test is the Duo-chrome test.

3.3.4. Duo chrome test:

A Duo-chrome Test is a test commonly used to refine the final sphere in refraction, which makes use of the chromatic aberration of the eye. Because of the chromatic aberration of the eye, the shorter wavelengths (green) are focused in front of the longer wavelengths (red). The patient is asked to compare the clarity of the letters on the green and the red side. If the letters of the green side are clearer +0.25 D sphere is added and if the letters on the red side are clearer -0.25 D sphere is added. With optimal spherical correction, the letters on the red and green halves of the chart appear equally clear.

The application consists of screens with red and green colors displaying the character to be identified.





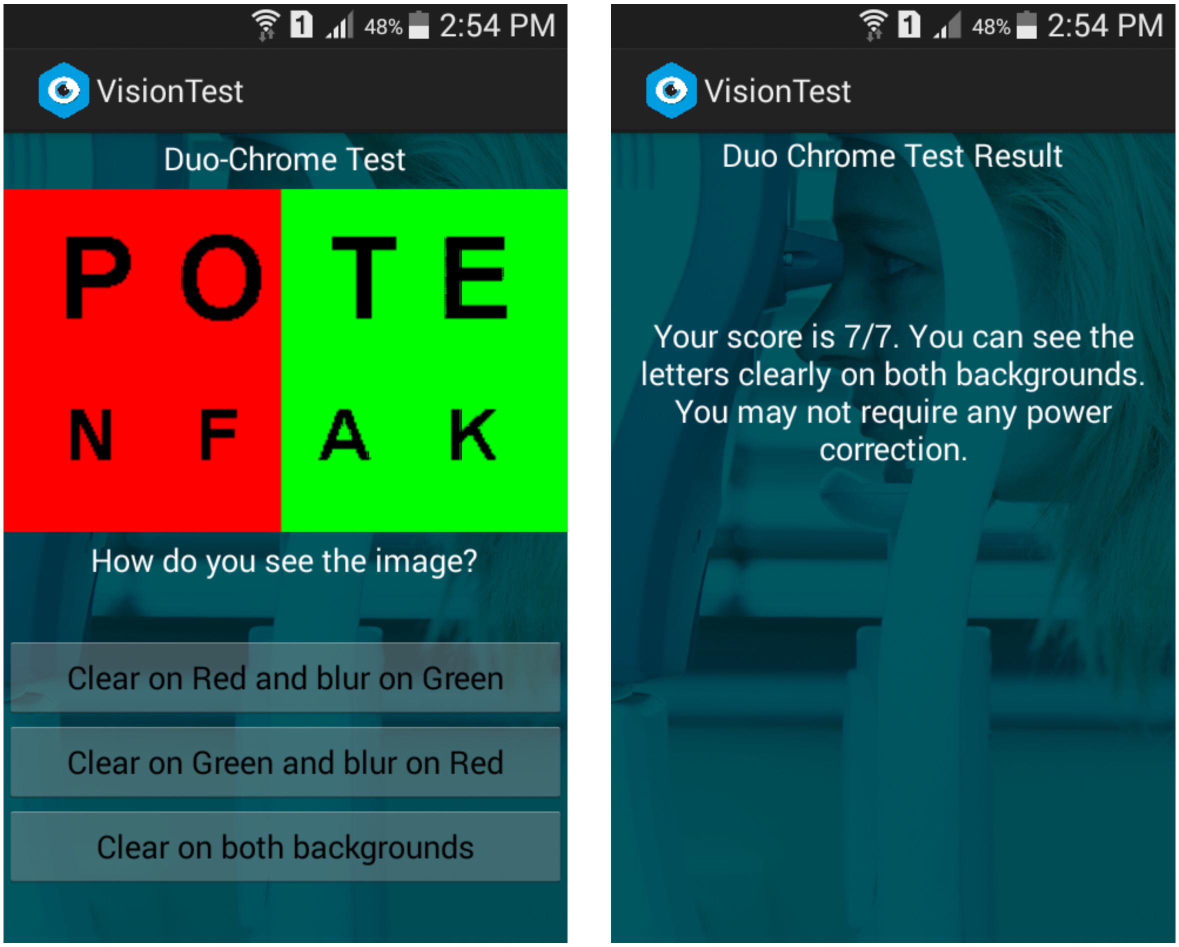


Figure 8 Screenshots of Duo- chrome test

Figure 8 shows the beginning screen of the Duo-chrome test. The next screen provides the description of the test. It also provides the directions required for the test. As the test is used for both eyes, the user can select any one of the eyes and begin the test. Different images are used in the application. The user has to be able to identify the symbols or letters on both Red and Green backgrounds. If the user is not able to see the letters clearly on both backgrounds, then he/she may require some power correction. The count of all answers is stored. Depending on the score the result is obtained. The next test is the Ishihara Color Blindness Test.

3.3.5 Ishihara Color Blindness Test:

The Ishihara Colour Test is an example of a colour perception test for red-green colour deficiencies. The test consists of a number of coloured plates, called Ishihara plates, each of which contains a circle of dots appearing randomized in colour and size. Dots form a number or shape within the pattern clearly visible to those with normal colour vision, and invisible, or difficult to see, to those with a red-green colour vision defect. The full test consists of 38 plates, but the existence of a deficiency is usually clear after a few plates. There is also the smaller test consisting only 24 plates. The plates to be used in the application can be made of different test designs:

- **Transformation plates:** Individuals with color vision defect should see a different figure from individuals with normal color vision.
- **Vanishing plates:** Only individuals with normal color vision could recognize the figure.
- **Hidden digit plates:** Only individuals with color vision defect could recognize the figure.
- **Diagnostic plates**: Intended to determine the type of color vision defect and the severity of it.

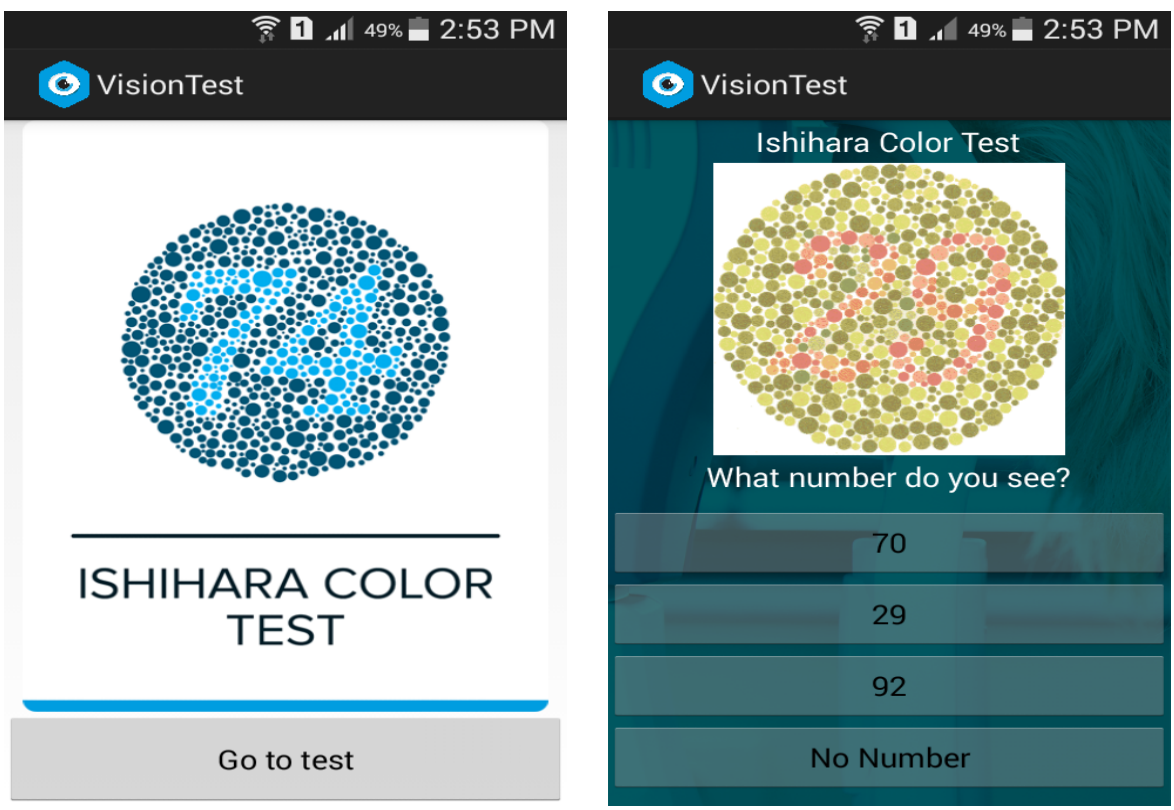


Figure 9 Screenshots for Ishihara Color Blindness Test

Figure 9 shows the beginning screen of the Ishihara Color Blindness test. The next screen gives a brief description of the test. The next screen shows the color plate images that are used for the application. The user has to identify the number or the design and colors on each plate. The count of all the answers is stored. Depending upon the score the result is obtained.

3.3.6 Sensor applications:

Applications for accelerometer sensor, gyroscope and GPS sensor were built using Eclipse IDE on the Android platform. Fig. 10 shows the screenshots of the accelerometer sensor.

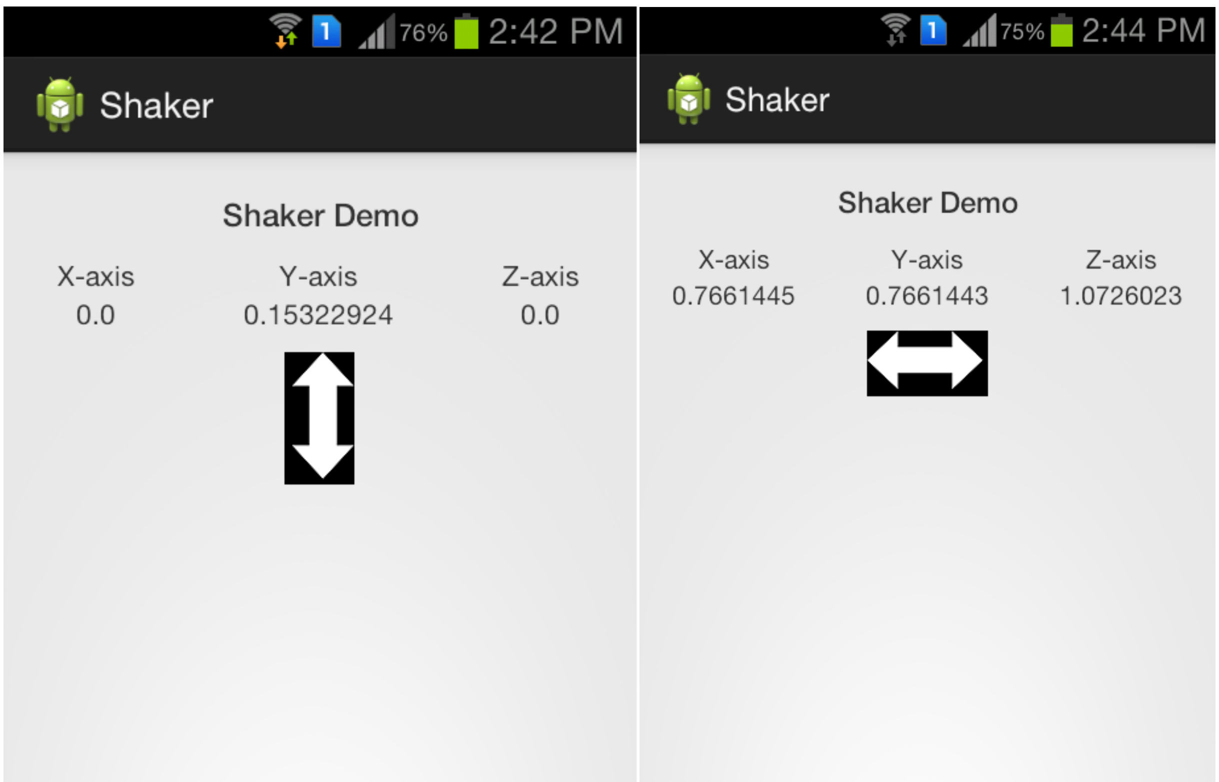


Figure 10 Screenshots of Accelerometer application

The figure 10 describes the screens of the accelerometer application. They consist of the parameters x, y and z axes. These are used to obtain the readings for lane changes (x-axis), forward acceleration (y-axis) and vertical peaks (z-axis).

The user interfaces for identifying the driving pattern are shown in the fig. 11. Fig. 11 describes the application used to show the driver behavior and patterns. The person has to enter a contact number to whom the warning message has to be sent. The images show the rating of the driver based on the accelerometer readings. If the z-axis experiences jerks then the message for sudden braking or hard braking is shown.

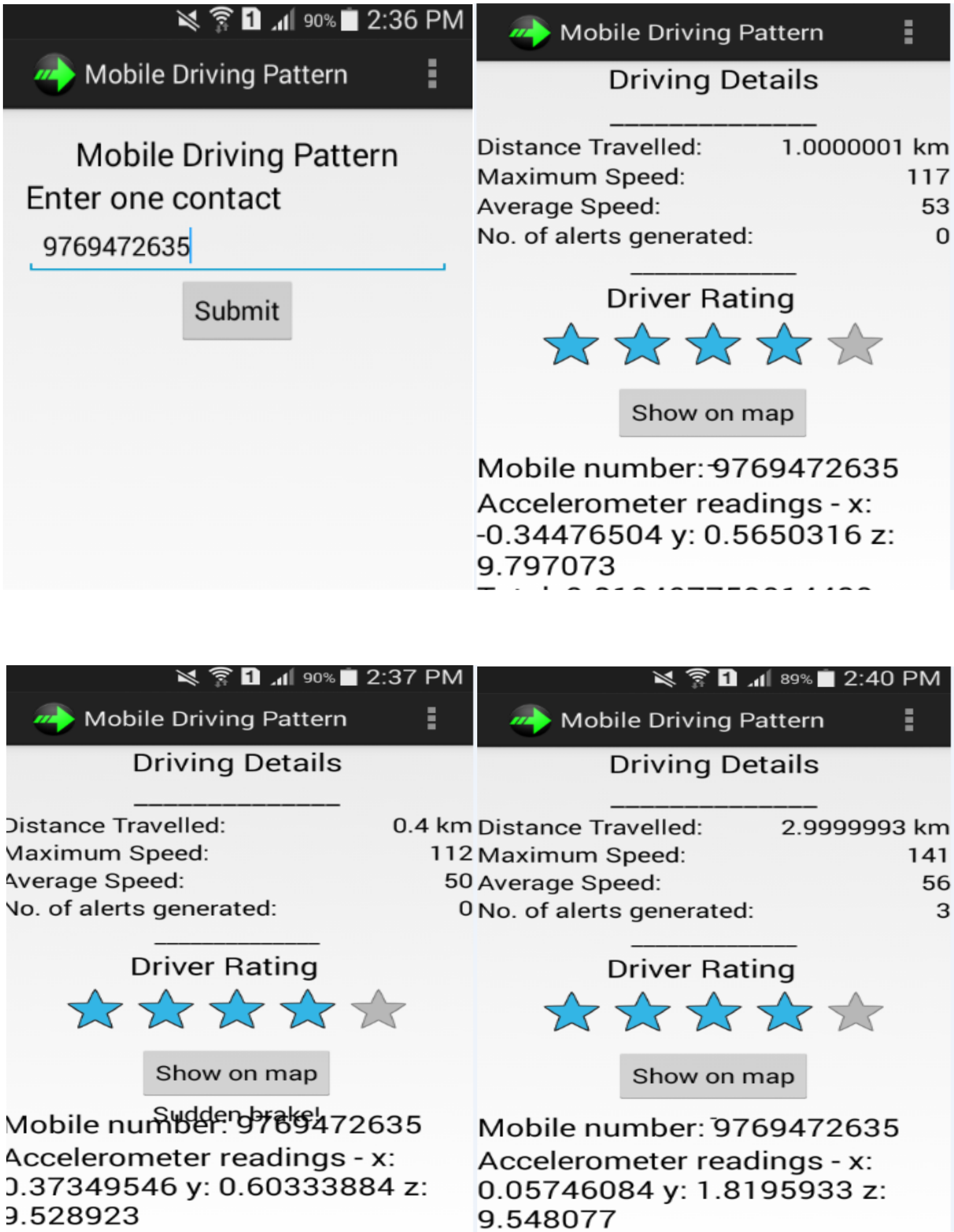


Figure 11 Screenshots for Mobile driving pattern

Fig.11. shows that if the driver performs rash driving then the no. of alerts generated increases. If this count increases above 3, then a warning message is sent to the submitted mobile number along with the latitude and longitude values obtained from GPS sensor shown in fig. 12

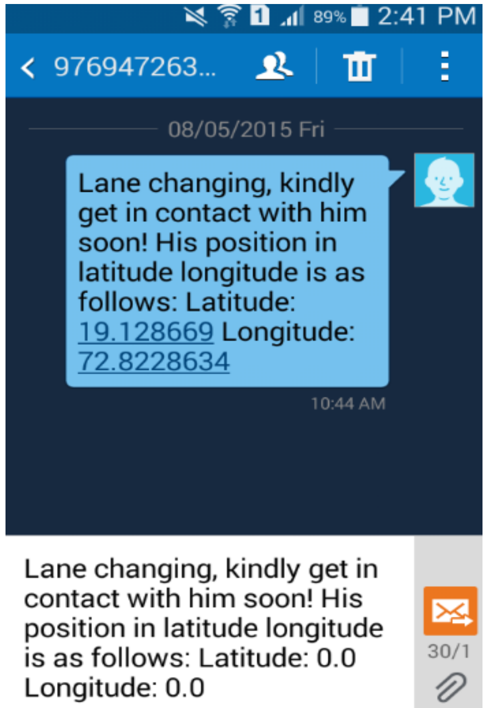


Figure 12 Screenshot of the warning message sent

The next sections consist of the validation process for Vision test and Sensor applications.

CHAPTER IV

4.Validation

4.1 Vision Test Validation

The above Vision Test can be used as a prerequisite for safe driving. Many features such as camera functionalities can be added into the application. Our application is a research prototype. This application was shared with the onsite team of IGATE and was demonstrated to one customer CIO who gave a positive response. To aid the driver safety along with the above application, the sensors embedded in the smartphone can also be used.

Different applications can be used for obtaining safe driving using smartphones. These applications can use the inbuilt sensors of the smartphones to obtain good results. Smartphones and their sensors are promising platforms for providing safe driving. The various sensors that can be used are explained in the next section.

4.2 Sensor application experimental validation

4.2.1 Phone orientation and location:

The phone's orientation for the experiment remained the same with the y-axis pointing towards the front of the vehicle and the screen (z-axis) facing the roof. The x-y plane of the accelerometer sensor is parallel to the touch screen of the device with positive directions of x and y pointing to the right and front of the device respectively. Ideally the device should be mounted in the vehicle such that all the three axes of the smartphone are aligned with the relevant axes of the vehicle[1].

4.2.2 Driving patterns:

The data from accelerometer is used to measure the driver's control of the vehicle as they accelerate, change lanes and apply brakes. Figure 11 shows the different axes of the smartphone. These axes are aligned with the relevant axes of the vehicle. Figure 12 provides description of the different accelerometer axes.

Figure 13 Three axes accelerometer

Source: Safe driving using mobile phones[3]

Accelerometers are used for detecting subtle or extreme vibrations experienced inside the vehicle. The different events that can be identified are as follows[12]:

Axis	Direction	Driving condition
X – axis	Left/right	Change in lane
Y – axis	Front/Back	Acceleration
Z – axis	Up/Down	Vibration

Figure 14 Description of accelerometer axes

4.2.3 Experimental setup:

The device used was an Android based smartphone: Samsung S-duos. Six test routes were used to record the readings. The readings were taken from the accelerometer, gyroscope and GPS applications. A set of readings for the phone is shown:

Accelerometer Values
filename: default__1.txt
Saving start time: Thu Oct 09 20:19:26 IST 2014
sensor resolution: 0.038307227m/s^2
#Sensorvendor: , name: 3-axis Accelerometer, type: 1,version : 1, range 39.2
X value, Y value, Z value, time diff in ms

Table 1 consists of the readings obtained from the application for x, y and z axes.

Table 1 Sample readings for a test route

X-axis(Lane changes)	Y-axis(Forward acceleration)	Z-axis(Bumps and Potholes-Vertical peaks)
-0.766	1.685	11.492
0	2.451	11.798
0.153	2.911	10.113
0.153	2.911	10.113
0	2.758	9.806
0	2.758	9.806
-0.306	2.911	9.959
-0.612	2.758	9.346
-0.612	2.768	9.346

The application for accelerometer was used to obtain data from the smartphone. Based on the data collected the graphs were obtained.

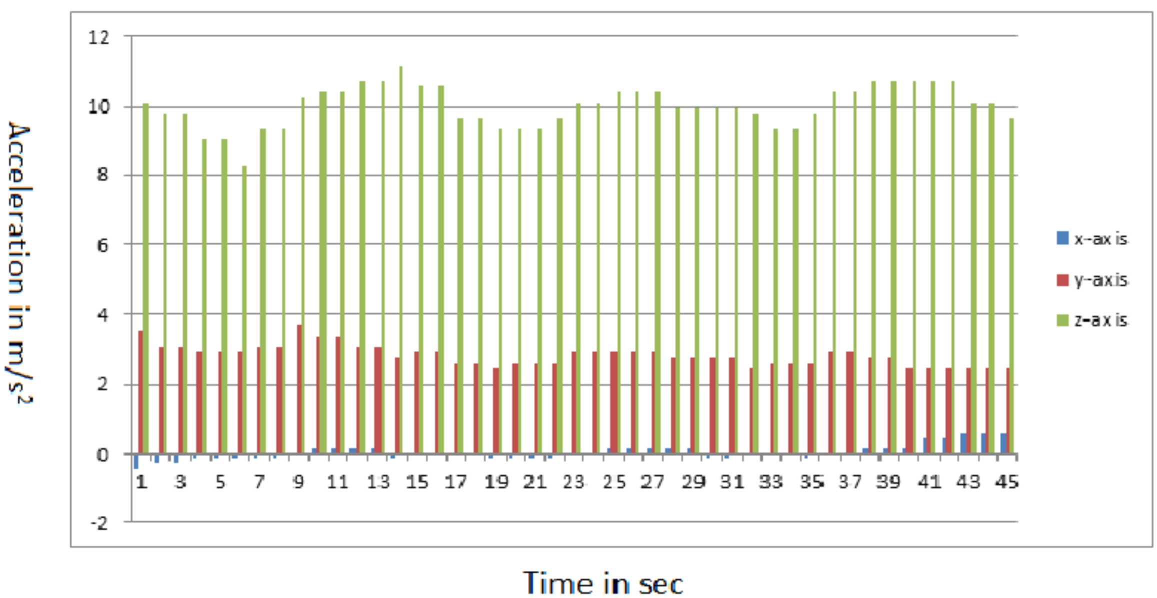


Figure 15 Readings from accelerometer application for first test route

Different driving events were used to obtain the results. As shown in fig.13. the x-axis represents the lane changes, y-axis represents the forward acceleration and z-axis represents the vertical rise or fall of peaks caused due to bumps and potholes. These events were validated with the help of a co-driver who recorded the time and corresponding events that took place while driving.

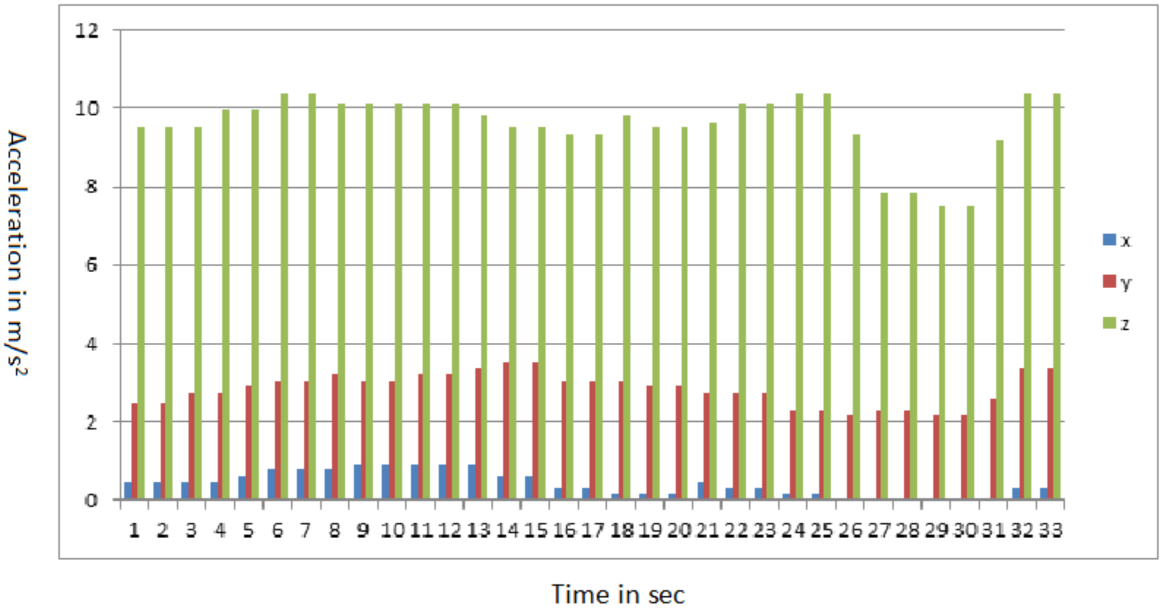


Figure 16 Readings obtained from accelerometer app for first test route (second interval)

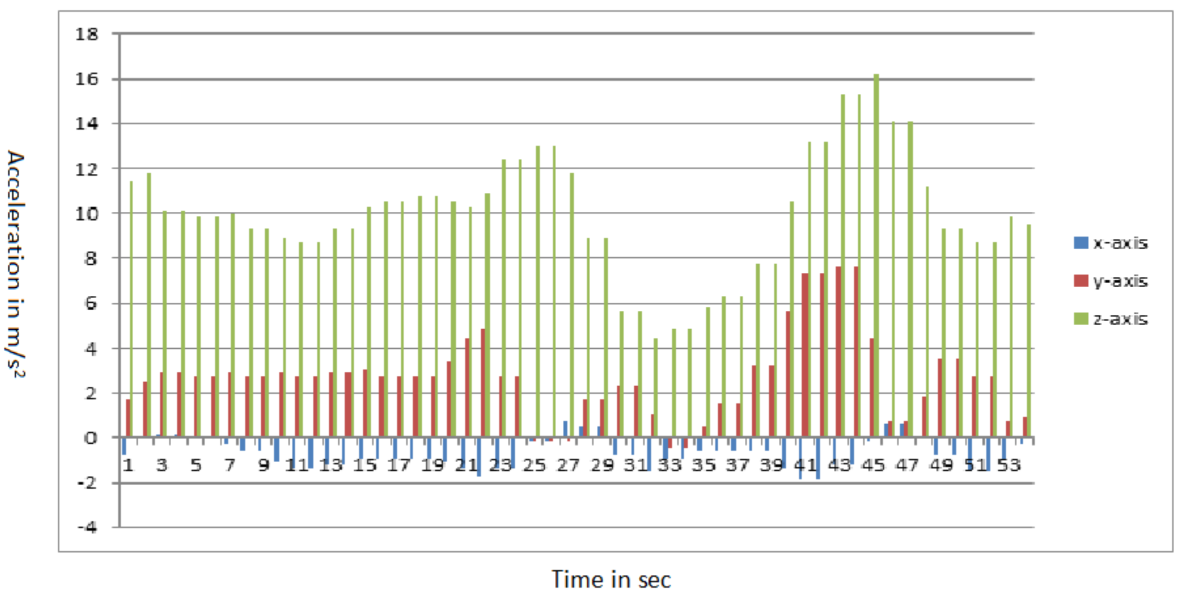


Figure 17 Readings from accelerometer application on detection of potholes and bumps

4.2.4 Readings obtained from GPS:

The application also collected data using the GPS sensor of the smartphone. The parameters obtained using the GPS sensor were accuracy, altitude, bearing, speed, latitude and longitude.

For the GPS sensor the parameters are defined as follows:

Accuracy:

Accuracy is defined as the radius of 68% confidence circle. If we draw a circle centered at the obtained location's latitude and longitude and with the radius equal to accuracy then there is 68% probability that the true location is inside the circle.

Altitude:

GPS altitude measurement refers to the geodetic altitude/ ellipsoidal altitude.

Bearing:

The bearing is defined as the bearing (in degrees East of true North) of the source location to the destination location.

Speed is obtained in m/sec. Latitude and Longitude of the position of the smartphone is obtained using the application.

Horizontal accuracy of ± 5 meters and altitude accuracy of ± 10 meters is expected. These values are too large for analysis of the location using GPS. As a result we do not include the above values for analyzing the events.

4.3 Observation and Analysis

4.3.1 Analysis of the readings obtained from accelerometer:

As mentioned in [2] the three accelerometers available on the Android smartphone Samsung S Duos can be used for the measurement of lateral and angular accelerations along three fixed axes. These axes form the coordinate frame of the device. The x-y plane of the sensor is parallel to the touch screen and the z-axis is perpendicular. The threshold required for detecting the events such as lane changes, braking and turnings are taken from [2].

Table 2 Threshold values for different events

Event type	Threshold sensitivity		
	Low	Medium	High
Acceleration	$0.1g<a_y<0.2g$	$0.2g<a_y<0.4g$	$a_y>0.4g$
Braking	$-0.1g>a_y>-0.2g$	$-0.2g>a_y>-0.4g$	$a_y<-0.4g$
Turning	$0.1g<\lvert a_x\rvert<0.2g$	$0.2g<\lvert a_x\rvert<0.4g$	$\lvert a_x\rvert>0.4g$

Table 2 provides the threshold values that are used to identify the driving events.

4.3.2 Results:

A total of 6 test routes were used for collection of data. The test routes were different and varied over different time periods. The data obtained from the application was analyzed for different events.

The graphs of sample data for second experimental test route are as follows: The X-axis represents the time in seconds and Y-axis represents the acceleration experienced by the sensors.

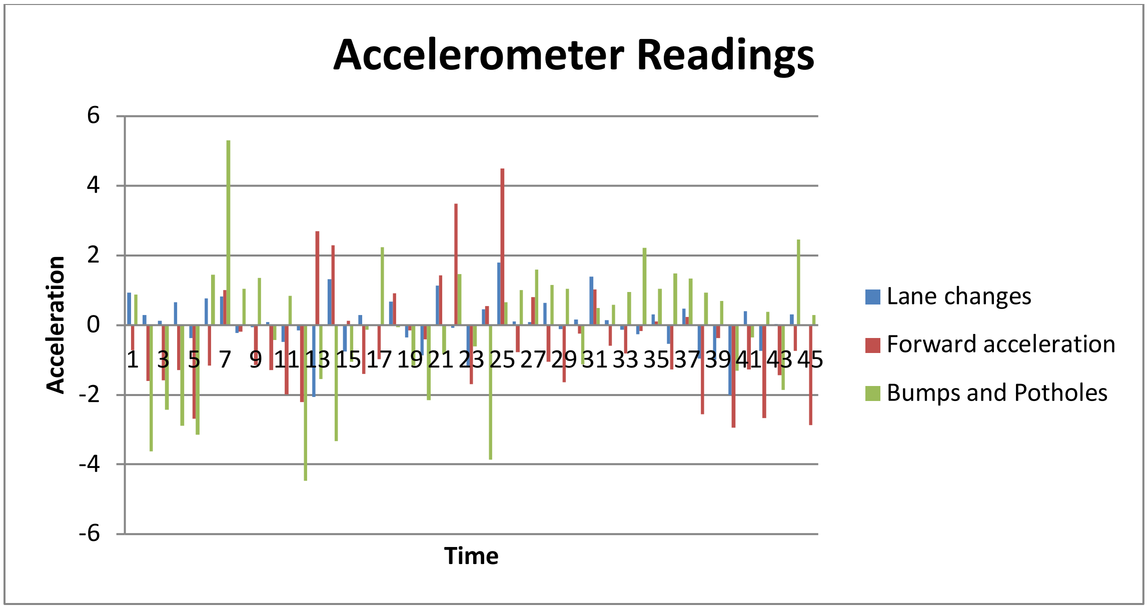


Figure 18 Accelerometer readings for second test route

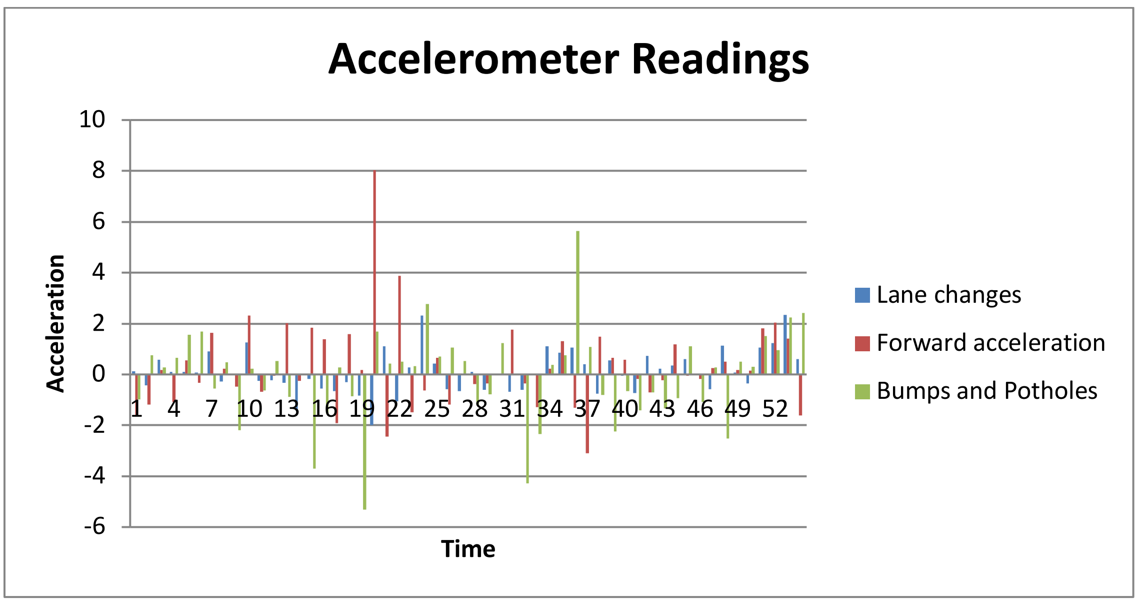


Figure 19 Accelerometer readings for third test route

From Figure 16 and 17 it is seen that the three-axis accelerometer of the smartphone provides sufficient data for analysis of driving behavior. The application can be used to obtain data for different driving events such as: Lane changes from the x-axis of the phone, Forward acceleration from the y-axis and Vertical rise or fall in peaks due to bumps and potholes from the z-axis. The application developed helps us to obtain the data required for identifying the driving behaviors. The various approaches that can be used for analysis are explained in the next section.

4.3.3 Approaches used for analyzing the data for identifying driving patterns:

The applications are able to collect sufficient information with respect to events such as braking, acceleration, deceleration etc. These events can be analyzed using various approaches for safe driving. For e.g. Fuzzy interpretation system has been used for detecting dangerous driving behaviors [19]. Such systems send messages to the user if dangerous driving behavior occurred. Similarly Hidden Markov Models (HMM) are used recognizing and predicting various driving events. For this, different model sizes can be used to recognize and predict driving events accurately and reliably [18]. Also Neural networks are used for monitoring driving behavior caused by overtaking.

4.3.4 Hidden Markov Models:

Hidden Markov Models (HMM) are probabilistic tools used for studying time series data. It consists of the Markov process with number of states and transitions between them. The Markov process moves from one state to another according to a set of transition probabilities. The two basic operations of HMM are-training and evaluation.

The HMMs have been widely used in signal processing to recognize events and predict them in future. [2] uses HMM for identifying driving patterns and for route recognition. The idea here is to consider the current driving event as the hidden state and the lateral acceleration signal as the observed sequence.

In an HMM, a training set is used to estimate the parameters of the model,while a test set is used to validate the model. The training set consists of allnecessary information for estimating the model parameters. In our experiment, thetraining set contains all history about the curves such as the start and stoppoints of them. We have simulated different lateral acceleration signals with different lengths and different number of eventsto generate the test data.

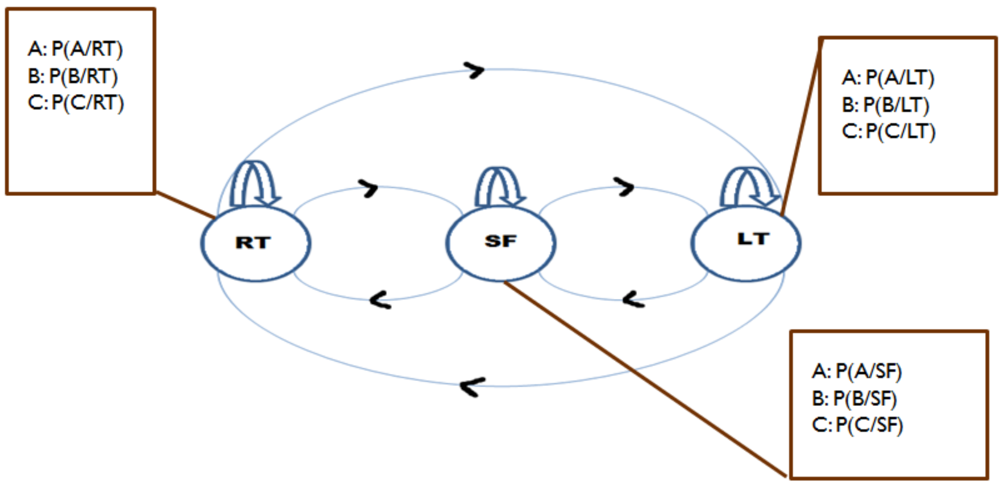


Figure 20 Markov model

In the model shown in figure 20, three events Right Turn(RT),Left Turn(LT) and Straight Forward (SF) were considered. The three classes A, B and C were defined as follows:

- A = "lateral acceleration" < −0.2 m/s^2
- B = −0.2 m/s^2 ≤ "lateral acceleration" ≤ 0.2 m/s^2
- C = "lateral acceleration" > 0.2 m/s^2

The classes are defined based on the threshold for lateral acceleration.

The Viterbi Algorithm was used for evaluation of the model.It gives a state sequence that maximizes the conditional probability of the observation sequence. The result will give the most likely sequence of hidden states from which it is possible to identify the driving events.

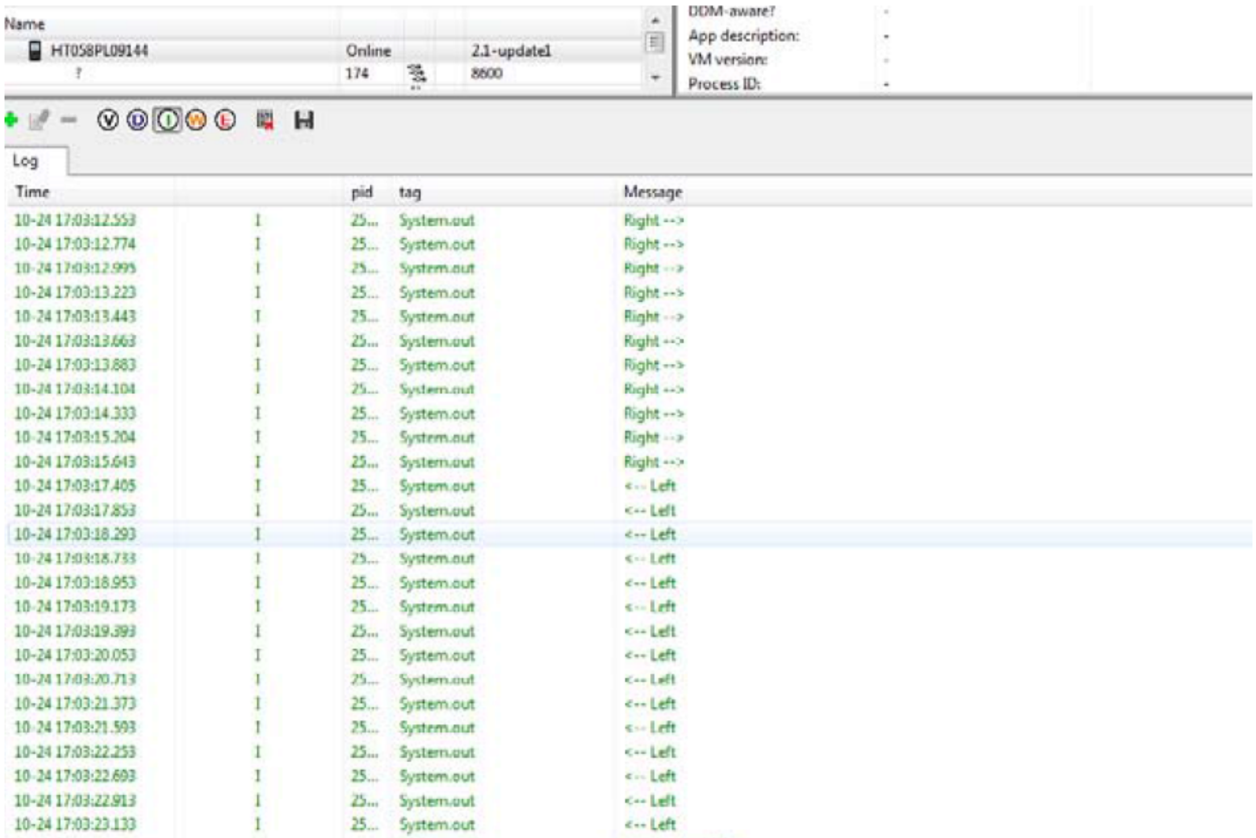


Figure 21 Screenshot of the HMM model (Log output)

However, the HMM model based on lateral acceleration values used for the training could not detect some states such as Straight Forward (SF) as shown. Also for some intervals it detected false states- e.g. The model detected Right Turn (RT) instead of SF.

For testing driver behavior it requires a combination of methods such as Bayesian classification, Dynamic Time warping algorithms etc. With increase in the number of input parameters, detection of the driving patterns becomes difficult and complex. Hence Fuzzy Logic-another approach was used for detection of driving events. The following section describes the Fuzzy Inference system.

4.3.5 Fuzzy Logic:

Fuzzy logic inference system can be used in vehicle tracking and fleet management to recognize the driving styles. Fuzzy inference system maps the input to output by means of combination rules using fuzzy logic. It consists of three stages:

- Fuzzification : The input variable is evaluated in terms of a specified condition

- Fuzzy inference : It consists of the calculation of the fuzzy output.
- Defuzzification : Conversion of the fuzzy output into a proper format

Different input parameters can be used for classification and detection of the driving events. For e.g. For acceleration input values, the algorithm has corresponding fuzzy values as: Positive small, Negative small and so on. The training data was fed into a Fuzzy inference model using MATLAB software.

The training data was analyzed and it was seen that the data obtained from the z-axis was mainly used to identify the peaks and jerks experienced by the vehicle due to bumps and potholes. During lane changing the z-axis values remained almost constant. Hence for analyzing, only x and y axes accelerometer sensor values were taken as the inputs to the system. The fuzzy rules were created for the training data using the triangular membership function. Different ranges were given to each of the axes based on the threshold values. These rules were generated using the inbuilt fuzzy toolbox of MATLAB software. As shown in fig. 22, the Mamdani[19] fuzzy model was used for evaluation. The code included the count of all the critical events and based on the fuzzy rules set for the training data, the driving score was calculated.

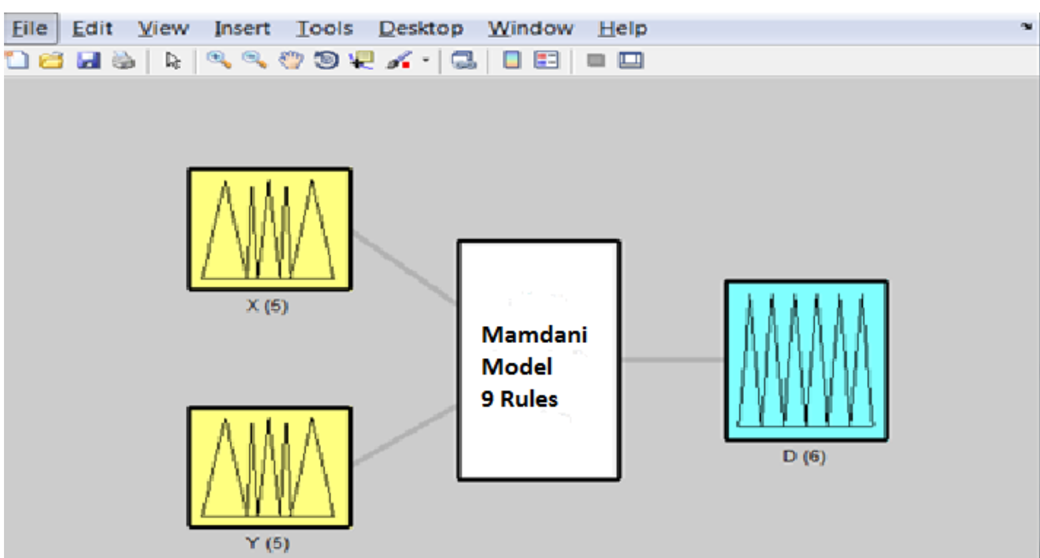


Figure 22 Screenshot of the input to the model

The fig. 22 shows the two input values given to the Mamdani model.

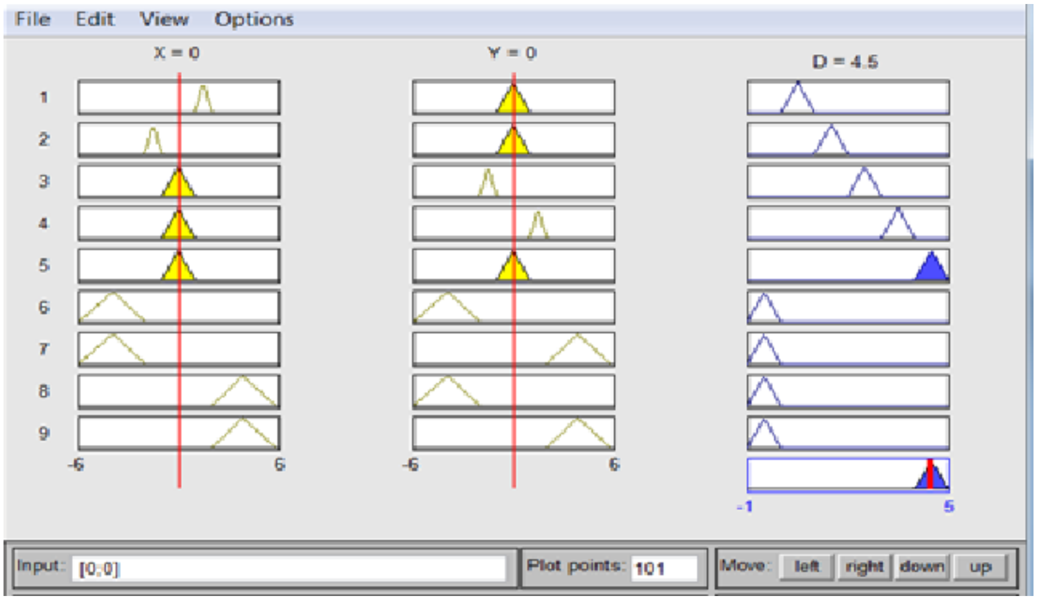


Figure 23 Rules generated using Fuzzy logic

The fig. 23 shows the rules generated using fuzzy logic for inputs x and y axes.

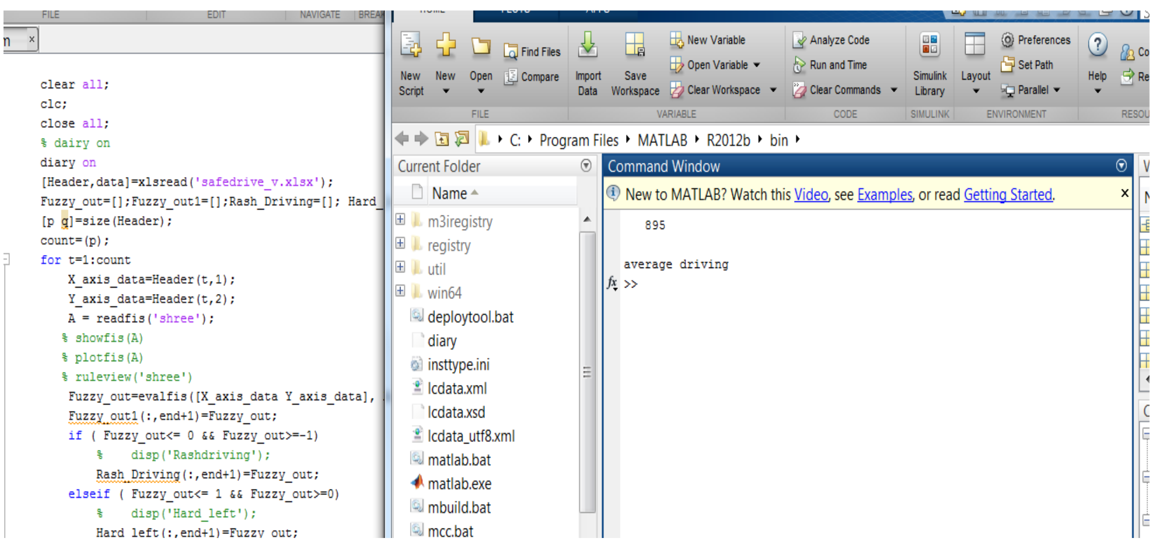


Figure 24 Screenshot of the output driving score

Rules and the thresholds have been defined for the acceleration input values. Based on them the score is calculated. Fig. 24 shows the output of the system.

4.3.6 Validation of the Fuzzy approach

Table 3 Comparison of detected events (first and second test routes)

Time(seconds)	Sensor Detected Event (peaks detected in the graphs)	Event detected by Fuzzy logic
1-5	Forward acceleration (Negative y-axis)	Negative acceleration (y-axis)
13-17	Left lane change (negative x-axis)	Left
19-22	Forward acceleration(Positive x-axis)	Hard accelerate
25-31	Forward acceleration (Negative y-axis)	Constant acceleration
37-49	Right lane change (positive x-axis)	Hard right

Time(seconds)	Sensor Detected Event (peaks detected in the graphs)	Event detected by Fuzzy logic
8-13	Left lane change (negative x-axis)	Left
15-19	Forward acceleration (Negative y-axis)	Sudden brakes
25-30	Left lane change (negative x-axis)	Hard left
50-58	Forward acceleration (Negative y-axis)	Negative Hard acceleration (y-axis)
65-73	Right lane change (positive x-axis)	Right

Table 3 shows the comparison of the events detected using the embedded sensors of the smartphone and events detected using the fuzzy system for first and second test routes. The events detected by smartphone embedded sensors have been compared with the events detected by the fuzzy logic for the different test routes. Table 4 shows that majority of the events have been detected accurately.

Table 4 Percentage of critical events detected

No. of Test routes	No. of input values taken	Events detected by sensors	Events detected correctly by system	Percentage of correctly detected events
1.	221	25	21	84 %
2.	140	17	15	88.23 %
3.	214	21	18	85.17 %

Thus the values obtained from the sensor such as accelerometer can be used to obtain the driving patterns and behavior of the driver.

CHAPTER V

5.Conclusion and future work

Smartphones have a significant impact in terms of performance and design. Applications such as Vision test can be used as a prerequisite for evaluating an individual's vision. The various smartphone sensors can be used to detect and recognize driving events and driving style. Sensors such as accelerometer, gyro meter, GPS, orientation, temperature etc. are able to collect sufficient data that can be used for analysis of the driver behavior. Analysis using approaches like Fuzzy systems, Neural networks, and HMM will help in increasing the awareness of potentially aggressive actions and further promote driver safety. Hidden Markov Models (HMM) were used to determine the curves and events based on lateral acceleration. However in order to detect events accurately HMM proves to be more complex with increase in input parameters. Fuzzy logic inference system uses membership functions to provide accurate outputs. Membership functions are inferred from the analysis of a real data that is recorded for normal and aggressive driving. This system is an effective way to detect and recognize the driving events, patterns and driving styles. The events detected by smartphone sensors are compared with events detected by the fuzzy system. About 85 % of all the critical events have been detected correctly. A combination of the input parameters lateral, longitudinal and speed values using the FIS will help in the detection of driving behavior. With real time analysis we can increase a driver's overall awareness to maximize safety.

CHAPTER VI

6.References

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