ALGORITHM FOR ABNORMAL DRIVING BEHAVIOR DETECTION.

A PROJECT REPORT

Submitted in partial fulfilment for the award of the degree

Of

Master of Technology

In

POWER ELECTRONICS AND EMBEDDED SYSTEMS

By

VINU XAVIER **MUHAMMADALI K P**

(16MPD0024) **(16MPD0017)**

Under the guidance of

A.Rammohan

Assistant Professor (Sr.), TIFAC-CORE,

Vellore Institute of Technology

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Institute for Industry and International Program

November, 2018

Institute for Industry and International Program

DECLARATION BY THE CANDIDATE

I hereby declare that the thesis entitled "**ALGORITHM FOR ABNORMAL DRIVING BEHAVIOR DETECTION.**" submitted by me to Vellore Institute of Technology, Vellore in partial fulfillment of the requirement for the award of the degree of **Master of Technology** in **POWER ELECTRONICS AND EMBEDDED SYSTEMS** is a record of bonafide project work carried out by me under the supervision of Mr. A.Rammohan. I further declare that the work reported in this project has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other Institute or University.

Place: Bangalore

Date: **Signature of the Candidate(s)**

Institute for Industry and International Program

BONAFIDE CERTIFICATE

This is to certify that the project work entitled "**ALGORITHM FOR ABNORMAL DRIVING BEHAVIOR DETECTION"** by **VINU XAVIER (16MPD0024) and MUHAMMADALI K P (16MPD0017)**, to Vellore Institute of Technology, Vellore, in partial fulfillment of the requirement for the award of the degree of **Master of Technology** in **POWER ELECTRONICS AND EMBEDDED SYSTEMS** is a project bonafide work carried out by him under my supervision. The project fulfills the requirement as per the regulations of this Institute and in my opinion meets the necessary standards for submission. The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma in this Institute or any other Institute or University.

A.Rammohan
Internal Supervisor
Asst.Prof (Sr.)
TIFAC-CORE
VIT

External Supervisor

Internal Examiner(s) **External Examiner(s)**

ACKNOWLEDGEMENT

We wish to express our heartfelt gratitude to **Dr.G.Viswanathan**, Chancellor, Vellore Institute of Technology, Vellore for providing facilities for the project.

We are highly grateful to our Vice Presidents. **Shri. Shankar Viswanathan** ,**Shri. Sekar Viswanthan and Shri.G.V.Selvam**, **Dr. Anand A.Samuel** Vice Chancellor, and **Dr. S.Narayanan** Pro-Vice Chancellor for providing necessary resources.

Our sincere gratitude to **Dr.M. Subaji**, Director, **Institute for Industry and International Program** and **Jaidev Venkataraman,** Head of Vehicle Dynamics, Continental Automotive Components (India) Pvt. Ltd , **Girish Ramaswamy**, Head of Engine Systems, Continental Automotive Components (India) Pvt. Ltd.. for giving us the opportunity to undertake the project.

We would like to express my special gratitude and thanks to my internal guide **A.Rammohan,** Asst.Prof. (Sr.), TIFAC-CORE for encouraging me to complete the project successfully.

We thank the Management of Vellore Institute of Technology for permitting me to use the library resources. I also thank all the faculty members of VIT for giving me the courage and strength I needed to complete my goals. This acknowledgement would be incomplete without expressing my whole hearted thanks to my family and friends who motivated me during the course of the work.

Place:

Date:

VINU XAVIER

MUHAMMADALI K P

TABLE OF CONTENTS

1 ABSTRACT

The most modern trends in the automotive industry is heading towards highly or fully automated driving. When we consider how far it can resolve the existing troubles which cause the road accidents, it's a very important fact that the human error is the most probable root cause for the majority of all accidents. The studies say that the driver negligence plays a vital role in the in the various reasons which cause an accident. Each and every abnormality in the driving behaviour is visible as a pattern and this thesis would like to consider various algorithms to detect the abnormalities in the driving behaviour and thereby either taking failed reactions in an appropriate manner so that prevention of accidents are possible. A drowsy or a drunken driver will always follow a driving behavioural pattern. It is also called the degree of abnormality when comparing with the regular way of driving to the same road in the same conditions. These abnormalities are visible mainly in the brake pedals the steering wheel and the suspension sensors. By carefully studying the factors which are observed in these sensors, it is possible up to an extent, to detect the abnormality which is not expected in that driving situation. The driving style can be continuously monitored into a database which may be efficient inside the cloud and make available continuously to run this comparison in the entire duration of driving. This thesis is mainly concentrated on the steering wheel and a sensor and various patterns which are carefully studied when taking the actual vehicle data. The software algorithm is developed as a prototype simulation in Matlab.

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

SAS	Steering wheel Angle Sensor
ESC	Electronic Stability Control
CAN	Communication Area Network
PS	Pressure Sensor
YRS	Yaw Rate Sensor

2 INTRODUCTION

2.1 MOTIVATION

The road accident cause death of millions and facilities of more than that every year in the world. According to the reports of National Crime Records Bureau, Ministry of Road Transport & Highway, Law commission of India, report shows up nearly 400 human deaths are causing every day in the world by traffic accidents. The majority of these accidents are reported as human errors.

- One serious road accident in the country occurs every minute and 16 die on Indian roads every hour.
- 1214 road crashes occur every day in India.
- Two wheelers account for 25% of total road crash deaths.
- 20 children under the age of 14 die every day due to road crashes in in the country.
- 377 people die every day, equivalent to a jumbo jet crashing every day.
- Two people die every hour in Uttar Pradesh – State with maximum number of road crash deaths.
- Tamil Nadu is the state with the maximum number of road crash injuries

Even though the most modern technology heading towards autonomous driving, the limitation of the technology is always the human driver and the various decisions he makes while handling the vehicle. Irrespective of how much advanced is the technology, the errors caused by the situations of negligence, situations of lack of skills, situations of ignorance, situations of absence of mind, situations of carelessness etc. be in the leading position of the root causes of any accidents. Irrespective of how best is the system which is fitted into a car or any automotive, it can only react to the situation but cannot prevent it completely. More than that, it is impossible to predict the future and take early preventive mechanism. The root cause of the situation is, we do not having as many trained and skilled drivers, as many automotive vehicles available in the world. A highly or a fully automated driving can be the final solution for this, but the time it would take to come into an action can be decades or more than that. Under developing countries like India needs more time to have that infrastructure, which can help the introduction of fully automated driving. In the next 5 years, India will be the third largest automotive vehicle producing countries in the world. When considering the death rate of road accidents caused every year in India we stand in the top of the world.

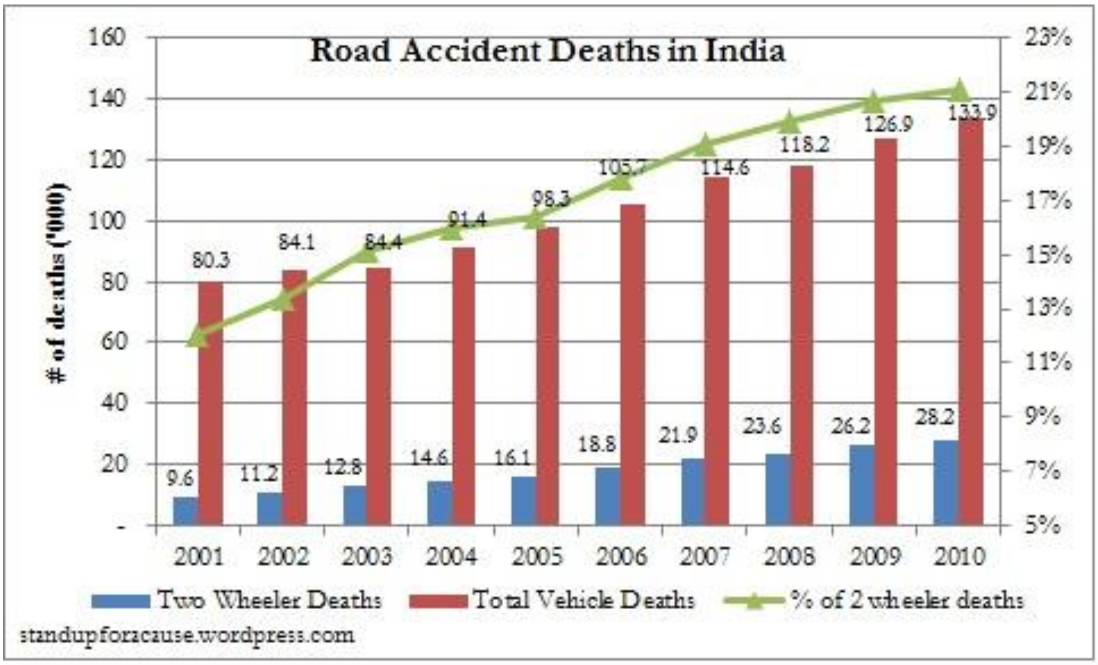


Figure 1 Statistics about road accident deaths in India

In parallel, the computational Technologies and the cost of implementing that is going down drastically into a very cheap opportunity so that implementing a Complex algorithm and deploying that it to bigger Industries like automotive would not make a huge amount of time to come into the market as compared to the fully automated driving. More than that, people following the road rules and having the right skill set to be eligible to drive in a complex driving situation like in Indian roads, is very less. The authority is even providing out the driving licenses, without even checking whether the driver has the right skills physically and mentally to handle complex situations. People do not even think about following the line, wearing a seatbelt, following the speed rules and giving way to the most deserved.

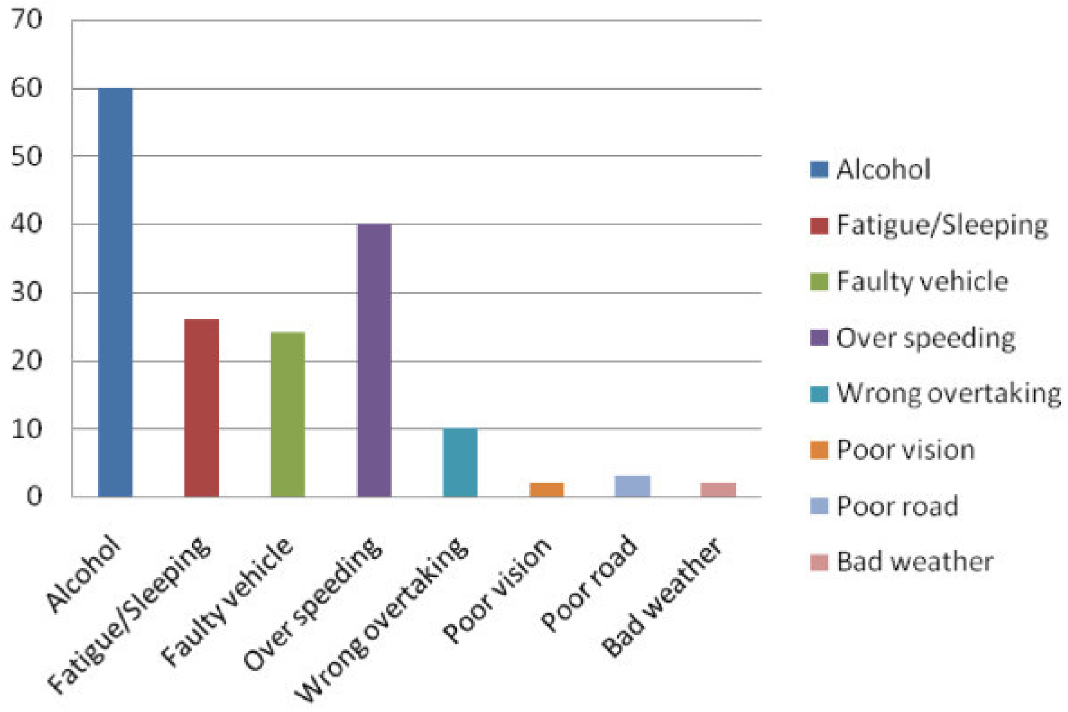


Figure 2 Statistics about Causes of Road Traffic Accidents caused death

Policing each and every situation like this is hard. The only way in which it can be solved is self-monitoring of the driving behaviour by an installed system which is fitted into the vehicle itself. The system will be effective when it try to re-use the existing sensors in the same vehicle environment. This system should be able to take care by itself when an abnormality is continuously visible and the human driver who is driving that vehicle is not taking care of or not improving the driving situations. Accumulating all these decisions, the system should be able to judge that the person who is driving the car is not in the physical and mental situation to safely execute the driving manoeuvre.

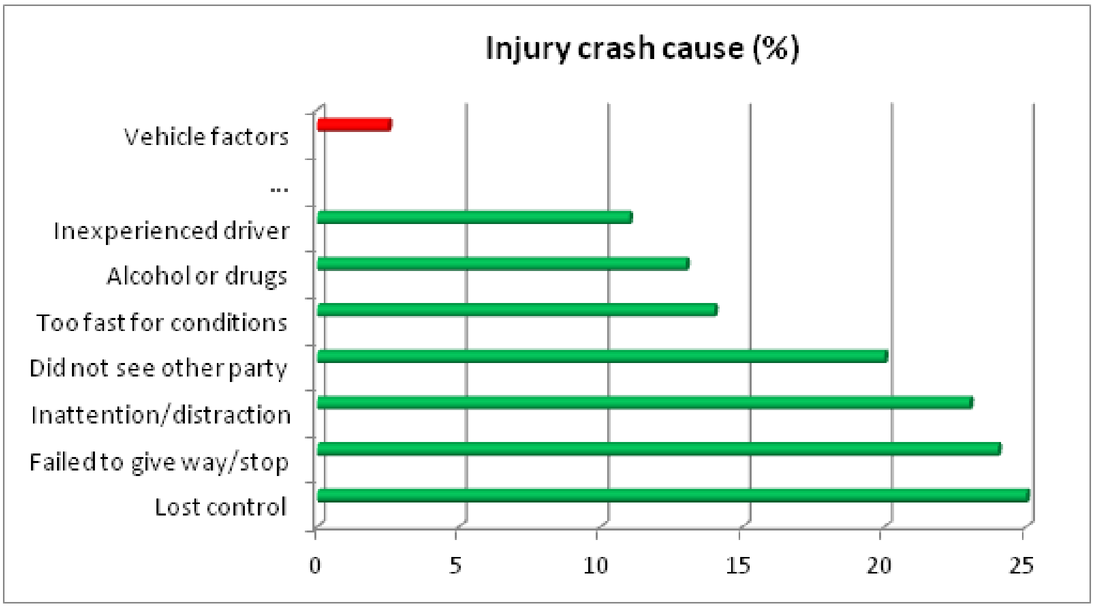


Figure 3 Statistics about Causes of Road Traffic Accidents caused injuries

By that way, the software mechanism would be helpful to detect such kind of situations. The installed software can react by taking preventive actions like, reducing after speed limit or glowing the hazard warning lamps or even take over the control of the vehicle and park to the nearest safest possible area and thereby allowing removing this vehicle from the traffic. The software could be complex to detect pattern based on machine learning and therefore, lead to complex hardware to be installed into each and every vehicle , can increase the cost of the vehicle from affordable range. This situation can be solved by the technology of cloud computing where the input data is transferred into the cloud and the complex data processing happens in a remote area in the cloud. And, the decisions are given back to each and individual vehicles so that there are actuators which are mechanical and software facilitated and thereby reacting to the situation by considering the intensity of abnormality in the driving behaviour.

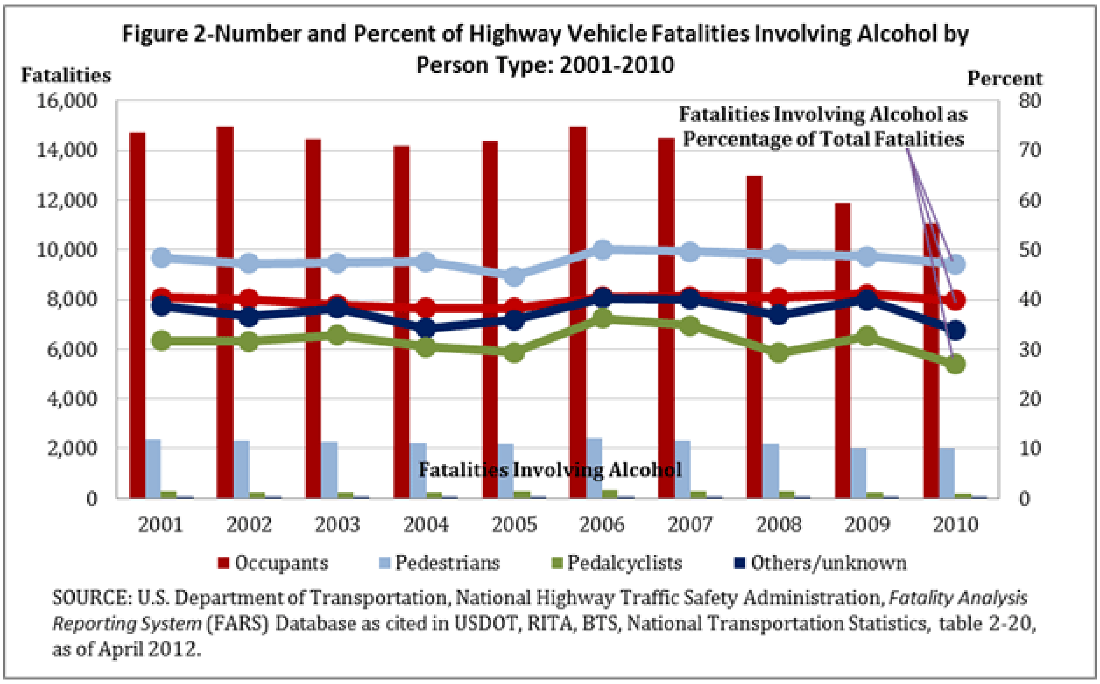


Figure 4 Statistics about the number and percent of highway vehicle alcohol by person type

3 LITERATURE SURVEY

Literature review was conducted to better understand the principles and applications of this research. Below are the findings of this review.

3.1 ABNORMALITY IN DRIVING

In this chapter let's consider about, the basic abnormality in driving when considering to the acceleration behavior. A sudden acceleration is always treated as a chance of losing the vehicle stability. Especially, when the road condition is not demanding to have a sudden acceleration at that situation ,or accidental deceleration in other words the hard breakings and in case the driver is doing this so repeatedly, then the degree of abnormality is counted up and should be treated as a suspicious abnormality in the driving.

Considering the forces on the vehicle, the vehicle stability is an equilibrium of all these above forces. This statement can be read in other way that, when the equilibrium is lost, the vehicle can move out of control.

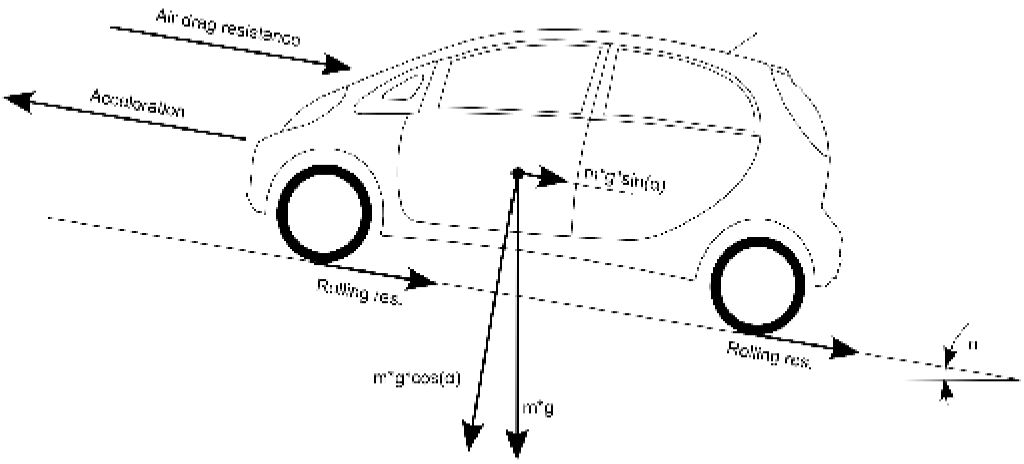


Figure 5 Force acting on a vehicle (Various degrees of movement possible in vehicle)

Acceleration is a rate of change of velocity. When doing so the Dynamics accepted into a vehicle act longitudinally, which can overtake the static friction range provided by the road friction. If the static friction range is overridden, then the vehicle can move sliding away into a condition which is not controllable by the driver. There is a big chance that the driver is not doing this intentionally, but due to the effect of alcohol consumption, or by the effective physically and mentally tiredness due to the absence of a proper relaxation which is mandatory to maintain a healthy situation while driving.

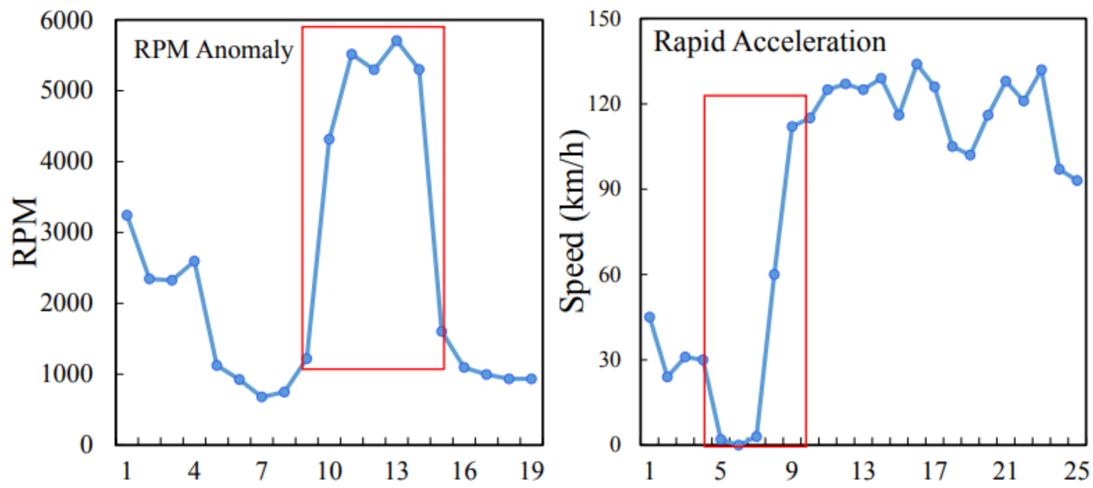


Figure 6 Examples of contextual driving anomalies

It is also very much important that the wrong detection of this normality in driving behavior can lead to frequent and unexpected degradation of the services which itself can cause the public projection of such kind of a system in a car. Due to that, in the case when the system detects the abnormality of a driving behavior then it has to be 100 percentage evaluated against the very recent and massive collected data in this am driving situations.

Let's think about how this abnormality behavior can be listed down. In general cases, the drivers are always affected by fatigue drugs alcohol or any kind of distraction such as cell phones texting. This drivers are not only dangerous to themselves but also dangerous to the other innocent and regular drivers around.

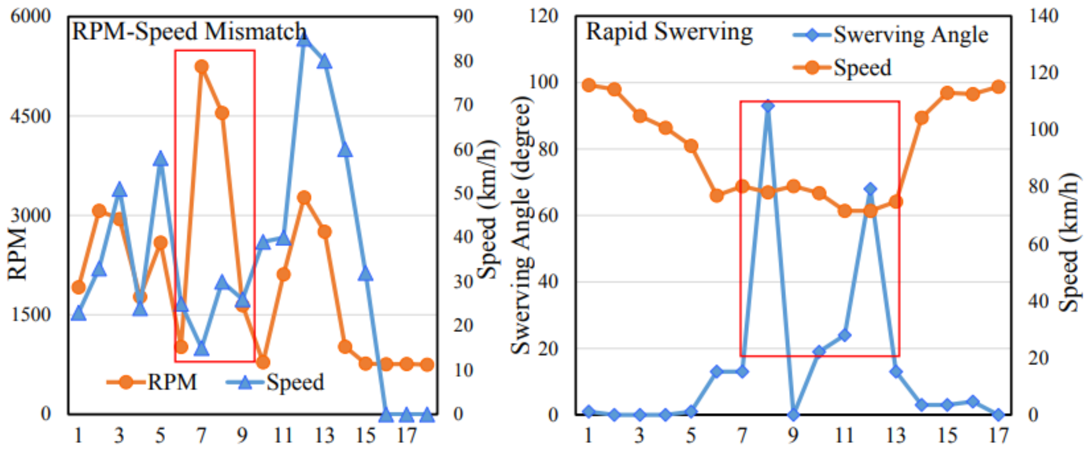


Figure 7 Examples of correlational driving anomalies

If two driver makes cornering without making the term indication lamps illuminated is a very generic case of absence of mind while driving. Such kind of situation has taken out huge amount of lives. In a very special case while driving in the night and not making the headlamp on is a very clear case of the abnormality in driving.

While considering the steering behavior, which is going to be more focused in this thesis, let’s consider various situations which can be deeply analyzed and identified symptoms of abnormality. And illegal of a sudden turning return which is responded late etc. can be treated as input situations for our studies. During a straight line driving, if the driver continuously is keeping the steering wheel angle not in the straight line but into a very minute way of moving the car in the left or right slide away, and late responding to that by making a fast turn back into the line was identified as a situation to analyze.

3.2 SENSORICS AVAILABLE

In this chapter let us consider the various sensors available in automotive electronics system and which can be made useful for the input data collector for the abnormality driving behavior software algorithm. The main aim is to reuse the existing sensors thereby reducing the extra hardware cost come as a burden to install a new system into the automotive electronics clusters.

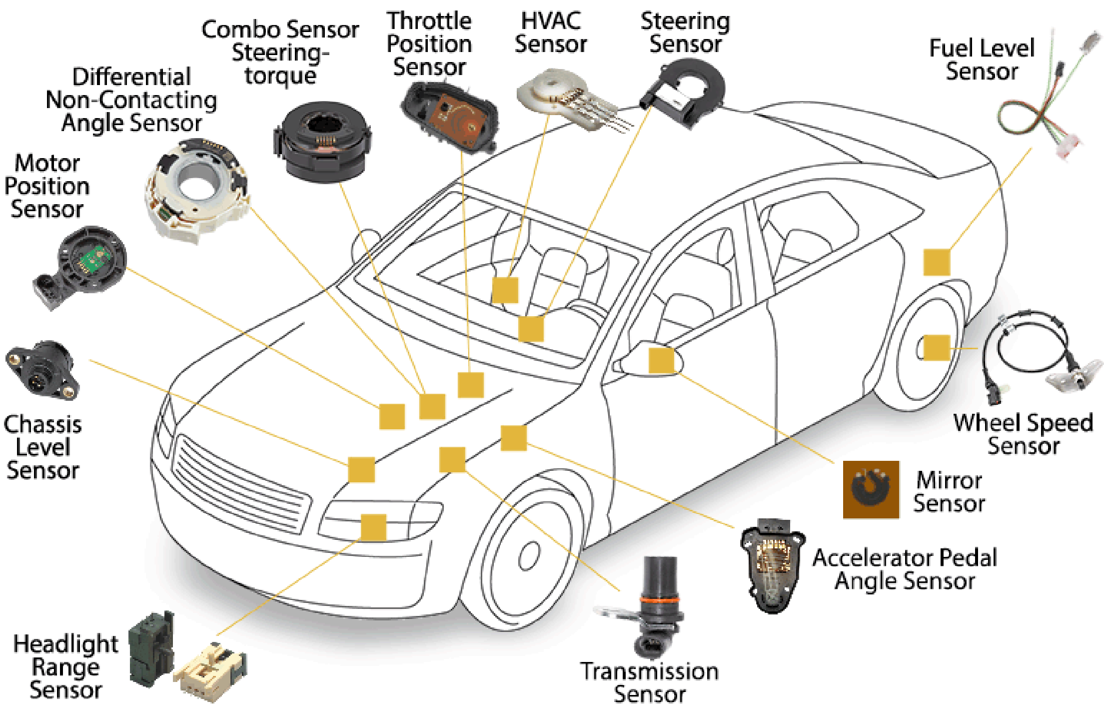


Figure 8 Sensors available in an automotive vehicle

3.2.1 BRAKE PRESSURE SENSOR

The brake pressure sensor is so high-pressure piezoelectric sensor, which can measure the hydraulic brake fluid pressure when pressurized by the brake pedal unit. The piezoelectric high-pressure sensor is able to measure the pressure input which is in the range of light pedal touch until the high slamming of the brakes. This sensor is available with an electronic brake system unit, which is going to be a mandatory safety measure in any future automotive vehicles. This statement is true for the cars getting produced and used in India.

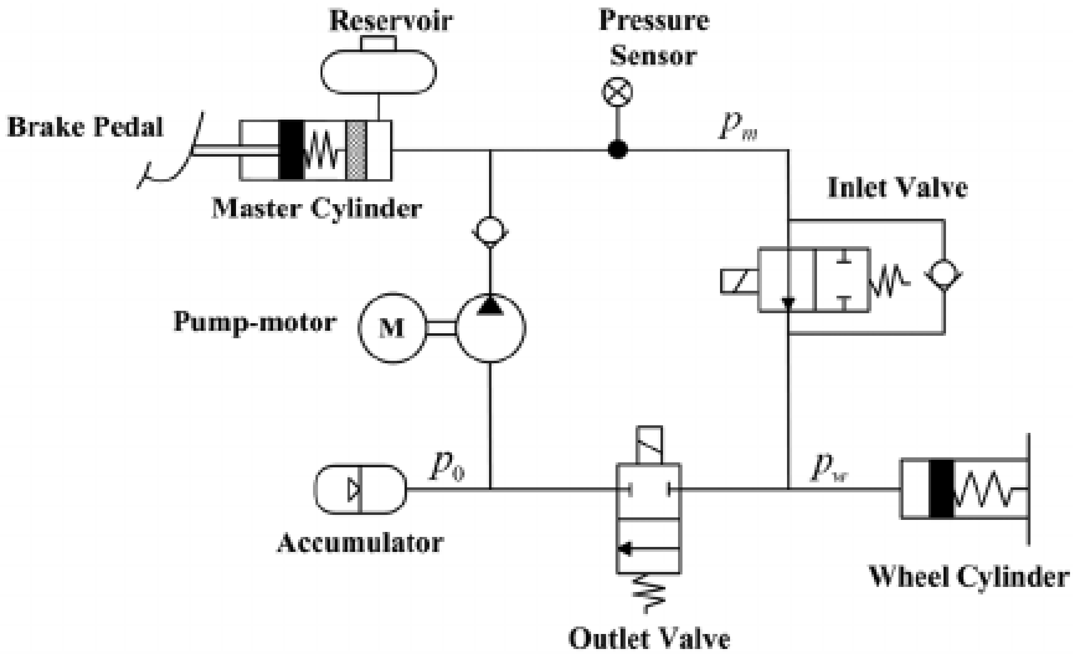


Figure 9 Pressure sensor in electronic brake system (ESC)

The positioning of the brake pressure sensor is in the Hydraulic electronic control unit of the electronic brake system. These sensors are assumed as very highly accurate with respect to the accuracy and the reproducibility of the pressure profiles exerted by the human driver. The brake pressure sensors are even visible to the pressure ranges of lesser than one bar, which is generally any gentle touch of the brake pedal. In other words, these pressure sensors shall monitor any activity applied on the brake pedal. These pressure values are continuously sensed in the range of 2-3 milliseconds. Moreover, the brake pressure sensor is also made available in the vehicle CAN/FlexRay network communication bus. The availability of this pressure values shall be considered as the primary input into the SW algorithm to detect the driving abnormalities

3.2.2 STEERING WHEEL ANGLE SENSOR

The steering wheel angle sensor is an absolute sensor which is a critical and mandatory component of Electronic Brake system. The sensor is positioned in the steering column. The steering wheel angle sensor is also widely referenced by the name SAS (Steering angle sensor). The absolution position of the steering and the rate of steering is measured by this sensor. For any vehicle which is equipped with Electronic Stability control, shall have the steering wheel angle sensors associated with it. Being remotely positioned from the ESC control unit, the SAS acts always as an independent sensor and always have an intelligent part to have the data processing associated and included in the sensor unit itself.

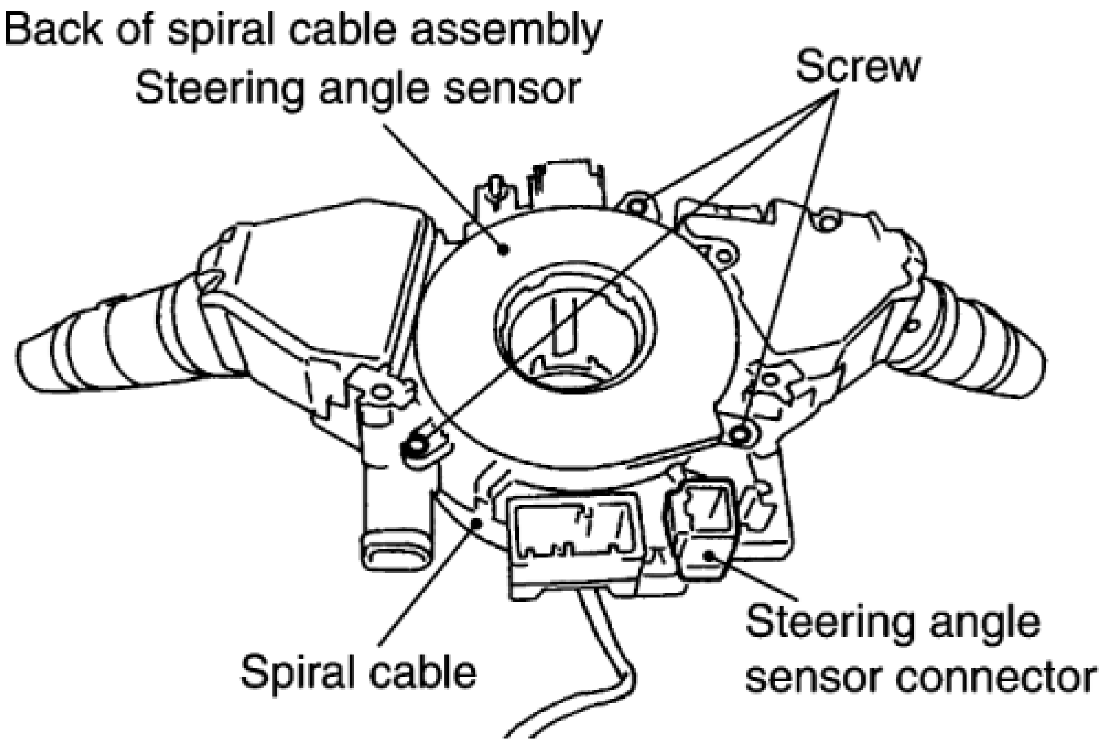


Figure 10 Steering wheel angle sensor as a universal sensor (SAS)

The SAS is also able to make self-calibration of the steering sensory. Mostly, the ESC unit is helping the steering wheel angle sensor to have the steering center detection every time when the vehicle undergoes an straight line driving maneuver ,which is visible in the wheel speed sensor unit.

Figure 11 Steering wheel angle sensor as a universal sensor (SAS) and its usages

The sensors of interest for the algorithm are the Steering Wheel Angle Sensor, SAS and the longitudinal speed sensor. Both sensors are available on all vehicles. The SAS is mounted just behind the steering wheel on top of the steering column and is a rotating sensor measuring the absolute steering angle. The front wheel angle is (simplified) determined by the previously mentioned steering ratio. A third sensor, Yaw Rate Sensor, YRS is also of interest in this report. Since the developed algorithm needs validation, the YRS can be used as it measures the movement around the Z-axis thus indicating the headed direction of the vehicle. All signals are transmitted in the vehicle via can to ECU where the signals are used as input to various functions, such as the previously mentioned TAS.

3.2.3 SUSPENSION SENSORS /HEIGHT SENSORS

The sensors placed in a suspension unit is not widely used in a common automotive scenario. With the introduction of advancement into the electronic brake system unit and Vehicle Dynamics control the importance of being the sensors in suspension is increasing. In general these sensors can be used to see the dynamics which are occurring in the vertical direction for any vehicle. These sensors are also known as ride height position sensing, the distance between a specific points in the gases suspension of car body when compared to the road positions. These sensors can be used to measure the vertical oscillation or in general known as the pitching motion of any vehicle after the potential behavior of abnormality. The sensors are also indirect sensors which are sometimes pressure sensors which continuously monitor the compression of the suspension Springs and calculate the vehicle height from a mathematical model.

Figure 12 Suspension height sensor (General Motor Corp)

3.3 ANALYSIS OF INPUT SENSORS DATA

While designing the software algorithm needs a careful analysis about which all abnormality is visible in the available sensors. Let's consider a detailed analysis associated with each sensor described above.

3.3.1 ABNORMALITY IN THE SUSPENSION BEHAVIOUR

When considering the driving pattern shown up by a drunken driver it is very common that he cannot judge the humps present on the road. in most of the cases, the recognition of the hump happens too late followed by if delayed reaction which mostly results in jumping onto the home with the not so reduced speed which additionally makes pitch motion together with a not well-planned braking. Such kind of incidents is collectively visible in the suspension sensors and the brake pedal angle sensors. Especially the road hump is permanently positioned and may be well known to the driver if he is a regular user of that Road.

3.3.2 PROPERIES OF SAS SENSNORS

The SAS offset is defined as the deviation, in degrees, from the zero position when the vehicle is travelling straight-ahead. The sas offset can appear in two ways: stationary and temporary. The stationary offset typically occurs as a consequence of deformation of axis or stays in the chassis, tire wear or service. The stationary offset persists until service is done. The temporary offset can occur during loading of a vehicle. The forces from the load affect the positions of the wheels and if the load is not evenly distributed it can affect the steering. Also certain driving conditions can be defined as temporary offsets which are presented in the next section. One way of determining an offset in a sensor is by mathematically modelling the system. By then calculating the residual, i.e the deviation from the measured sensor signal with the modelled system an offset can be obtained. The accuracy of the offset depends partly on the accuracy of the measurement and the accuracy of the model. Noise or measurement errors in the sensor signals and model errors results in an inaccurate offset.

3.3.3 DRIVING CONDITIONS AND VEHICLE DYNAMICS

In speeds below 60 km/h the torque applied on the steering wheel results in cornering of the vehicle, and with reduced speed a higher torque can be applied on the steering wheel, resulting in ranging of the vehicle. Speeds above 60 km/h decrease the SWA as forces affecting the vehicle disable the possibilities of applying certain torques on the steering wheel without risking rollover. Crosswinds affect the steering such that the driver has to counter steer towards the wind direction. In order for the crosswinds to affect the steering and result in a new offset, the winds need to be persistent. Gusts that influence the steering for shorter periods of time will presumably not result in an offset. In theory, an understeered vehicle does not need to counter steer when the pressure point from the crosswinds is behind of the center of mass of the vehicle. In reality however, the pressure point from the crosswinds more often hit center of mass thus counter steering is necessary in strong crosswinds.

Banking and cross slopes also have a certain impact on the steering. Both banking and cross slopes have the characteristic of an inclination perpendicular to the direction of the road. Cross slopes are used in order to drain water more efficiently and according to [9] a 2% to 2.5% slope angle is the most widely used design. Banking appears on curves to deal with centrifugal forces that act on the vehicle and are usually steeper than cross slopes

3.3.4 ABNORMALITY IN THE ACCELERATION BEHAVIOR

The acceleration behavior which happens to the vehicle is visible in the longitudinal and lateral acceleration sensors in addition to the wheel speed sensors. There are some stories which are associated into the accelerator pedal position which is used by the engine system for the throttle control of driver acceleration demand. This sensor data is well visible in the communication networks.

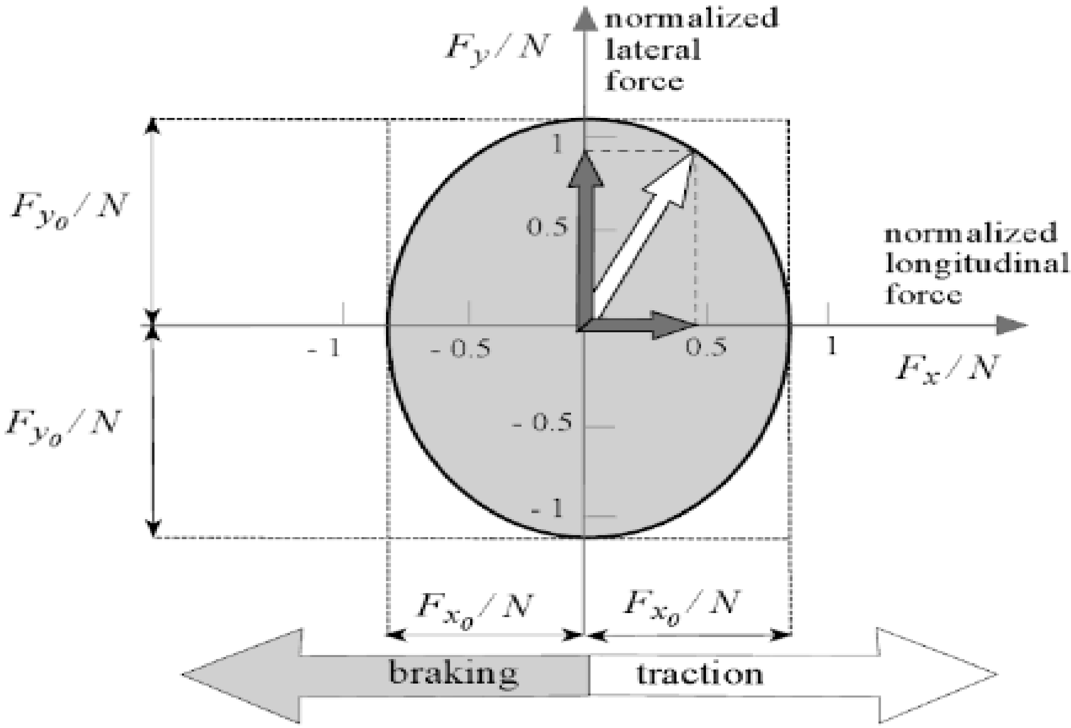


Figure 13 Traction circle

We can analyze the behaviors which are abnormal when associated with accelerator pedal position. While starting the car the driver may not engage the proper gear or keep the vehicle in neutral and try to press the accelerator hard. The delay in recognition of this situation is an indication that the driver's mental situation is not showing good attention to the driving. Without engaging the first gear, the driver may try to push the accelerator many times, and later recognize the gears are not engaged.

Shifting Gears
Recommended Shift Points

Upshifting (Accelerating)			Downshifting (Decelerating)	
Gear Change	Recommended Speed		Gear Change	Recommended Speed
1 to 2	15 MPH (24 km/h)		6 to 5	40 MPH (64 km/h)
2 to 3	25 MPH (40 km/h)		5 to 4	35 MPH (56 km/h)
3 to 4	35 MPH (56 km/h)		4 to 3	25 MPH (40 km/h)
4 to 5	45 MPH (72 km/h)		3 to 2	15 MPH (24 km/h)
5 to 6	50 MPH (80 km/h)		2 to 1	10 MPH (16 km/h)

Figure 14 Gear shifting points recommended

After engaging the first gear, the driver will always make a sudden acceleration it is not expected in that situation. This high acceleration is a dangerous situation when the parking is in a public place. Careful study of this behavior and accumulating the number of such incidences point to the degree of abnormality.

Using the right gear, without allowing the vehicle to run in the high engine RPM for a very long time is an additional indication of abnormality. Such kind of instances are continuously measured, driving fails to gear up or gear down without noticing the high engine RPM or the tendency to stall the engine. automatic transmission vehicle automated manual transmission vehicle solve this problem by itself, but there also the delay which happens to put to the drive position from neutral can be also monitored.

3.3.5ABNORMALITY IN THE STEERING BEHAVIOR

In this project, the major attributes which are visible in the steering wheel angle sensor which leads to the successful determination of the degree of abnormality are considered exclusively. While creating this algorithm, a pre calculated machine learning data is used as a reference to make a comparison analysis to determine the incidence of abnormality. This pre calculated data is a collective which is measured from another set of vehicles which were present in the same driving situation and the road conditions and in the nearly same timings. Judgment of the machine learned pre calculated data is very important with focusing the following objectives.

- The machine learned data should not be less enough that the data itself is example for the abnormality in that situation
- To pre calculated data should not be massively different from the data to be analyzed. This can lead to two different situations that, a good behavior shall not be misunderstood and abnormality. On the other hand the abnormality shall never be escaped due to the absence of a trusted pre calculated data.

It is quite difficult to store huge amount of Pre calculated machine learning data into the installed system. Due to that this that I shall be continuously made available on demand into the installed system is one way to solve this. A more practical approach would be to keep these data in the cloud storage and let the computational effort is taken care by the cloud computing, and therefore the vehicle being a continuous supplier of the input data like whatever we already discussed about the various type of sensors which can reflect the abnormality behavior.

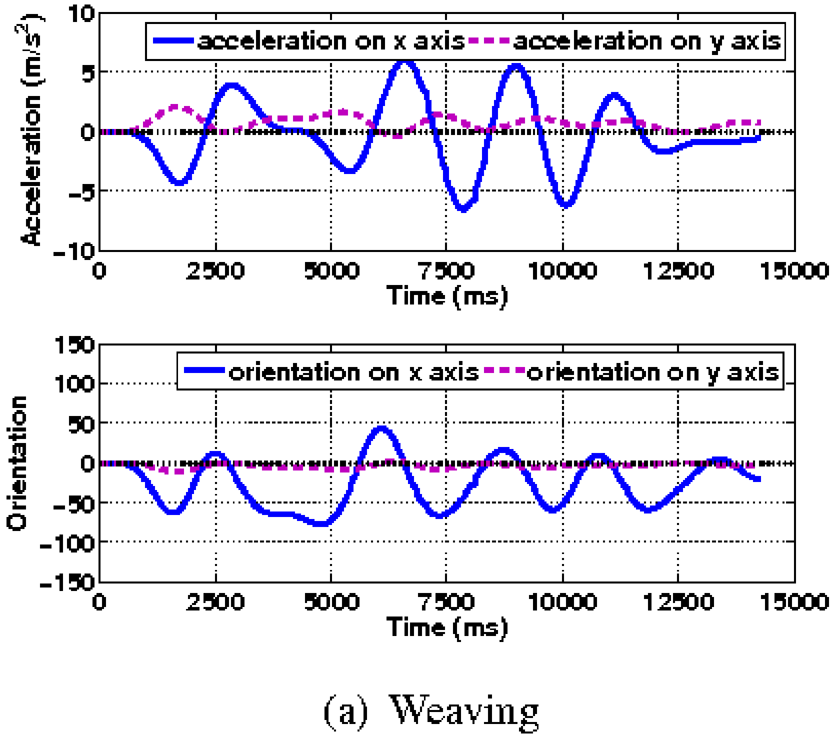
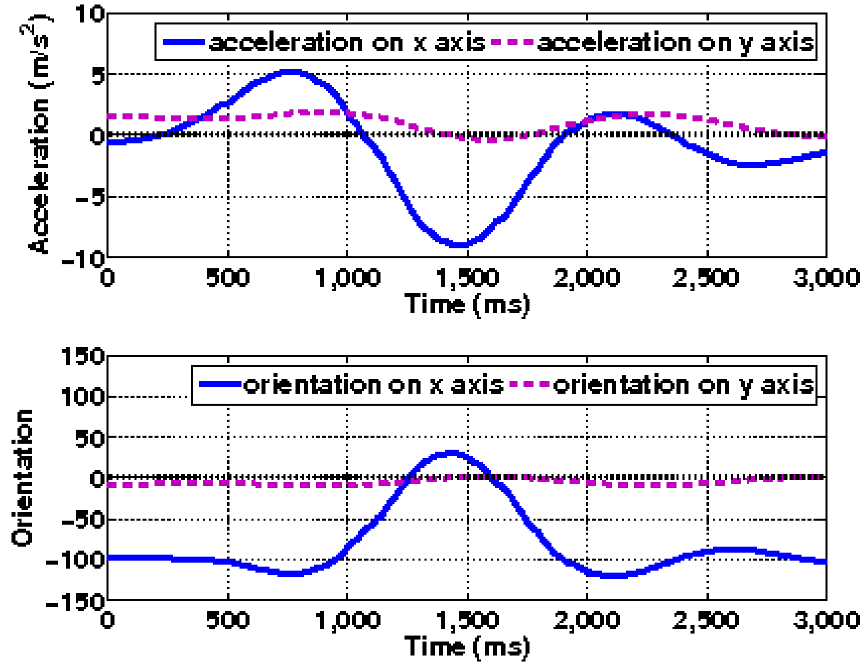
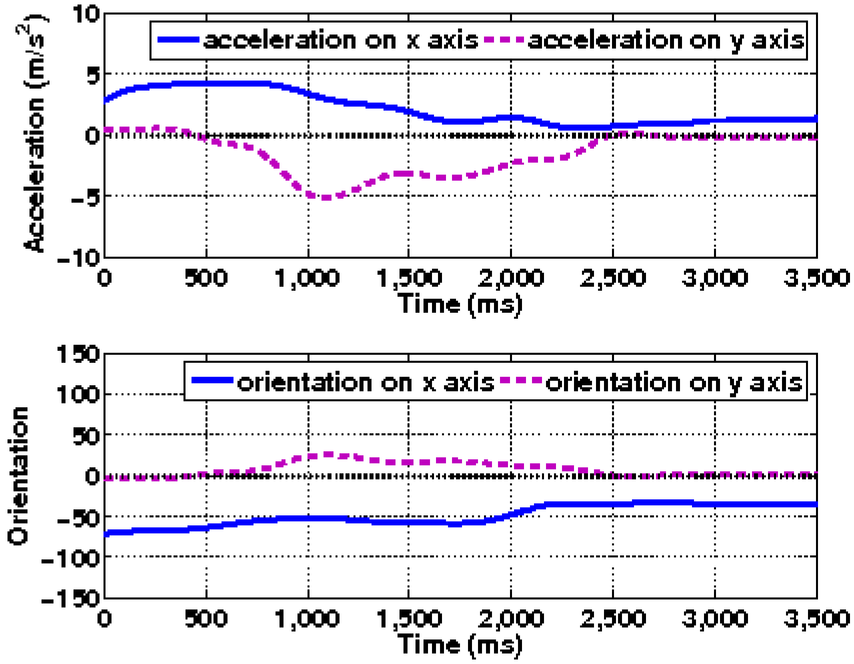


Figure 15 Acceleration and Steering behaviour Situation 01



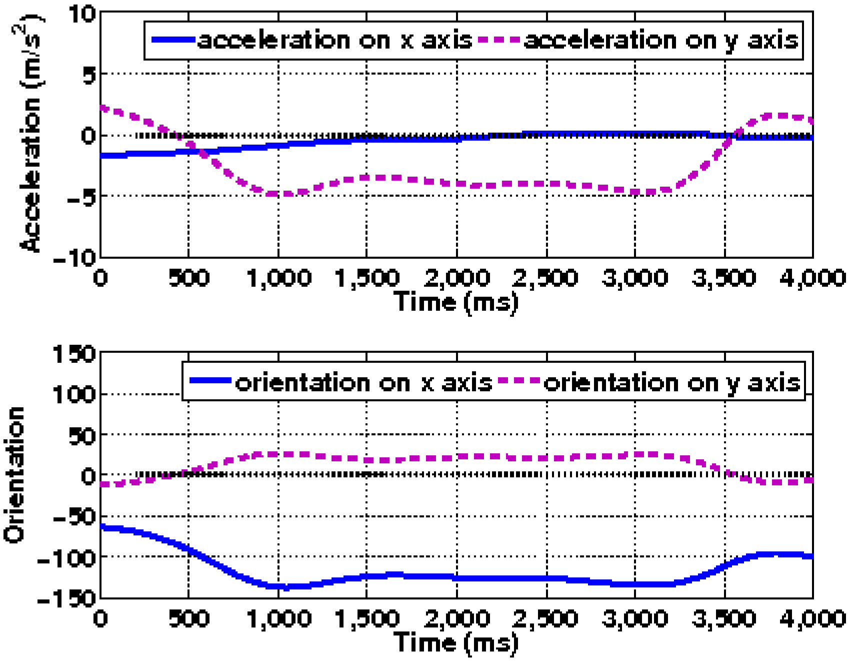
(b) Swerving

Figure 16 Acceleration and Steering behaviour Situation 02



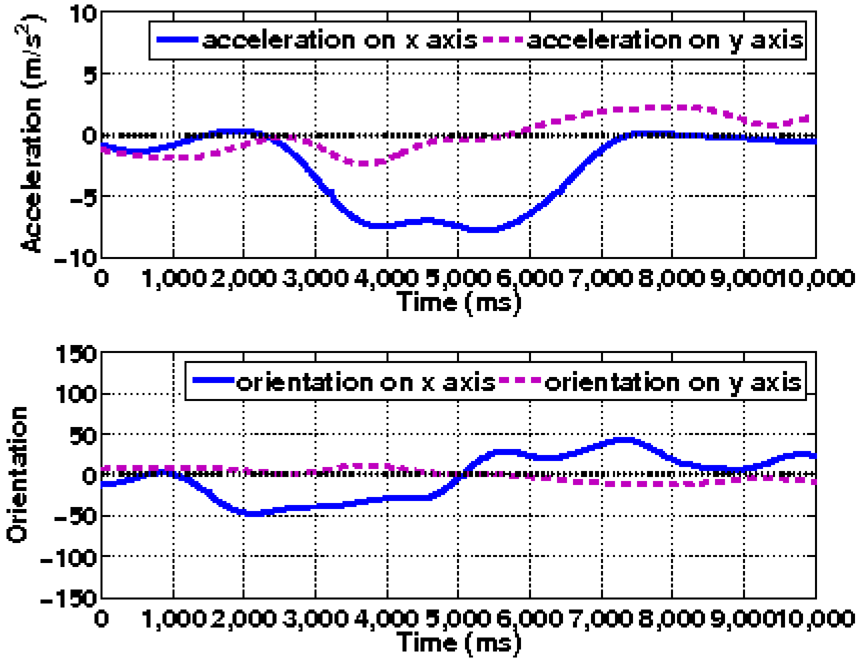
(c) Sideslipping

Figure 17 Acceleration and Steering behaviour Situation 03



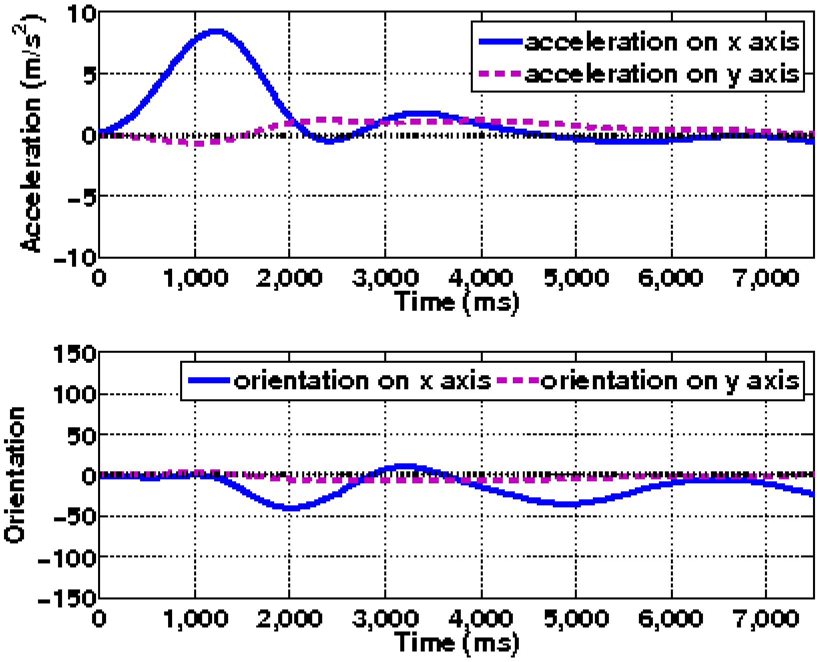
(f) Sudden braking

Figure 18 Acceleration and Steering behaviour Situation 04



(d) Fast U-turn

Figure 19 Acceleration and Steering behaviour Situation 05



(e) Turning with a wide radius

Figure 20 Acceleration and Steering behaviour Situation 06

The proposed solution would be a system which continuously monitors the communication channels running inside the vehicle and this minimum amount of data input is given to the cloud computing and computational effort of matching this reference data, with the already pre-calculated and stored machine learning data. It is also the responsibility of cloud computing module to take necessary actions according to the degree of abnormality. It is also the responsibility of cloud computing to remember the previous history of the driver and achieve a predictable algorithm which should point towards the truthfulness in the findings about the abnormality. The basic rule here is nobody can be a bad driver on a certain day when he has a previous history of good driving behavior which should overkill the degree of suspicion after analyzing a particular data.

4 DESIGN OF THE PROJECT

4.1 BLOCK DIAGRAM

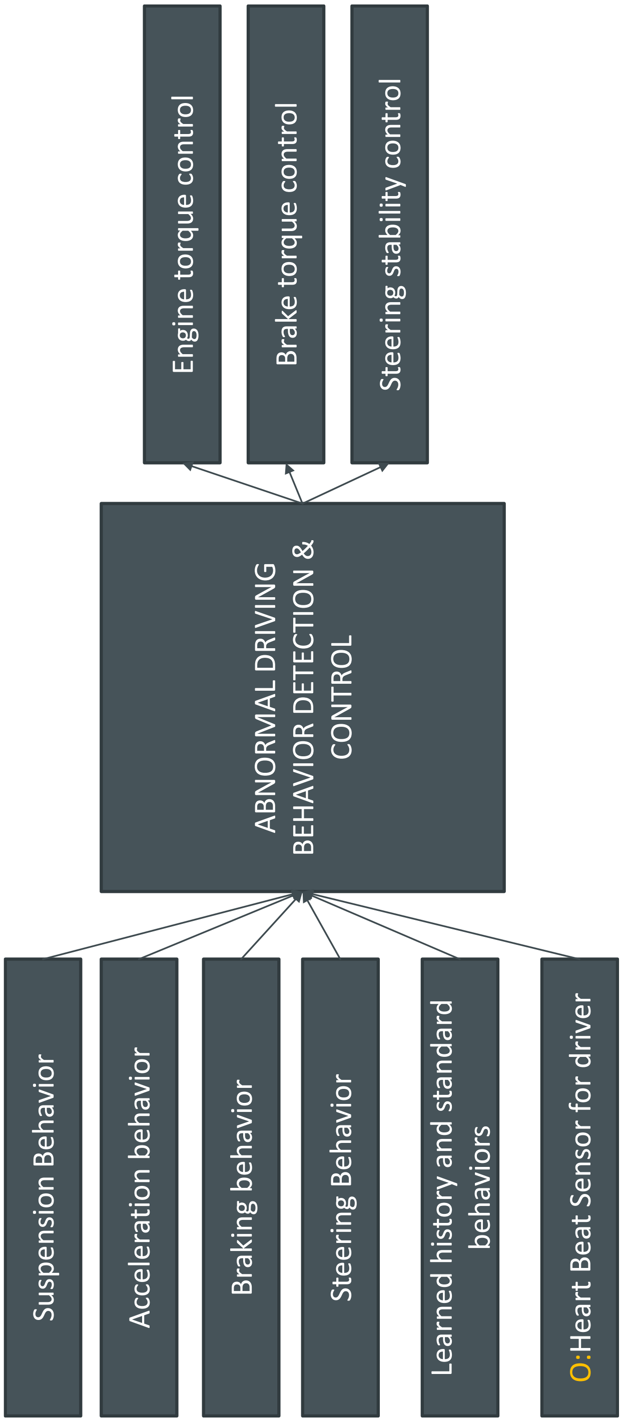


Figure 21 SW Algorithm Components

4.2 SW DESIGN

4.2.1 SIDE SLIPPING DETECTION ALGORITHM

The first software algorithm which we want to discuss is the side slipping algorithm. This is very common behavior that keeping a straight line is so hard for a drunken driver or driver who is out of his mind. In all these situations, the result is visible on the steering wheel angle sensor. Areas are identified where street light driving is expected is particularly under the focus of this algorithm.

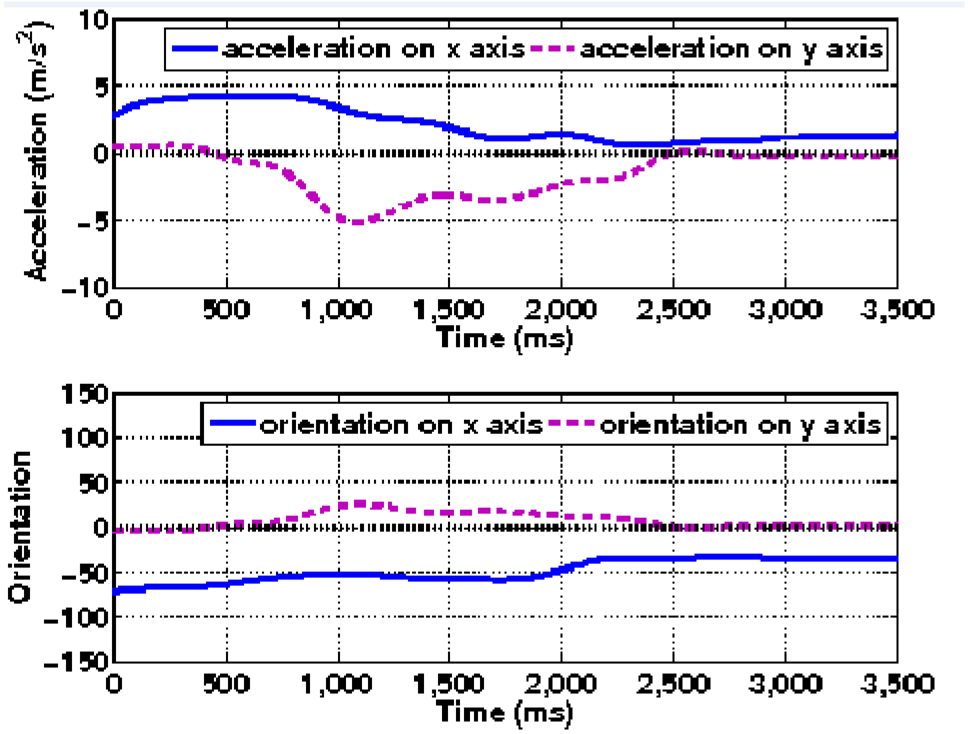


Figure 22 Slide Slipping algorithm –Data inputs

Machine learning reference data is coming from the geographical map of the land area and the nature of the road. To check this reference algorithm, the road has to be minimal 300 straight line. When the vehicle enters into that Geographic area the Lane deviation algorithm starts looking for the abnormality. Standard reference driving line is imagined by considering the recent history of those vehicles which covered that area of road. In the recent history says that it is impossible to go straight line via that road in that particular situation then the basics of the algorithm ignore the attempt to check the abnormality behavior. Example for such kind of situation is, if a car is breakdown and parked near to the side of the road and there is no choice for the vehicles to move into right or left to avoid that vehicle. If all those vehicles are showing up that behavior then according to the core probability theory this data cannot be used as a reference data to compare the vehicles abnormality behavior because in that geographical land area a straight line driving is expected but cannot have many or almost all vehicle showing the abnormality.

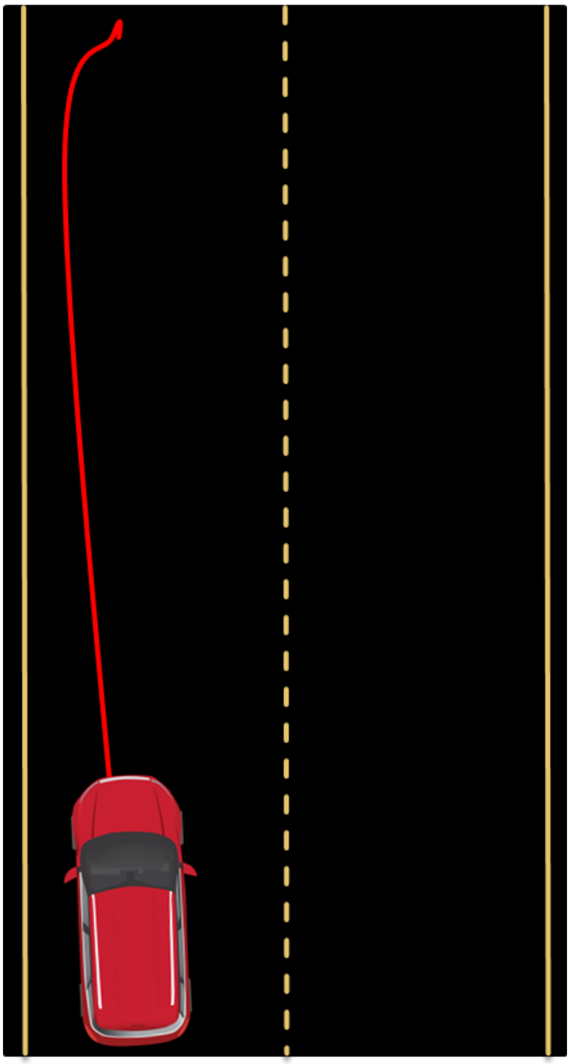
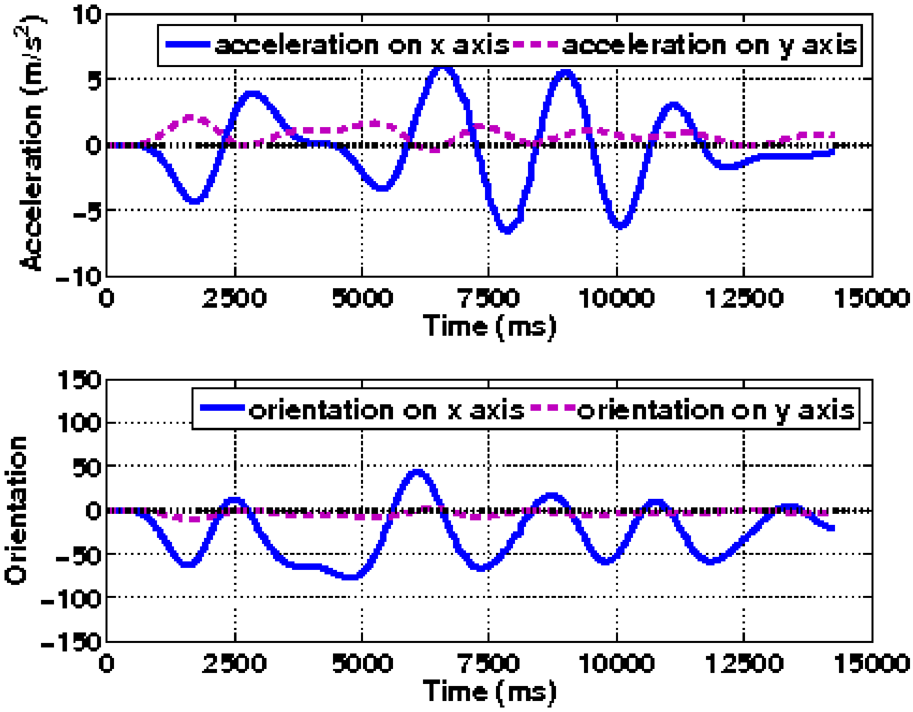


Figure 23 Slide Slipping algorithm –Behaviour analysis

If such kind of the situation is not present then the reference line for taking that straight Road is assumed by the software algorithm. A strong case of abnormality is the vehicle is continuously gradually losing the straight line drivability. This deviation is never a huge in number but a very minor gradual deviation happens and when the deviation is sufficient enough the driver and self-recognize it and try to correct it with the very sharp and short counter steering which may or may not overshoot in the opposite direction. This can be treated good pattern showing the absence of mind. A very long straight road is a very good root cause for making the drowsiness, due to the fact that the absence of actions in a straight line driving makes the driver to go into the sleepy situation.

4.2.2WAVING DETECTION ALGORITHM

Another software algorithm implemented according to referencing the steering wheel sensor is the waving detection algorithm. This is a very common behavioral abnormality and this can be visible even both in the straight line and immediately after negotiating a curve. This algorithm should detect the driver's inability to keep the steering on the desired set point to keep the vehicle in control.



(a) Weaving

Figure 24 Waving detection Algorithm – Data Inputs

The waving detection algorithm considers oscillations in a higher frequency in the range of seconds. The aim is to detect the situations in which the driver tries to keep the Steering Wheel in control by moving toward the left and the right direction continuously before reaching the set. This waving is also visible in the lateral acceleration sensor. A Road situation in which such kind of a waving is not expected but demonstrated by the driver is caught in this algorithm.

In this algorithm, the usage of the machine learning data is less. The geographical reference of the road is available from the map. The comparison algorithm with uses this reference for the situation detection. This algorithm is not used inside a curve. This algorithm is very much visible into the straight line entry immediately after negotiating a turning. The number of oscillations what the driver make is accounted as a degree of abnormality. The strength of the oscillations is also considered to account since that is a direct indication about the driver's inability to bring back the situation into control

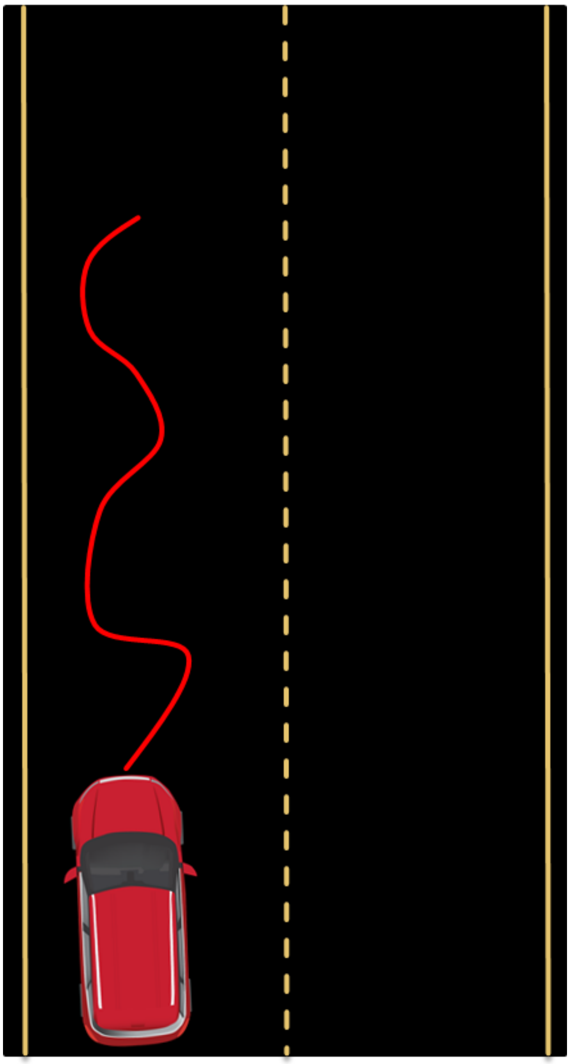


Figure 25 Waving detection algorithm- Behavioural analysis

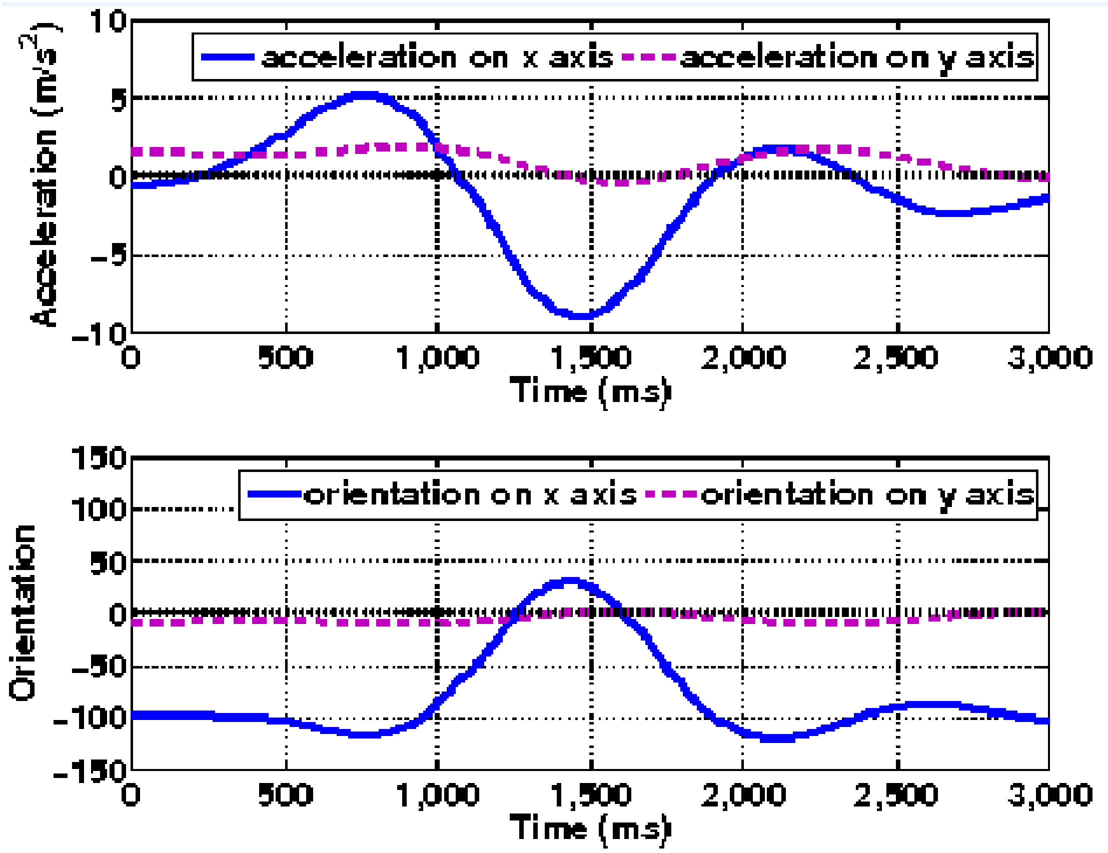
The software algorithm uses a minimum threshold for both of the parameters.

- Number of oscillations made to come back into control
- Strength of the oscillations

•

4.2.3 SWERVING DETECTION ALGORITHM

Swerving detection algorithm takes care of situations in which sudden turn is observed in any of the driving scenarios. An abrupt turning or swerving is always root cause for the high amount of lateral acceleration which can cause instability towards the lateral direction which cannot be controlled even with an experienced driver. Almost all these situations result in the fishtailing of the vehicle. When the lateral forces are more than the traction which can be handled by the tire, the static friction immediately changes to dynamic friction and results into the slipping of the Wheels.



(b) Swerving

Figure 26 Swerving Detection Algorithm – Data Inputs

Especially two scenarios in which a Lane change has to be executed, but the vehicle has to undergo a preparation by informing the preceding vehicles with a turn indication lamp, allow them to react by driving straight at least 30 M with the turn indication operated, and carefully make the lane change. Swerving is equally important to the upcoming traffic as important as the vehicle under consideration.

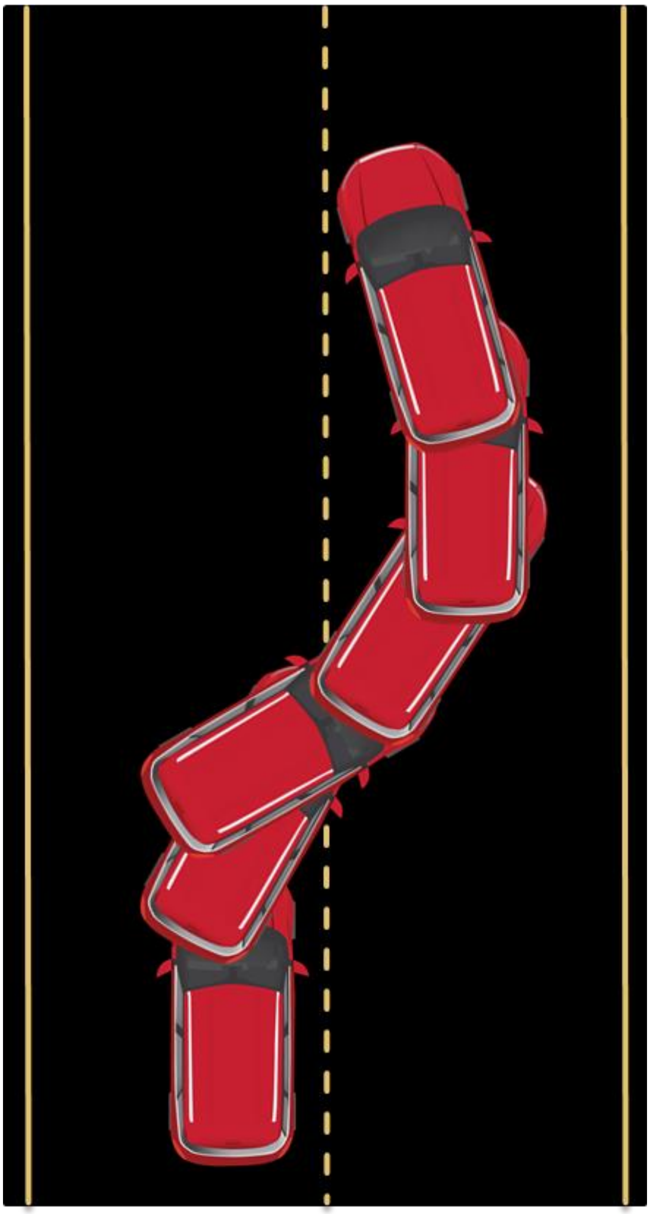


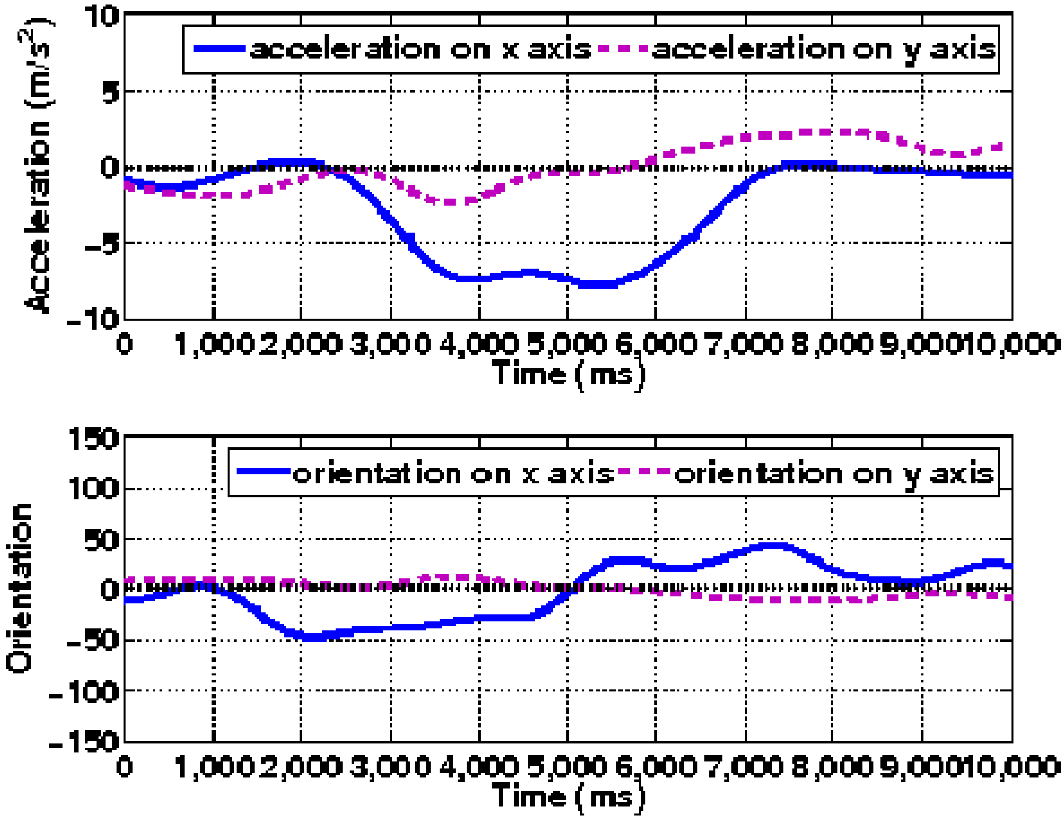
Figure 27 Swerving detection algorithm- Behavioural analysis

This algorithm also does not make use of the predefined machine learning data. Control functions which are fitted into the electronic stability control like Lane change assist are helping to have a safe negotiation of such kind of situations. But continuously making these kinds of situations is a very well defined indication that the driver is not aware of the Dynamics of the vehicle which he handles. Continuously repeating this situation can increase the degree of abnormality especially if this situation is occurring very frequently.

The detection algorithm has to reduce its threshold when the driver is already in a high speed and Road situations like highways. The reason behind that is the high speed increases the momentum of the vehicle and bringing a lateral acceleration force is easy even with moderately abrupt steering action. By considering the threat of having a very high speed and making an abrupt Lane change, the situation detection algorithm have to be active in high speed.

4.2.4 FAST U-TURN DETECTION ALGORITHM

Another situational threat while driving in a normal way is taking the fast U-turns. U-turns is another high dynamic scenario where the centrifugal force acting on the entire mass of the vehicle while turning the radius in a very high speed and with minimum radius after is so huge that the lateral traction of the tires is already on its limit. The very immediate reaction order fast U-turn is drifting away of the car towards outside the curve. The centrifugal force is directly proportional to the velocity with which it is taking the turn and inversely proportional to radius of the turn.



(d) Fast U-turn

Figure 28 Fast U-Turn Detection Algorithm – Data Inputs

Making the form U-turn is always visible of a combined analysis of the steering angle sensor and the wheel speed sensor. The centrifugal force acting on the human body who is sitting inside the car is also very huge that the high blood pressure which is resulting due to this stress, will not allow the body to react in a proper manner.

The fast U-turn also reduces the reactive time if there is an upcoming traffic in the other road. especially, if the driver is not waiting enough time in the crossing of the road thereby allowing the active in traffic to see this vehicle and make enough preparation to judge who should take the priority to forward. When the reaction time is very less the upcoming traffic even do not have a chance of slowing down.

The entire scenario will result in a collision, and this collision will always occur toward the side of the car, where most any regular car may not have side airbag to protect from the lateral collisions.

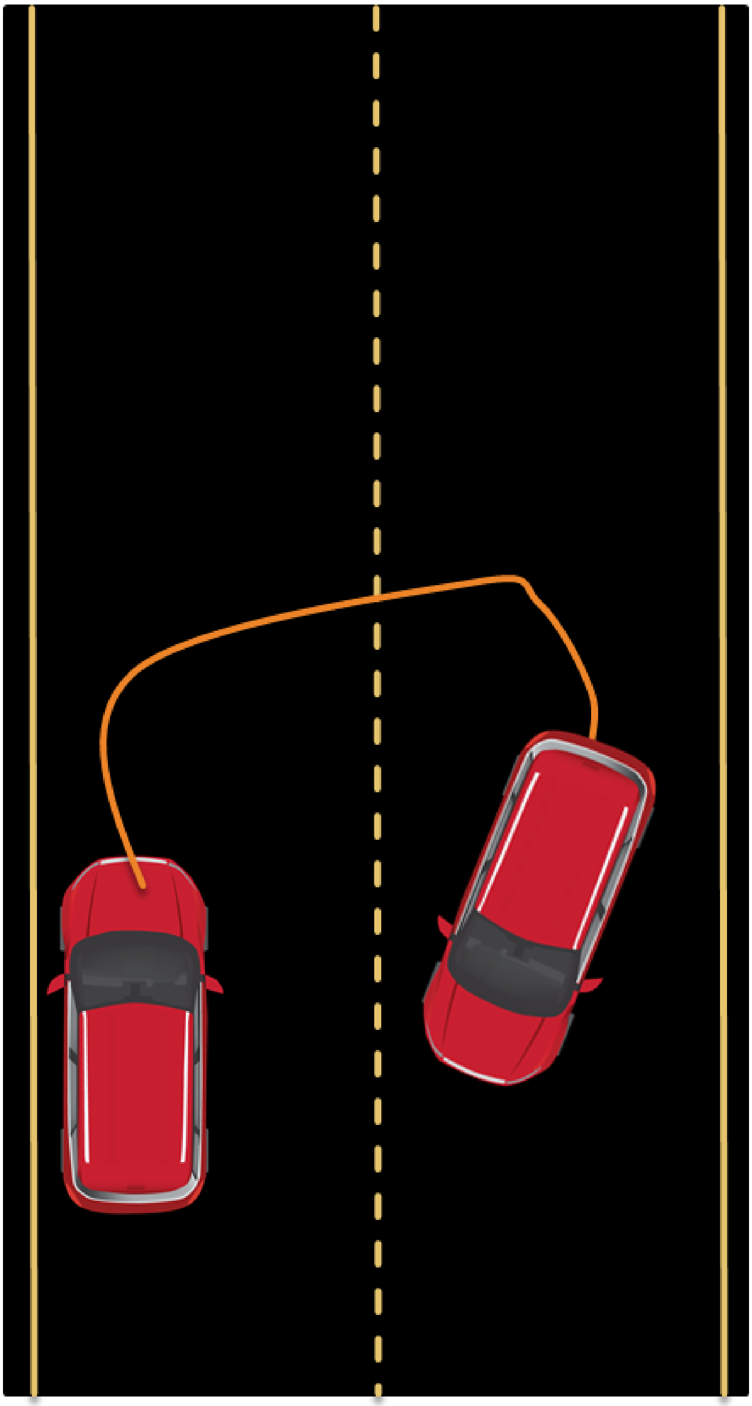
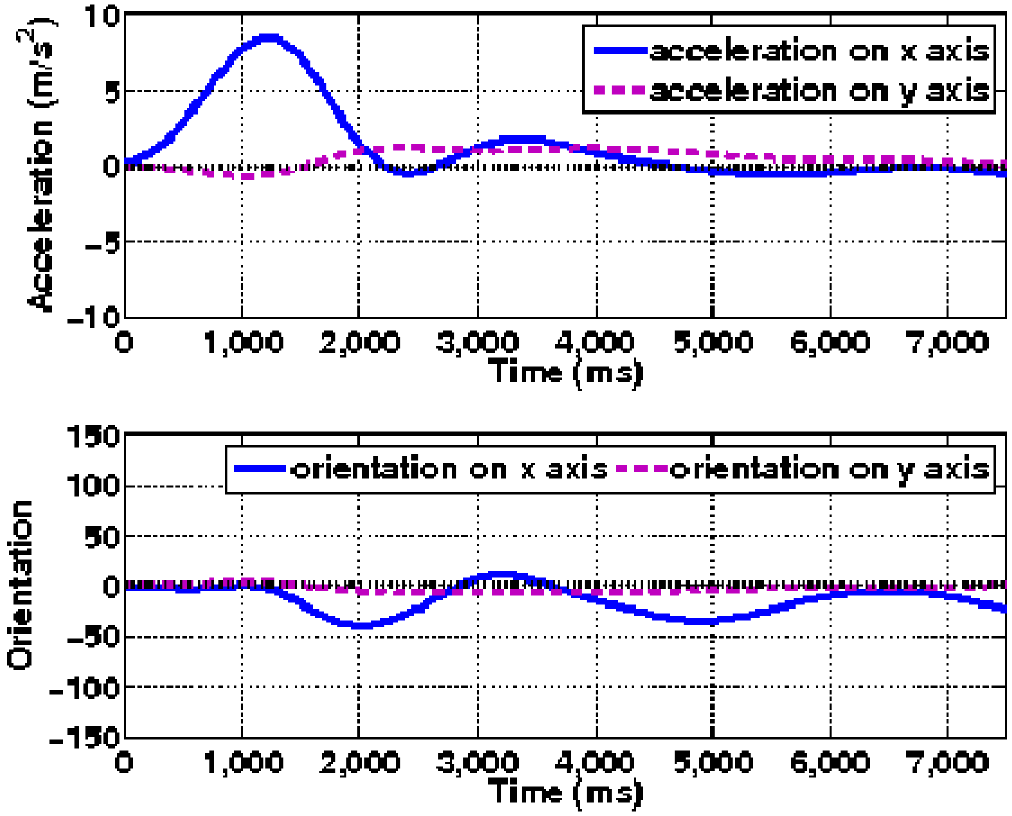


Figure 29 Fast U-Turn Detection Algorithm – Behavioural Analysis

4.2.5 TURNING WITH WIDE RADIUS ALGORITHM

Another abnormal behavior while driving in a normal way is turning with wide radius. Wide radius turning will cause collision with other vehicles which is moving around and who is anticipating right turning behavior from all the moving vehicles. The situation will cause panic for other vehicles and will end up in accident. The centrifugal force is directly proportional to the velocity with which it is taking the turn and inversely proportional to radius of the turn.



(e) Turning with a wide radius

Figure 30 Turning with wide curve Detection Algorithm – Data Inputs

For detecting the abnormal wide turning radius, the data from steering wheel sensor has to be correlated with reference data for that particular location. The reference data can be collected from cloud with respect to the vehicle position or from vehicle moving in front by car to car communication or from car to infrastructure communication.

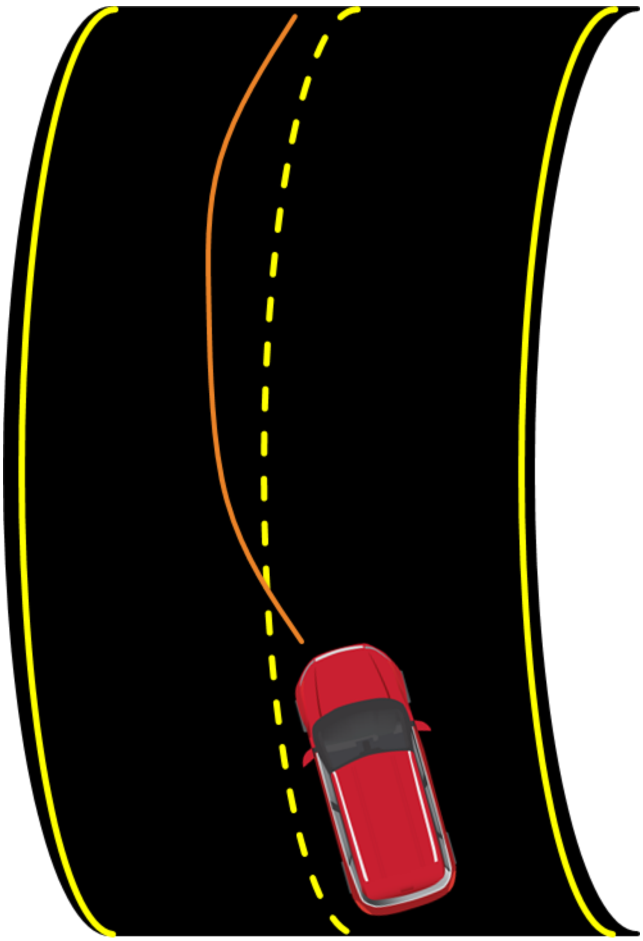


Figure 31 Turning with wide curve Detection Algorithm – Behavioural Analysis

5 IMPLEMENTATION

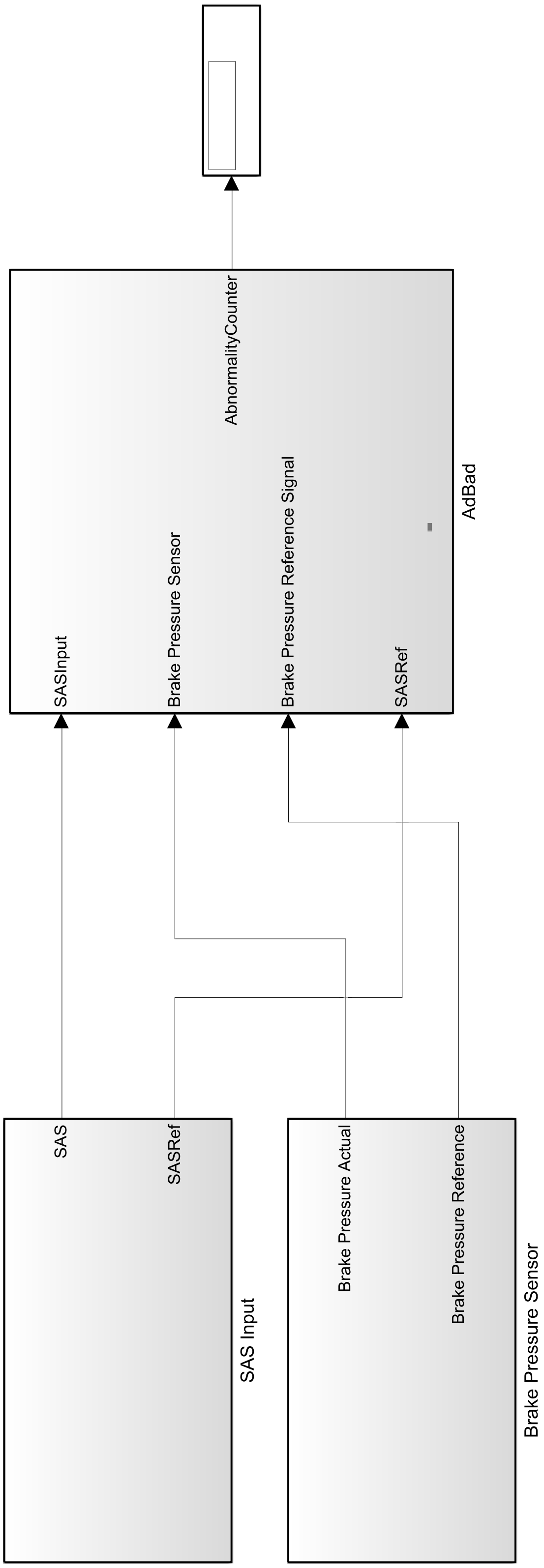


Figure 32 Abstract Level of Subcomponent Features Implemented

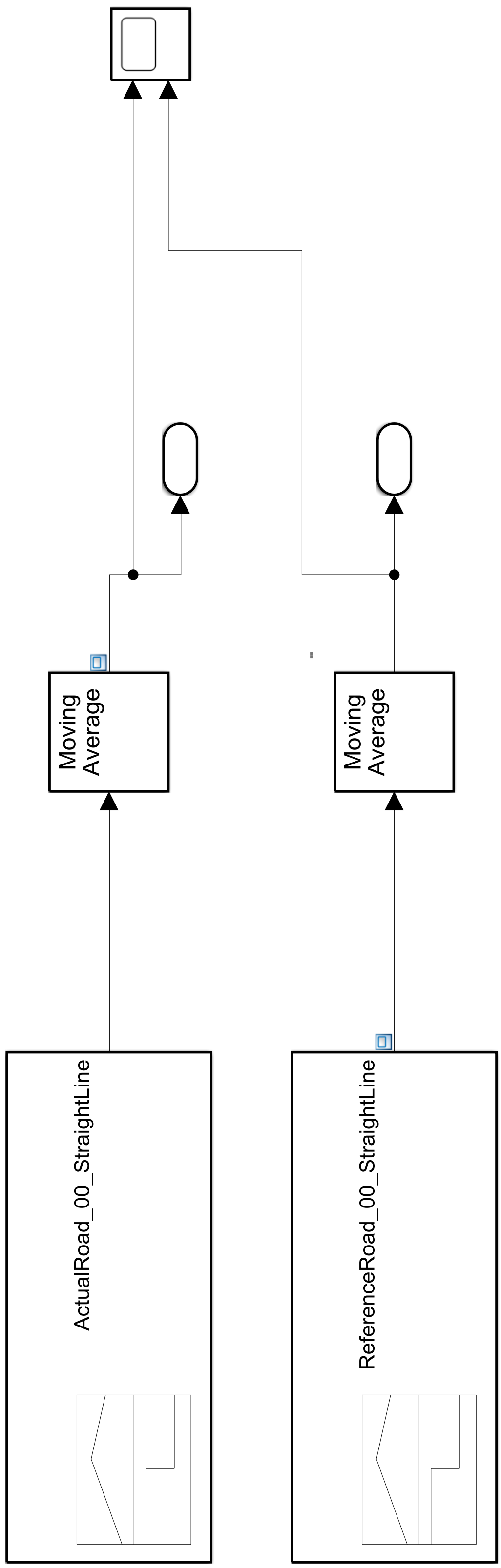


Figure 33 Reference signal generation for SAS

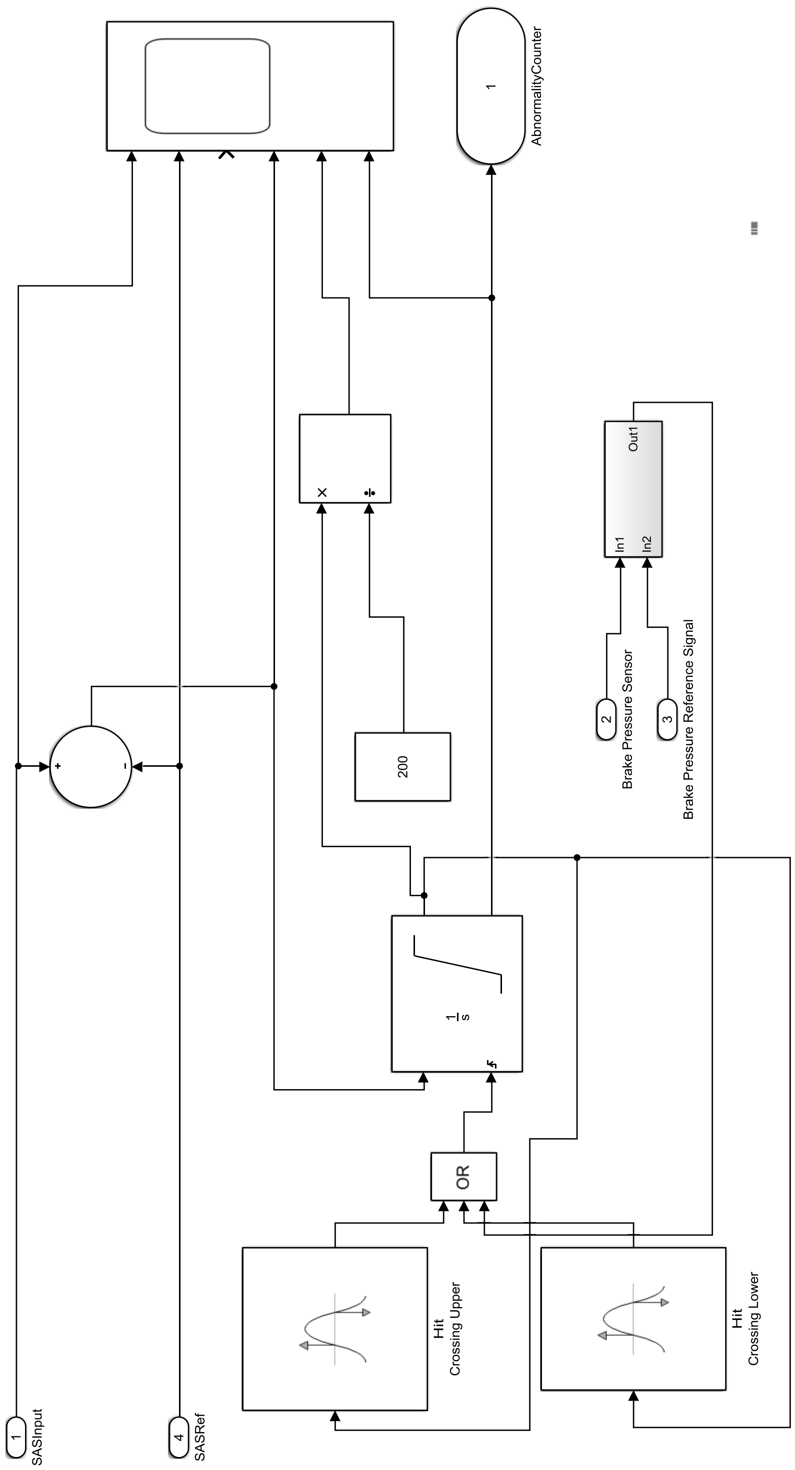


Figure 34 Abstract Level of Subcomponent Features Implemented

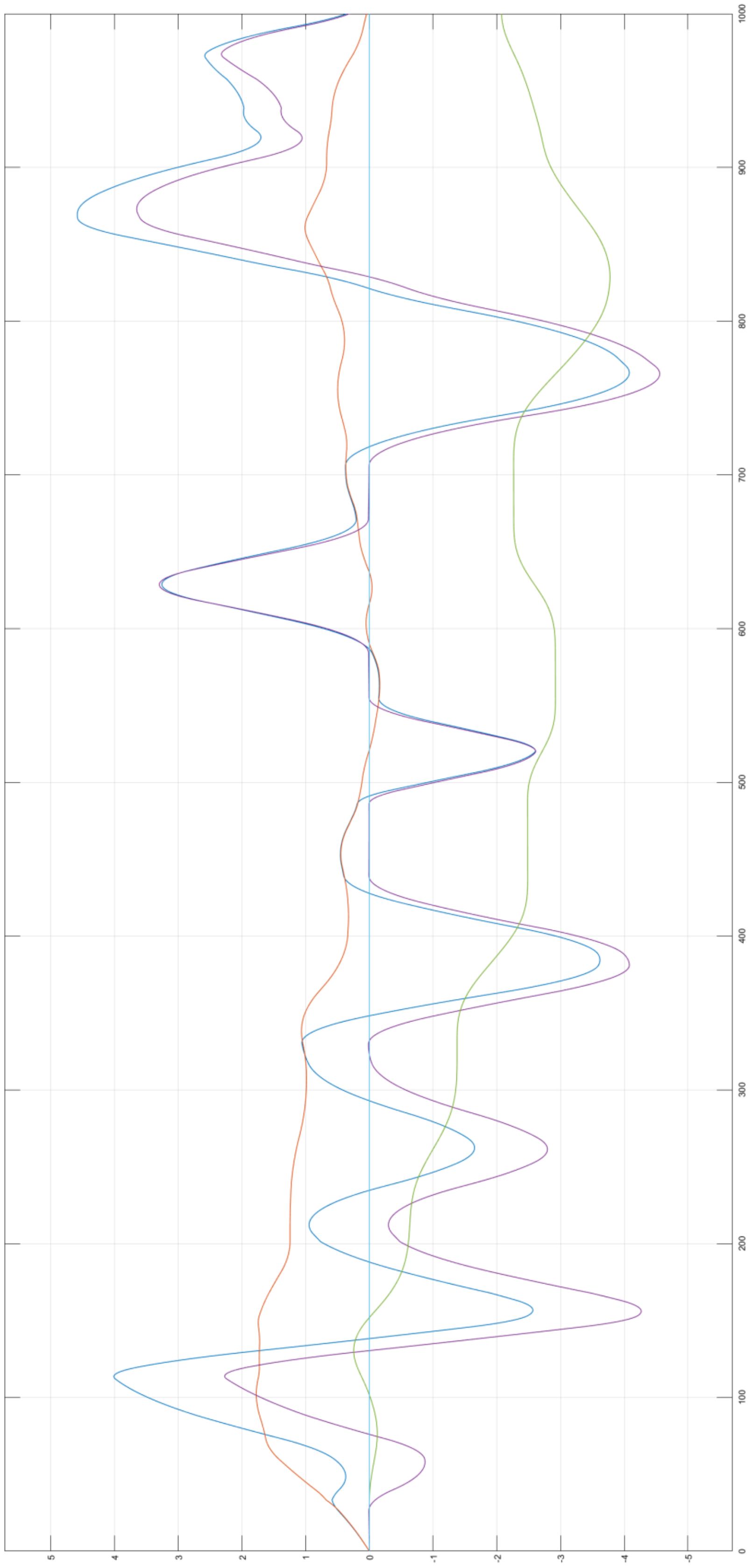


Figure 35 Abnormality Detection – SAS –Waving Detection Algorithm output

6 RESULTS AND DISCUSSIONS

The abnormal behavior detection algorithm which uses the SAS as input reference data is demonstrated in as a Matlab simulation. The real time input data is given to the Simulink input section and the truthfulness of the algorithm is verified.

Software models are implemented as subsystems in Matlab so that the modularity of each software algorithm can be kept. The current scope of this project takes attention only to the steering wheel angle based behavioral detection algorithms. As a potential use case the software algorithm has to be implemented in the cloud to reduce the overhead of an additional system getting installed into an automotive vehicle.

7 CONCLUSION

The various software algorithms are implemented after prototype implementation with the help of Mat lab. Various driving manuals are given as input and the detection of abnormality is observed. These abnormality detections are accumulated into the account of an individual driver and thereby determining the degree of abnormality with respect to his driving style.

Adjustment of Threshold is needed to fine-tune the behavioral analysis defined in all these detection algorithms. Real-time data inputs are given of driving profiles in order to understand the practicality of implementing this software algorithm into a wide range of use. The GUI based verification mechanism was provided to evaluate the truthfulness of this software algorithm.

8 FUTURE WORK

The current scope of implementation was the software algorithms which are associated with steering wheel angle sensor. As an enhancement into the already existing system, the additional sensors have to be integrated and everything all mathematical model is generated which is taken as the reference model for the good behavior and getting continuously evaluated together with the running behavior in that present situation.

The integration of the brake pressure sensor is an important fact because it directly affects the Dynamics of vehicle motion. Combining the result of brake pressure sensor and Steering Wheel angle sensor the mathematical model generated for the existing software algorithm gets an improved accuracy. Due to that, any decisions made by that algorithm have less chance of a false detection of abnormal behavior.

These Sensors have to be continuously given into the cloud computing unit, by using the means of the vehicle to X communication. The fallback mechanism after detecting the abnormality and the degree of abnormality is already above the safety threshold, then the decision towards making an action to prevent this abnormal driving behavior ends up in an accident or a chaos created into a public traffic. The output of this software algorithm can be used to deliver this data to the traffic control department in the runtime itself so that they can decide to take new action by seizing the vehicle. The preventive action can be counselling or a medical assistance provided to the driver.

9 REFERENCE

[1] National Highway Traffic Safety Administration, "2013 Traffic Safety Facts FARS/GES Annual Report," 2015. [Online]. Available: http://wwwnrd.nhtsa.dot.gov/Pubs/812139.pdf.

[2] W. W. Wierwille, L. A. Ellsworth, S. S. Wreggit, R. J. Fairbanks, and C. L. Kim, “Research on vehicle-based driver status/performance monitoring: development, validation, and refinement of algorithms for detection of driver drowsiness,” National Highway Traffic Safety Administration, Final Report, DOT HS 808 247.

[3] L. M. Bergasa, J. Nuevo, M. A. Sotelo, R. Barea and M. E. Lopez, "Real-time system for monitoring driver vigilance," IEEE Transactions on Intelligent Transportation Systems, vol. 7, no. 1, pp. 63-77, 2006.

[4] J. Jo, S. J. Lee, H. G. Jung, K. R. Park and J. Kim, "Visionbased method for detecting driver drowsiness and distraction in driver monitoring system," Optical Engineering, vol. 50, no. 12, pp. 127202-127202-24, 2011.

[5] F. Vicente, Z. Huang, X. Xiong, F. De la Torre, W. Zhang and D. Levi, "Driver Gaze Tracking and Eyes Off the Road Detection System," IEEE Transactions on Intelligent Transportation Systems, vol. 16, no. 4, pp. 2014-2027,

2015. [6] R. O. Mbouna, S. G. Kong and M. G. Chun, "Visual Analysis of Eye State and Head Pose for Driver Alertness Monitoring," IEEE Transactions on Intelligent Transportation Systems, vol. 14, no. 3, pp. 1462-1469, 2013.

[7] E. Murphy-Chutorian and M. M. Trivedi, "Head Pose Estimation and Augmented Reality Tracking: An Integrated System and Evaluation for Monitoring Driver Awareness," IEEE Transactions on Intelligent Transportation Systems, vol. 11, no. 2, pp. 300-311, 2010.

[8] X. Fu, X. Guan, E. Peli, H. Liu and G. Luo, "Automatic Calibration Method for Driver's Head Orientation in Natural Driving Environment," IEEE Transactions on Intelligent Transportation Systems, vol. 14, no. 1, pp. 303-312, 2013.

[9] S. J. Lee, J. Jo, H. G. Jung, K. R. Park and J. Kim, "RealTime Gaze Estimator Based on Driver's Head Orientation for Forward Collision Warning System," IEEE Transactions on Intelligent Transportation Systems, vol. 12, no. 1, pp. 254-267, 2011.

[10] A. Tawari, S. Martin and M. M. Trivedi, "Continuous Head Movement Estimator for Driver Assistance: Issues, Algorithms, and On-Road Evaluations," IEEE Transactions on Intelligent Transportation Systems, vol. 15, no. 2, pp. 818-830, 2014.