**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*

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**Institute for Industry and International Program**

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**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**: 07 October 2, 2018 **Signature of the Candidate**



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**BONAFIDE CERTIFICATE**

This is to certify that the project work entitled “**ALGORITHM FOR ABNORMAL DRIVING BEHAVIOR DETECTION”** by **VINU XAVIER (16MPD0024)**, 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.

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# 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.

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**LIST OF Abbreviations**

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| --- | --- |
| **SAS** | Steering wheel Angle Sensor |
| **ESC** | Electronic Stability Control |
| **CAN** | Communication Area Network |
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# INTRODUCTION

## 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.

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| 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.

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| Image result for causes of road accidents |
| 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 sensorics 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.

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| Figure 3 Statistics about 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.

# **LITERATURE SURVEY**

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

## 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.

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| Image result for forces acting on a vehicle |
| Figure 4 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.

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.

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.

## 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.

### 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.

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| Image result for pressure sensor in brake system |
| Figure 5 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

### 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.

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| Image result for steering angle sensor SAS |
| Figure 6 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.

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| Image result for steering angle sensor SAS |
| Figure 7 Steering wheel angle sensor as a universal sensor (SAS) and its usages |

### 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.

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| Image result for suspension sensors |
| Figure 8 Suspension height sensor (General Motor Corp) |

## 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.

### 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.

### 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.

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| Image result for traction circle |
| Figure 9 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.

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| Image result for gear shifting points |
| Figure 10 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.

### ABNORMALITY 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.

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| Figure 11 Acceleration and Steering behaviour Situation 01 |

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| Figure 12 Acceleration and Steering behaviour Situation 02 |
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| Figure 13 Acceleration and Steering behaviour Situation 03 |
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| Figure 14 Acceleration and Steering behaviour Situation 04 |

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| Figure 15 Acceleration and Steering behaviour Situation 05 |
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| Figure 16 Acceleration and Steering behaviour Situation 06 |
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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.

# DESIGN OF THE PROJECT

## BLOCK DIAGRAM

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| Figure 17 SW Algorithm Components |

## SW design

### LANE DEVIATION ALGORITHM

The first software algorithm which we want to discuss is the line deviation 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.

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.

If such kind of the situation he is not present then the reference line for taking that straight Road is AC unit 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.

# RESULTS AND DISCUSSIONS

# CONCLUSION

# FUTURE WORK

Figure 6.1: Expanded Block diagram DC Motor control

# REFERENCE

1. Ehsani, M., **Modern electric, hybrid electric, and fuel cell vehicles: fundamentals, theory, and design**. CRC Press, Boca Raton, 2005.