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Driver Behavior Detection Techniques: A survey

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Abstract:

Driver behavior considered an important factor in vehicle-driver-environment system. Real driving monitoring system has a big role in increasing driving safety. Several factors effect on the behavior of the driver like the fatigue, distraction, experience, environment condition, vehicle condition, and so on. Improper driver behavior will lead to increase the probability of accidents occurring. So detecting driver behavior is one of interested research area. By identifying and distinguishing between normal driving and aggressive driving, driving monitoring system alert the driver about his dangerous driving. The driver can enhance his driving style and decrease accident occurring probability. The important factor in driving monitoring system is the accuracy of it. Different techniques have been used to identify driver behavior based on the objectives of each system. Sensors are the key factor of driving monitoring systems. In this paper, we discuss several methods which have been proposed for detecting driver behavior and identify the advantages and disadvantages of each method.

Keyword: *aggressive, behavior, driver, dangerous, detection, monitoring, sensors, systems.*

INTRODUCTION

Road accidents are undoubtedly becoming a growing concern in many countries because they are rising to become one of the leading causes of death and injuries. According to the World Health Organization (WHO), road accidents are considered the 9th leading cause of death worldwide and the leading cause of serious injuries [1]. In addition to traffic safety, fuel consumption and gas emissions also led vehicle manufacturers, other industries and research centres all over the world to develop solutions to monitor driving behavior, style, manoeuvres and performance. A driving behavior and style profiling system involves automated collection of driving data and application of computer algorithms and models to generate a taxonomy that describes the driver performance profile. The major module in any driving behavior and style profiling system is the identification of driving manoeuvres and the classification of the driving style for these events using intelligent systems. The real-time capturing of driving manoeuvres and events requires various types of sensors, such as acceleration, orientation, velocity and positioning [2-4]. Generally, current available monitoring systems are based on different technologies, such as global positioning services (GPS), Global Navigation Satellite Systems (GNSSs), In-Vehicle motion sensors accessible through CAN-BUS or OBD systems, external special purpose developed systems, vision systems and very recently smartphones. Smartphones are now includes different types of sensors and probes, such as GPS, Inertial Measurement Units (IMU), cameras, and etc. Although, Different sensors and classification methods have been employed for this driving manoeuvres and events detection and recognition; the low-cost solutions and high performance are still research targets [5-8]. The emergence of mobile-phones and sensor technology has led to the resurgence of smartphones. This widespread of smartphones with their increasing processing capacity and their increasingly rich sensors set led to the development of a numerous number of applications especially in driving safety area. Smartphones are now playing an important role in the field of Intelligent Transport Systems (ITS) such as driver behavior detection and vehicle monitoring [9]. In this paper, recent researches that proposed methods to detect driver behavior based on different parameters will be reviewed to identify the suitable method for driver behavior detecting. Note that there are different techniques used for driver behavior detection systems will be mentioned such as Advanced Driver Assistance system (ADAS), Simulator, Remotely mounted cameras and others.

The organization of this paper as follows: Section 2 discuss driver behaviour detection techniques briefly with strength and weakness of each one of them and section 3 the conclusion.

DRIVING MONITORING SYSTEM TECHNIQUES

Classification of driver behavior considered as a complex issue because it is a multi-dimensional problem and is subjected to several peculiarities of driver and traffic state [9].The traffic state is derived by group of variables like road conditions, vehicle kinematic and driver behavior [51]. All these factors can be described by a set of vague driving rules developed through experience for different drivers and conditions. Therefore, driver behavior recognition in terms of manoeuvres and tactics must be obtained. Different factors have to be considered to evaluate and recognize driving style such as environmental factors, road states and vehicle [11], events classification and identification [12] and biological and physiological status [10]. Building an accurate and complete model based on all these factors is difficult and also impossible in practice. In the last 10 years different commercial and research systems have been proposed to analyse the driver behavior and present systems to evaluate driver performance and assist drivers [13]. A common infrastructure all these systems are shared which is the driving monitoring system. Driving Monitoring Systems generally are classified into In-Vehicle Data Recording Systems and Real-Time Monitoring Systems [14].

In-Vehicle Data Recording Systems

Classical monitoring systems usually utilize the in-vehicle sensory or external devices with data acquisition systems to monitor and record driving performance. The available systems are usually based on obtaining driving data from the CAN-BUS directly or by using OBD interface [13-15]. Other systems utilized external sensory systems to extract some information and parameters that are not accessible or obtainable through the CAN-BUS [16-18]. Hybrid systems that combine both in-vehicle and external sensory systems are also used to improve the accuracy and reliability through the sensor fusion of both systems [19-21]. In [22], proposed a system to detect if the driver distracted or fatigue based on Camera installed inside the car, the camera can alert the driver directly. In [23], they installed two cameras in front and at the end of the car to help the driver in lane changing decisions. Data recorder In-vehicle was installed in [24] to identify different driving maneuvers take environment condition as a factor in the analysis. In [25], proposed a system to detect drowsiness of the driver and swinging heads based on visual features to detect behavior of the driver. The violations of the traffic detection system proposed in [26] based on RFID technology.

Smartphone-based sensing in vehicles

The development of smartphones during the last ten years has enabled those whom own smartphones to carry a significant computational and processing power on their person at all times. Furthermore, all newly smartphones are now equipped with a wide range of sensing devices such as accelerometer, a gyroscope, magnetometer and many other sensors. In addition to build-in sensors, smartphones provide a link to the Global Positioning System satellite network thus allowing for navigational and tracking systems [27].

Various driving behavior systems have been proposed based on smartphone to avoid the several problems related to use different hardware devices, also the development in smartphone technology such as availability of different sensors (Accelerometer, gyroscope, magnetometer,…) , cheap cost and different other advantages help the smartphone to be a good and efficient platform for driver behavior detecting and monitoring systems [28]. In [17], they used smartphone motion sensors to classify the driving into normal and aggressive driving. In [29], they proposed a system to detect driver maneuvers based on accelerometer sensor only. System for recognize driver behavior have been proposed in [30]. Based on smartphone motion sensors in [31] based on smart phone they presented a system to detect the distraction of the driver with mobile. In [32], they presented application for mobile to detect dangerous and inefficient driving. A system to detect driving maneuvers based on smartphone has been proposed in [33]. In [34], based on accelerometer and orientation sensor of the smartphone a system proposed to detect unsafe driving. In [35], based on smartphone sensors they proposed a system to detect six types of maneuvers. In [36-37], they proposed a system to estimate the behavior of the driver based on smartphone. In [38], they proposed a system based on smartphone work as a black-box way in case of accidents. In [39], system work after accident occurring and inform other predefined persons about the accident.

All of the old systems have been proposed based on external devices or installing sensors in- vehicle to monitor and derived driving behavior. As well as, various systems have been proposed based on smartphone to avoid the several problems related to use different hardware devices, also the development in smartphone technology such as availability of different sensors (Accelerometer, gyroscope, magnetometer,…) help the smartphone to be a good and efficient platform for driver behavior detecting.

Behavior Detection Methods

In [40], they installed CAN BUS in vehicle for collecting data. They used statistical method: Hidden Markov Model (HMM) and Gaussian Mixture Model (GMM) for detecting. Based on one parameter (Speed) they analyse the data using Matlab and compared between speeds in different events such as lane changing, over taking, stopping, and stable driving, all with distraction and natural driving. They found that HMM got more accurate results than GMM. As well as, they found that the speed is decreased with distraction driving in dangerous events like overtaking. However, they got high probability for false alarm in all events. In [41], Based on CAN-BUS they collected different data from real driving trips, they used statistical method for detecting driving behavior such as mean, median and standard deviation in uncontrolled condition.

In [42], they used utilized external sensor such as GPS to extract some information and parameters that are not accessible or obtainable through the CAN-BUS, based on lateral, longitudinal and velocity as parameters they identified three events: Acceleration, Braking, and Turning. They used support vector machine for analysing data. They found that there is high potential for using external devices beside CAN_BUS to identify the type of event. However, their accuracy percentage considered low compared to other systems. In [43], they used accelerometer, gyroscope and magnetometer of physical device to analyse and detect behavior of the driver by using statistic method. They found that there are fixed axes changes for each type of maneuver for example in braking event the acceleration in x axes (a_x) of a car reduces to a negative value. As well as, they found that mean and peak value of acceleration in X, Y and gyroscope in Z axes are help to distinguish between brake , acceleration, turns and the slope information can help in differentiate between left and right lane change. They got good results but the need for design their physical device considered very costly. In [44] proposed detection system for driver behavior by using pattern recognition method for detection based on acceleration only. They used three axes of accelerometer sensor to analyse and detect behavior. They found that there is a big different in longitudinal acceleration between aggressive and normal driving. Their results show that more than 10% of the features are distinct for each style of driving. However, they did not mention to events which they are detected it.

In [45] a model that distinguishes between lane keeping, lane change and emergency lane change was suggested

implemented using Bayesian Networks. In this model the steering wheel angle was used as the only information to detect and recognize manoeuvres. Their result shows good accuracy related to the relation between angle of steering wheel and type of changing lane. However, long time analysis related to Bayesian network considered not good in driving behavior systems. The prediction of stopping event and behavior at intersections was suggested in [46]. The traffic signs, pedestrian crossing, and leading vehicle were used to assist the stopping behavior and evaluate the driver. They used multiple linear regression analysis for detect accelerating status and Bayesian networks for decelerating status. By using multiple linear regressions for analysis they got the dependencies between variables. By identifying three different coefficients for regression, they found that there is a relation between types of driving with traffic condition.

In particular [47], Dynamic time warping (DTW) algorithm and Bayesian classifier are used to estimate driver event by matching a predefined abnormal event templates with new real time data. A Bayesian network has been successfully applied for human-behavior modelling and driver manoeuvre recognition. However, the major drawback in utilizing Bayesian networks is due to the difficulty of including historical information. Therefore, more complicated forms of Bayesian networks such as dynamic Bayesian networks are suggested to overcome this drawback. However, this type of solution will add-up to the complexity in the construction as well as long time analysis which will lead to lose power of the battery [48-49].

Intelligent techniques such as neural networks are also used in the field of driver modelling. Neural networks proved to be a powerful technique for learning sample input/output relationships. In the case of predicting driving manoeuvres using neural networks, the input to the network could be behavioural parameters such as vehicle speed, acceleration and attitude or steering wheel angle. While the network's output could be a model that predicts a manoeuvre and its assessment. In [50], an intelligent system (Neural Network) to perform an erratic driving diagnosis was proposed, Backbone propagation algorithm used to identify and recognize manoeuvres. Their work shows how differently drivers perform an overtaking manoeuvre and produce different styles with different speeds. Good method and high accuracy but there is a need for many external sensors which lead to increase the cost as well as, they collected data based on simulator. In [51], Neural Network used to detect and predict behavior of the driver based on Deep Recurrent algorithm. They used many devices to collect data such as camera, GPS, Can Bus and microphones to increase the accuracy of predicting. Very good performance was achieved but many devices used led to increase processing time. A neural network is used to learn how to execute overtaking maneuvers was implemented in [52], based on longitudinal and lateral position they identified the type of the driving. They used three networks architecture in the system and applied propagation algorithm for detecting. Authors in [53] built a model to predict lateral and longitudinal vehicle acceleration by way of training a neural network. The error of prediction was very low. Even though neural networks are powerful learning mechanisms, their main drawback is that they are very difficult to analyse since the information they encode is not easily interpretable. Another disadvantage is that most neural networks are not able to handle a temporal sequence of data points, but only compute the output for one data vector at a time. In the domain of driver behavior modelling, especially for the prediction of driving maneuvers, the data usually consists of sequences of individual phases and including this temporal information is essential.

Fuzzy logic systems were also used in the field. As it is well known, fuzzy logic is a form of logic used for approximate, rather than exact reasoning. Since driving a vehicle is largely a reasoning process, it is intuitive to use fuzzy logic to model driving behavior, especially in the context of driving maneuvers. A detection system based on fuzzy logic method was presented in [54] to distinguish emergency braking from merely strong braking behavior. The pressure on the brake was the parameter to detect. Based on relation between brake length of the pedal stroke and its ratio of variance they put their fuzzy rules. The system presented high performance. However, they focused only on the braking event and their tests were based on simulator only. In [55], based on GPS sensor they got velocity and position to detect behavior of the driver if it is aggressive or not. They used fuzzy logic and Neural Network methods for detecting. They focused on three events braking, throttle, and steering. Based on their fuzzy logic rules they found that the acceleration more ±0.3 in the units of Gravity Force is aggressive driving. High performance got in simulated conditions but the problem of losing signal of GPS can be avoided. In [56], proposed a module to detect car following event only based on speed, acceleration and distance parameters. Fuzzy logic method applied to identify car following event. Their system presented high efficiency through simulation environment. However, they did not identify other events which are affected by car following status. Based on accelerometer and orientation sensors of smartphone as well as GPS device in [57], they detect driver behavior and send the information to predefined server for several issues. They used fuzzy logic method to detect if the driving risky or not. They identified their fuzzy rules based on over speed, acceleration and steering rate through turning and intersection events. The output of fuzzy set is normal, moderate and aggressive. The results were accurate but the problem of external device may be effect on the reliability of results.

In[58] Gaussian Mixture Model used to detect driver behavior in case of car following based on brake pedal, accelerator pedal, vehicle velocity, and distance from the vehicle in front as a parameter for algorithm. Gaussian Mixture Model is a statistical model that is a linear combination of Gaussian basis functions. Good result in real time environment as well as in simulator, while the rate of identification was 73% which can improve by using multiple statistical models.

In [59] based on statistical method (Multiple linear regression and principal component analysis (PCA)) driving-events-based eco-driving behavior evaluation model are proposed. Driving mode duration, speed and acceleration are the parameters used to identify three events including Long-Time Accelerating, Accelerating Sharply and Decelerating Sharply.

The results provide good accuracy and simple computational process. However, the speed of the vehicle more than 100 km/h is ignored in their model. In [60], proposed develop a comprehensive knowledge about the feature and characteristics of stopping dilemma zone drivers at signalized intersections. Based on Brake response time and deceleration they identified several events. They used SPSS for multiple linear regression (Brake-Response Times recognition) and logistic regression (for Prediction of Stop and Go-Through Events) recognition. Their results shows that speed and distance have the strongest effect on deceleration rate. Based on accelerometer and orientation smartphone sensors cooperated with Car DVR for video recording used in [61] they identified six types of abnormal driver maneuvers with distinct parameters as a ground truth(Swerving, Side slipping, Fast U-turn, Turning with A wide radius and Sudden braking.). Support vector machine (SVM) machine learning algorithm used for identify driver maneuvers. They got distinct features for each type of maneuvers based on acceleration, orientation and time duration. Very good performance was achieved. However, there is some kind of restriction to the driver related to Car Video recorder. In [62], an application for iphone devices proposed to detect behavior of driver based voice, GPS, video, and inertial sensors for collecting data. . They identified thresholds for each pattern of maneuvers and after that they used pattern recognition and computer vision as methods for detecting the behavior. High performance got from application. However, the location required for device under the mirror may be restricted in some countries. In [63], abnormal maneuvers related to drunk drivers were detected. Lateral acceleration and longitudinal acceleration which are achieved from accelerometer sensor used as a parameter to recognize the event. They identified patterns for drunk driver and applied pattern matching algorithm on smartphone for compared between new data and predefined pattern. Their system alerts the driver directly Results show high efficiency and high accuracy. While the mobile position in the front seat consider as a drawback for the system. In [64], they identified aggressive driver behavior take in consideration several environmental conditions like road rage and anger emotions. They did a questionnaire for driver how are participate in driving trips, questionnaire contained several parts related to the causes which make them angry during driving. Based on Chi square method their system can detect if the driver is angry or not. Their studies was good for differentiate between normal driver and angry driver, but other factors like age and gender were not considered in their study.

In [65] proposed system to predict the consumption of gasoline. By applying linear regression their system can predict consumption of gasoline based on acceleration and speed. As well as, they applied K-means clustering and Naïve Bayes for recognition trying to find more accurate patterns for gasoline consumption. They found that Naïve Bayes propose more accurate pattern than K-means clustering. However, they did not collect a full utilization of data set for analysing also there is a need for gear shift information and throttle paddle.

CONCLUSION

Generally the sensors are the key factor in driving monitoring systems. To detect driver behavior we need automated collection of driving data and application of computer algorithms and models to generate a taxonomy that describes the driver performance profile. In this review, we have divided driving behavior detection systems in general into two type in-vehicle sensors systems and real time systems. Several techniques have been used to detect and recognize driver behavior. Each one of these techniques has its own strength and weakness points. The techniques of non-real time system are very important in training and feedback to the driver but it is not good in alert driver through his driving. In other hand, real driving monitoring systems need to several hardware devices with long processing time and high memory capacity. However, these systems have its own disadvantages like signal losing, large memory needed, and long-time processing. The development of smartphone, availability and cheap cost helped in enhancing and improving driver behavior monitoring systems by overcome all the obstacles faced in previous systems. We can see that large number of researches proposed based on classification problem to detect several behaviors of driver as well as, statistical method presented a good and accurate result, it gives valuable insights in detection problem. Additionally, we found that there are no fix parameters for detecting systems, it based on the objective of each system as well as based on the type of a tool which is used to collect data.

REFERENCES

[1] http://www.who.int/violence_injury_prevention/road_safety_status/2013/en/: "Global Status Report on Road Safety", World health organization, 2013.

[2] http://www.who.int/violence_injury_prevention/publications/road_traffic/world_report/ en /: "World Report on Road Traffic Injury Prevention", World Health Organization Report, 2004.

[3] http://www.car-accidents.com/country-car-accidents/oman-car-accidents.html.

[4] MucahitKaraduman and HalukEren(2017). Smart Driving in Smart City, 5th International Congress and Fair on Smart Grid and Cities (ICSG), pp.115-119.Turkey-Istanbul.

[5] Saqib Ali Haidery and Muhammad Rizwan (2017). Vision based autonomous vehicle for smart transportation system, 4th International Conference on Smart and Sustainable City .pp 9-14, Shanghai, China.

[6] Rob Bakker, JeroenHogema, WimHuiskamp and Zoltan Papp. IRVIN (2005) - Intelligent Road and Vehicle test Infrastructure, Proceedings of the 8th International IEEE Conference on Intelligent Transportation Systems, pp. 947-952, Vienna, Austria.

[7] AshwinGumaste, Rahul Singhai and AnirudhaSahoo(2007).Intelligent Vehicular Transportation System (InVeTraS). Australasian Telecommunication Networks and Applications

Conference.pp.58-63, Christchurch, New Zealand.

[8] www.telegraph.co.uk › Technology: Driverless car technology could leave users asleep at the wheel, Oct. 2017.

[9] https://www.gsma.com/iot/wp-content/uploads/2015/06/ITS-report.pdf. Intelligent Transportation Systems Report for Mobile.2015

[10] R. Vivoli, M. Bergomi, S. Rovesti, P. Bussetti, G.M. Guaitoli (2007). Biological and behavioral factors affecting driving safety.Journalof Preventive Medicine and Hygiene, Vol. 47, pp. 69-73.

[11] Darren Wishart, Jeremy Davey, James Freeman and Bevan Rowland (2009).IDENTIFYING INFLUENCES OF DRIVING BEHAVIOUR: COULD THE AUSTRALIAN WORK DRIVING SETTING BE UNIQUE.PROCEEDINGS of the Fifth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design.Iowa City, USA.

[12] Claire D'Agostino, AlexandreSaidi, Gilles Scouarnec, and Liming Chen (2013).Learning-based driving events classification.Proceedings of the 16th International IEEE Annual Conference on Intelligent Transportation Systems .The Netherlands.

[13] Hang-Bong Kang (2013).Various Approaches for Driver and Driving Behavior Monitoring: A Review. Proceedings of IEEE International Conference on Computer Vision Workshops.Sydney, Australia

[14] Luis Miguel Bergasa, Jesus Nuevo, Miguel A Sotelo, Rafael Barea, and Maria Elena Lopez (2006).Real-time system for monitoring driver vigilance. Intelligent Transportation Systems, IEEE Transactions.

[15] Lionel Nkenyereye and Jong-Wook Jang, "Integration of Big Data for Querying CAN Bus Data from Connected Car", Ninth International Conference on Ubiquitous and Future Networks (ICUFN), July 2017, pp. 946-950, Milan, Italy.

[16] Minh Van Lyy, Sujitha Martiny and Mohan M. Trivediy, "Driver Classification and Driving Style Recognition using Inertial Sensors", IEEE Intelligent Vehicles Symposium (IV) June 2013, pp. 1040-1045, Gold Coast, Australia

[17] Minglin Wu, Sheng Zhang and Yuhan Dong, "A Novel Model-Based Driving Behavior Recognition System Using Motion Sensors", Sensors, Vol 16, 2016.

[18] Nanxiang Li ; Jinesh J. Jain ; Carlos Busso' "Modeling of Driver Behavior in Real World Scenarios Using Multiple Noninvasive Sensors", IEEE Transactions on Multimedia, Vol. 15, Issue: 5, Aug. 2013, pp. 213 – 1225.

[19] Jinesh J Jain, "Analysis of driver behaviors during common tasks using frontal video camera and CAN-Bus information", IEEE International Conference on Multimedia and Expo (ICME), July 2011, Barcelona, Spain.

[20] Juan Carmona, Fernando García, David Martín, Arturo de la Escalera and José María Armingol, "Data Fusion for Driver Behaviour Analysis", Sensors, Vol. 15, Oct. 2015, pp. 25968-25991.

[21] Hamad Ahmed and Muhammad Tahir, "A Low-Cost, Wireless, Multi-Modal Sensing Network for Driving Behavior Modeling and Early Collision Warning", web.lums.edu.pk/~spnav/hamad/papers/AbnormalDrivingBehavior.pdf.

[22] Wang Rongben, Guo Lie. Monitoring Mouth Movement for Driver Fatigue or Distraction with One Camera. IEEE intelligent Transportation Systems Conference,2004.

[23] Jiann-Der Lee, Jiann-Der Li, A Novel Driving Pattern Recognition and Status Monitoring System, ds.): PSIVT 2006, LNCS 4319, pp. 504 – 512, 2006.

[24] TOMER TOLEDO . IN-VEHICLE DATA RECORDER FOR EVALUATION OF DRIVING BEHAVIOR AND SAFETY, HTTPS://DOI.ORG/10.3141/1953-13, 2013.

[25] H. SINGH, J. S. BHATIA, AND J. KAUR.EYE TRACKING BASED DRIVER FATIGUE MONITORING AND WARNING SYSTEM.PROC. IEEE IICPE, NEW DELHI, INDIA,2006.

[26] S. Hajeb, M. Javadi, S. M. Hashemi. Traffic Violation Detection System based on RFID, International Journal of Mechanical and Mechatronics Engineering Vol:7, No:2, 2013.

[27] Abhijit Suprem, Vishal Deep, and Tarek Elarabi, "Orientation and Displacement Detection for Smartphone Device Based IMUs", IEEE Access, Vol. 5, Nov. 2017, pp. 987–997.

[28] Pimwadee Chaovalit*, Chalermpol Saiprasert, A method for driving event detection using SAX with resource usage exploration on smartphone platform. Journal onWireless Communications and Networking 2014

[29] Radoslav Stoichkov, Android Smartphone Application for Driving Style Recognition. Project Thesis,2013.

[30] Yantao Li1 · Gang Zhou2, Determining driver phone use leveraging smartphone sensors. Multimed Tools Appl DOI 10.1007/s11042-015-2969-7,2015.

[31] Adnan K. Shaout and Adam E. Bodenmiller, A Mobile Application for Monitoring Inefficient and Unsafe Driving Behaviour. The Electrical and Computer Engineering Department.

[32] Nattakorn Promwongsa1, Pramookh Chaisatsilp1, Automatic Accelerometer Reorientation for Driving Event Detection Using Smartphone, 2National Electronics and Computer Technology Center,Tailand.

[33] Prarna Dhar1, Sarika Shind, Unsafe Driving Detection System using Smartphone as Sensor Platform, International Journal of Enhanced Research in Management & Computer Applications, ISSN: 2319-7471,2014.

[34] Zhongyang Chen, Jiadi Yuz. D3: Abnormal Driving Behaviors Detection and Identification Using Smartphone Sensors,2015

[35] 1,2H.Eren, 1,2S.Makinist, Estimating Driving Behavior by a Smartphone*, Intelligent Vehicles Symposium,2012.

[36] Javier E. Meseguer, Carlos T. Calafate,

DrivingStyles: a smartphone application to assess driver behavior. 978-1-4799-3755-4/13/$31.00 ©2013 IEEE

[37] J. Zaldivar, C.T. Calafate. Providing accident detection in vehicular networks through OBD-II devices and Android-based smartphones. IEEE Conference on Local Computer Networks 2011.

[38] Chris Thompson, Jules White, Using Smartphones to Detect Car Accidents and Provide SituationalAwareness to Emergency Responders, Springer Berlin Heidelberg, 2010

[39] SangJo Choi , JeongHee Kim, DongGu Kwak. Analysis and Classification of Driver Behavior using In-Vehicle CAN-Bus Information. University of Texas at Dallas. 2014

[40] RahelHadgu (2015).Statistical Analysis of Driver Behaviour and Eco-Driving model based on CAN bus Data. M.Sc. Thesis, Halmstad University.

[41] Minh Van Lyy, SujithaMartiny and Mohan M. Trivediy(2013).Driver Classification and Driving Style Recognition using Inertial Sensors.IEEE Intelligent Vehicles Symposium (IV), Australia

[42] Minglin Wu, Sheng Zhang andYuhan Dong(2016).A Novel Model-Based Driving Behavior Recognition System Using Motion Sensors.

[43] Holger Berndt and Klaus Dietmayer. Driver intention inference with vehicle onboardsensor(2009). IEEE International Conference on In Vehicular Electronics and Safety.

[44] Vygandas Vaitkus and Paulius Lengvenis. Driving Style Classification using Long-Term Accelerometer Information. ©2014 IEEE

[45] Shigeki Tezuka, Hitoshi Soma, and KatsuyaTanifuji (2006).A study of driver behavior inference model at time of lane change using Bayesian networks.In IEEE International Conference on Industrial Technology (ICIT).

[46] HideomiAmata, ChiyomiMiyajima, Takanori Nishino, NorihideKitaoka, and Kazuya Takeda (2009). Prediction model of driving behavior based on traffic conditions and driver types. In 12th International IEEE Conference on Intelligent Transportation Systems.

[47] Grivon, D.; Vezzetti, E.; Violante, M.G (2013). Development of an Innovative Low-cost MARG Sensors Alignment and Distortion Compensation Methodology for 3D Scanning Applications. Robot.Auton.

[48] Shou-Tao Li, Li-ShuGuo, HuiXu, ChangfuZong and Rui-Kang Shi (2009).Drivers' braking intentions identification of EHB system based on fuzzy logic. International Conference on Machine Learning and Cybernetics.

[49] KunihiroOhashi, Toru YAMAGUCHI, and IkuoTamai(2004).Humane automotive system using driver intention recognition. In SICE annual conference.

[50] Anna Booth. Using Neural Networks to Improve Behavioural Realism in Driving Simulation Scenarios, 2007.

[51] Oluwatobi Olabiyi, Eric Martinson. Driver Action Prediction Using Deep (Bidirectional) Recurrent Neural Network. California, USA.2017.

[52] K.P. Kraiss and H. Kuttelwesch, "Identification and application of neural operator models in a car driving situation", In IFAC Symposia Series, Vol. 5, pages 121-126, 1993.

[53] Dejan Mitrovic, "Machine learning for car navigation", In International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems, pages 670-675. Springer, 2001.

[54] Shou-Tao Li, Li-Shu Guo, Hui Xu, Changfu Zong and Rui-Kang Shi, "Drivers' braking intentions identification of EHB system based on fuzzy logic", IEEE 2009 International Conference on Machine Learning and Cybernetics, pages 619-624, 2009.

[55] Christian G. Quintero M., José Oñate López. Driver Behavior Classification Model based on an Intelligent Driving Diagnosis System. 15th International IEEE Conference on Intelligent Transportation Systems Anchorage, Alaska, USA,2012.

[56] lireza Khodayari, Reza Kazemi, Ali Gha_ari, and Reinhard Braunstingl, "Design of an improved fuzzy logic based model for prediction of car following behavior. In IEEE International Conference on Mechatronics (ICM), pages 200-205, 2011.

[57] German Castignani and Raphael Frank. Driver Behavior Profiling using Smartphones.In International IEEE Annual Conference on Intelligent Transportation Systems,2013.

[58] Wakita and ozawa. Driver identification using driving behavior signals. In IEEE International Conference on Intelligent Transportation Systems, 2006

[59] Chen Chen,[1] Xiaohua Zhao. Driver's Eco-Driving Behavior Evaluation Modeling Based on Driving Events.In Journal of Advanced Transportation, 2018.

[60] Tim J. Gates, David A. Noyce. Analysis of Driver Behavior in Dilemma Zones at Signalized Intersections.In The Traffic Control Devices Committee.

[61] Zhongyang Chen_, Jiadi Yu. D3: Abnormal Driving Behaviors Detection and Identification Using Smartphone Sensors. Department of Computer Science and Engineering, Shanghai Jiao Tong University, Shanghai, P.R.China,2015.

[62] Bergasa L.M., Almeria D., Almazan J., Yebes J.J., Arroyo R. DriveSafe: An App for Alerting Inattentive Drivers and Scoring Driving Behaviors; Proceedings of the 2014 IEEE Intelligent Vehicles Symposium Proceedings; Deaborn, MI, USA. 8–11 June 2014; pp. 240–245.

[63] Jiangpeng Dai ∗†, Jin Teng. Mobile Phone Based Drunk Driving Detection.Germany,2010.

[64] Rajesh Sagar, Manju Mehta. Road rage: An exploratory study on aggressive driving experience on Indian roads. International Journal of Social Psychiatry,2013.