Driver Monitoring System: A review

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ABSTRACT

Human failures are identified as the biggest reasons for traffic accidents, whether due to use of alcoholic substances, inattention, distraction or drowsiness. Seeing this growing and persistent picture, the automotive industry has increasingly used fatigue and fatigue monitoring systems in its vehicles. In order to provide more security and better user experience. These systems work directly by image processing information from drivers' emotional, physical and situational states. Or indirectly, through the signs: vehicle acceleration, steering wheel angle, turn light indicator, etc. Thus, according to an evaluation criterion, the vehicle can emit an audible or visual signal to the user, as well as act on the driver assistant systems (ADAS) and can make them more sensitive according to the user's level of fatigue. One of the first automakers that focused its efforts on this technology was Toyota, through the Lexus car brand, and then other automakers such as VW and Ford began to develop their own. And with the rapid growth of this technology in the market, several discussions took place: how to use the images captured by drivers, how to safely establish the level of fatigue of users and how to make the use of this system law in world markets. For this, a series of regulations and market assessments are being made and improved, such as UNECE and NCAP. In the national scenario, the technology is still quite recent in terms of regularization, but the subject has been gaining more and more prominence through third-party systems that assess the level of attention of bus fleet drivers and report to employers, companies such as: Buser and Vale already have this system in their vehicles. Therefore, this work aims to carry out a synthesis on history, operation, rules and regulations on the world stage and finally analyze the potential of the Brazilian market for this technology.

1. INTRODUCTION

Advanced Driver Assistance Systems or better known as ADAS are safety designed to coordinate electronic, mechanical and automobile communication equipment with the purpose of users, shown in Figure 1. These systems have the driver alert for powers, such as: possible output of lane and blind spot warning. As well as avoiding or mitigating damages by Autonomous Emergency Brake (AEB) or applying evasive maneuvers. of the ADAS functions there is a specialization in checking the level of tiredness and attention of the driver, the driver monitoring system (DMS).[1]

Figure 1: ADAS systems. Source: European Comission [2019]

The DMS, in essence, is a system that acquires data about the driver in order to assess the ability to drive the vehicle safely. This technology can use data collected from the car, for example: steering wheel angle, pressure on the accelerator pedal, etc. As well as data acquired directly from the driver, examples: facial expressions, number of blinks, yawns and eye movement. And several researchers around the world are looking to improve this functionality.

This paper aims to present and discuss this technology, talking a little about its development, operation, standards and showing how it is being disseminated on the national scene.

The article is organized into 6 sections. In section 1, introduction, a description was given about the DMS and how it is part of the ADAS driver assistance systems. In section 2, a survey of the causes of traffic accidents caused by fatigue and a history of this application in the automobile market is shown. The functioning of this system is described in section 3, in which it will show more applied detection techniques to identify fatigue and inattention. Soon after, section 4 will show rules and regulations on this technology around the world. In section 5, the use of this function in the Brazilian transit scenario is discussed. Finally, section 6 conclusions about DMS are made and the future of this technology is discussed.

2. HISTORIC FACTS DRIVER MONITORING SYSTEMS

According to the government of Canada [11], 20% of reported fatal accidents were caused by fatigue. In another survey done in Pakistan, road accidents related to fatigue are 34%. In the United States, the percentage of fatal accidents caused by fatigue is the same as in Canada, 20%. In the European Union (EU), 25% of commercial transport collisions are related to tiredness and inattention. All these statistics and numbers alert you to how much consideration should be given to assessing and monitoring these conditions during a transit journey. [2]

Observing these data, the automobile industry began to develop the DMS. Well-known automakers such as Toyota, Volkswagen and Nissan were pioneers in research and construction of these systems. [2]

In 2006 Toyota's Crown model was the first fatigue detection system implemented by the automaker that was based on eye opening activity. Recently, Toyota developed Toyota Safety Sense P for compact and large vehicles. Safety Sense also has the following functions: detection of other vehicles, lane deviations, and pedestrians. [3]

In 2016, Nissan implemented in the Maxima model the detection of fatigue based on the steering wheel movement pattern, and since it shows an unusual deviation. An alarm signal is generated. This detection model adapts to user behavior by forming a pattern. Statistical analyses, based on measurements at angles of previous flywheels, are employed and used to identify fatigue. [4]

Rest Assist, developed by Volkswagen, offers a lane monitoring system, use of the accelerator pedal and erratic steering wheel movement to judge the drivers' level of fatigue and once detected. The panel beeps, visually; or tactile, by the vibration of the steering wheel. [5]

More and more car brands are adhering to driver supervision systems and the number of vehicles that have this technology grows. In addition, in this section, there are two fatigue detection modes: one that uses information from the driver himself, such as eye movement, called direct measurement. And another that uses car data, for example: steering wheel angle, called indirect measurement. These concepts and the functioning of the DMS are covered in section 3.

3. DRIVER MONITORING SYSTEM CONCEPTS

Driver monitoring systems have several methods to measure the level of tiredness or distraction. These methods are divided into 4 which are: subjective, physiological, behavioral and hybrid. The subjective methodology uses questionnaires to assess the level of tiredness. However, more focus will be given to the last 3, as they are the most present in automobiles and with it we can extract various measurement techniques from the DMS. As shown in Figure 2.

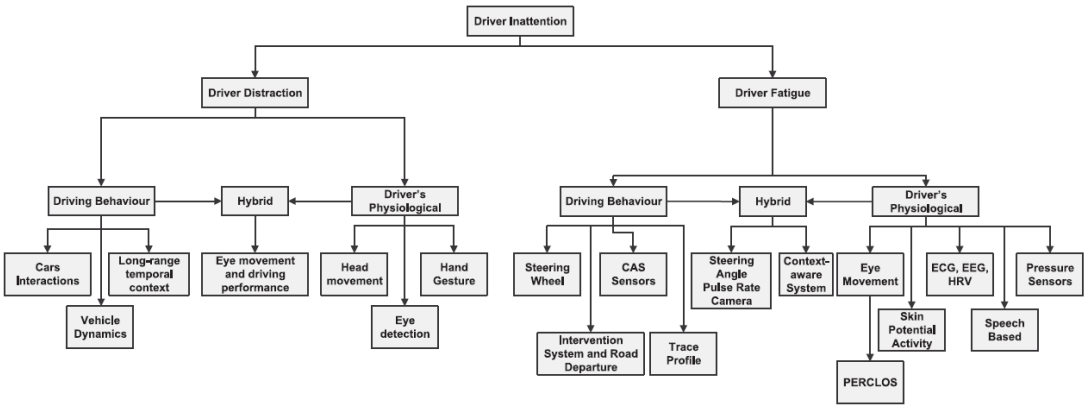

Figure 2: Taxonomy of driver inattention sources. Source: A. Koesdwiady e M. S. Kamel- Recent Trends in Driver Safety Monitoring Systems: State of the Art and Challenges,"[2017]

The physiological methods used are not very intrusive and are considered a direct measurement method. They are focused on the driver's facial observation and are based on the movement of the head, eyes and mouth. These signs often show signs of tiredness or distraction.[4]

Head movements: When the driver is tired or distracted, some muscles start to relax causing their head to start tilting. Or in case of distraction, its orientation changes and is not directed towards the highway. There are several computer vision algorithms that monitor this movement and generate alarms, shown in Figure 3. [7]

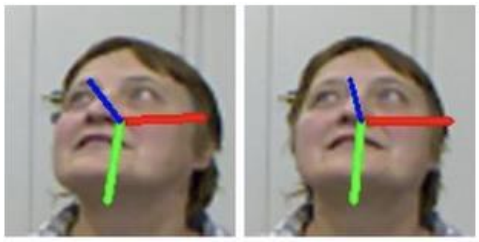

Figure 3: Head Movement Recognition. Source: https://paperswithcode.com/task/head-pose-estimation/codeless [2022]

Eye movement: The level of tiredness in human beings can be easily noticed by the muscular response of the eyelids. Fatigue people tend to close their eyes more or have slower blink patterns. As for distractions, the direction of the eyeballs can show that the driver is not looking at the track. Using computer vision programs, such as PERCLOS (PERcent of Eye CLOSure), it is possible to verify these patterns, illustrated in Figure 4 [5] [9]

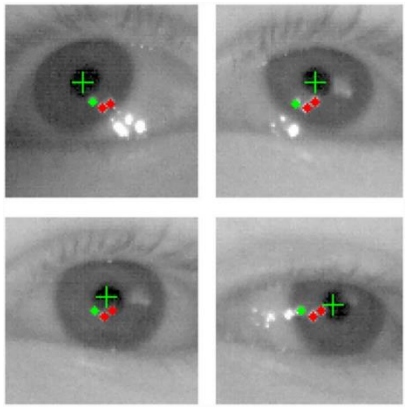

Figure 4: Head Movement Recognition. Source: https://link.springer.com/article/10.3758/s13428-019-01305-2 [2021]

Mouth movements: people when they are in a drowsy state have a yawning behavior that is opening and closing their mouths looking for more oxygen to the brain. Furthermore, the combination of mouth and eye movement makes it possible to determine the driver's level of distraction using computational algorithms, as shown in Figure 5.[1]

Figure 5: Mouth movement. Source: https://www.cs.auckland.ac.nz/~patrice/lip_algo.html [2015]

The behavioral methods, on the other hand, assess how the driver's behavior in the vehicle is already said. With interactions with the car it is possible to see if the driver is fatigued or not. They are known as indirect measurement methods. The two best known are: Steering Wheel Movement (SWM) and Standard Deviation of Lane position (SDLP). [6]

SWM uses a sensor that is located in the vehicle's steering column that allows measuring small variations in steering wheel angle. When the driver is tired, the number of micro corrections made to align the car on the road is less when the user is in full condition. The problem with this technique is the possibility of false positives, as shown in Figure 6. [6]

Figure 4: Driver Drownsiness Detection by Steering Angle. Source: https://alchetron.com/Driver-drowsiness-detection [2022]

The SDLP evaluates the vehicle's alignment on the highway. When the driver is drowsy, the car tends to go into the opposite lane or leave the highway. The main idea of this method is to use an external camera and verify that the vehicle is aligned with the road lane. This algorithm uses computer vision considering lane design.[7]

Finally, there are hybrid methods that are basically combinations of the techniques mentioned above, as each

tactic for measuring tiredness and physiological attention uses a camera and these can fail to measure when the driver is under high lighting, for example: sunset or obstruction using masks and goggles. On the other hand, the techniques that evaluate their behavior using the vehicle may not be so accurate in measuring fatigue patterns due to the limitations of variables. Thus, the best way to assess fatigue and inattention is to combine techniques. [7]

Legislation and standards are seeing this scenario and are creating rules and laws based on these studies that will be seen in section 4.

1. DRIVER MONITORING SYSTEMS: NORMS, REGULATIONS AND MARKET ASSESSMENTS

With the growth of DMS technologies and the large percentage of accidents caused by human error, it became necessary for these systems to have regulated fatigue assessment processes to standardize the market. As well as implementing mandatory use in new vehicles that will be manufactured, generating demand from automakers and increasing the safety of the population. One regulatory body that is at the forefront of this is the European Union (UN).[11]

In 2019, driver monitoring systems should be implemented in all vehicles, enabling the assessment of fatigue and the sending of audible or visual signals for the driver to keep an eye on the road. Another important fact was the regulation of the use of data for measurement, whether images from cameras or physical signals. These were to be used only for the system and could not be made available to third parties. [11]

In 2021, European regulation standardized the evaluation criteria to standardize the market. In this criterion, the use of behavioral techniques above 65km/h became mandatory in order to guarantee the robustness of the system. [12]

NCAPs (New Car Assessments Program) are voluntary vehicle assessment programs that were created to make it easier for consumers and their families to compare cars and help them make the safest choice for their needs. One NCAP that has had a lot of prominence in DMS systems is Euro NCAP.[13]

Based on European Union legislation, the EU NCAP score has changed for Safety Assist. Now it includes a special score for DMS or DSM system. This score currently has a lower weight than the SBR (Seat Belt Reminder) topic, which is the assessment for driver and passenger seat belt use. [14]

However, with the change in European regulation in 2021, Euro NCAP will increase the weight of the DSM evaluation in the Safety Assist (SA) item and has already written the documentation for the evaluative test of this system that will come into force in 2023. [14]

These changes both in legislation and in market assessment will make this technology penetrate more into the European market and other legislative bodies around the world are starting to create laws that encourage implementation, as in the US with the NTHSA.[15]

2. DRIVER MONITORING SYSTEM: BRAZILIAN SCENARIO

With a similar function to the European regulatory body in Brazil, there is the National Traffic Council (CONTRAM). This is the highest normative and consultative body of the National Transit System and prepares the national policy guidelines and coordinates all the bodies of the national system. [16]

Currently, there is no mention of attention and fatigue monitoring systems in force in CONTRAM and the technology has little spread in the national market. It is found in the category of high-cost vehicles and not very accessible to the consumer. [16]

In addition, the Latin NCAP, which is a voluntary vehicle evaluation program in Latin America, also does not have any evaluation criteria for the performance of fatigue systems, nor do they score vehicles that have this item. [17]

Even without legislation on this topic, vehicle assemblers are already starting to insert this technology into the domestic market, even because these vehicles are brought from foreign markets, examples of assemblers are: Stellantis, Volkswagen (VW), Renault-Nissan and Toyota.

Examples of cars on the domestic market that have a fatigue detector are the Jeep Commander, Jeep Compass, VW T-Cross and VW Nivus, which have the standard system. However, these cars are of a high standard. And there is no legislation that obliges popular cars to have this system.

3. CONCLUSIONS

This article contains a review on DMS driver monitoring technology, including state of the art; concepts and definitions; norms and regulations in the world scenario and the current Brazilian scenario. Therefore, with the advent of ADAS technologies, and the improvement in fatigue detection systems using image processing and vehicle data. The development and the need to reduce accidents caused by human factors, this technology has grown more and more and tends to be more important over the years. Therefore, estimating the level of fatigue and attention in drivers is essential to have safer traffic.

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