Innovative approach to integrative estimation of driver’s aggressiveness and comfort

To cite this article: M P Malinovsky et al 2020 IOP Conf. Ser.: Mater. Sci. Eng. 832 012051

View the article online for updates and enhancements.
Innovative approach to integrative estimation of driver’s aggressiveness and comfort

M P Malinovsky, E S Smolko and I R Nasibulov

Moscow Automobile and Road Construction State Technical University (MADI), 64, Leningradsky ave., Moscow, 125319, Russia

E-mail: ntbmadi@gmail.com

Abstract. Modern on-board intelligent systems of vehicles perform many tasks aimed at improving the safety and comfort of the driver and passengers, as well as the safety of the cargo carried. One such task is to prevent traffic accidents due to driver’s inattention, drowsiness, or loss of consciousness. In order to fulfill this task various driver attention, monitoring systems are applied. Authors of the article note that the statistics does not count how many accidents and emergency situations occur due to aggressive or dangerous driving. The authors have invented a new on-board device called Comprehensive Integrator of Driver’s Aggressiveness and Comfort (CIDAC), intended to train the driver to avoid the aggressive driving style by the method of scientific observation. CIDAC evaluates the driver’s behavior based on indirect indicators, such as longitudinal, lateral, and vertical acceleration. Construction of the CIDAC device includes an Arduino controller and a three-axis accelerometer. CIDAC warns the driver in cases of aggressive driving by flashing the signal lamps when acceleration exceeds the threshold meaning. Thus, CIDAC increases the safety of cargo and passenger transportation by providing a training effect for the driver.

1. Introduction

The statistics claims that up to 25 % of the total amount of road accidents in the Russian Federation occur because of carelessness, drowsiness, or loss of consciousness of the driver due to fatigue, stress, neglect of his own health, as well as mistakes due to reassessment of his driving skills. In order to solve the aforementioned problem, various driver attention monitoring systems (DAMS) and similar devices are becoming more widespread.

We can distinguish the following types of on-board devices designed to monitor the condition of the driver:

1. Direct DAMS that directly records the physiological parameters of the driver’s condition using biometric sensors (pulse, pupil condition, head position, sweating, skin conduction, respiratory rate).
2. Indirect DAMS that determines the condition of the driver by indirect signs (leaving the lane without turning on the turn signal, inadequate oscillating taxiing, prolonged lack of impact on the controls, ignoring traffic lights, analyzing the time of day and duration of the trip).
3. Vigilance control that periodically gives a light and sound signal. If the driver does not press the button, it takes measures to stop. It is widely used on railway locomotives.
4. Tachograph intended for registration of speed, fuel consumption and work schedule of the driver on a paper or electronic medium.
5. Remote DAMS that transmits data about the driver’s condition to the dispatch center by signals from the above devices, as well as video cameras installed in the cabin.

The task of DAMS is to prevent and fix such driver states as inattention, drowsiness, stress, loss of consciousness. For each of those, different monitoring tools are effective. For example, indirect monitoring can be used to record an aggressive state, distract attention and drowsiness, while lateral acceleration of the vehicle can be used as a parameter for analyzing involuntary deviations from an ideal trajectory.

The simplest direct monitoring parameter that allows you to successfully identify all of the listed driver conditions is the pulse. For example, with a pulse of less than 70 beats per minute the driver is in a state of monotony, a range of 70 to 85 beats per minute corresponds to functional comfort; values above 85 beats per minute correspond to stress. Electroencephalogram and electrocardiogram are highly informative characteristics of the mental and physical activity of a person, but their use is limited by the complexity of mounting equipment on the driver. The skin-galvanic reaction allows identifying stressful situations and fatigue, however, this parameter is dependent on the personal characteristics of each driver, therefore it often filters out significant information, which leads to false alarms. Oculography quite effectively reveals drowsiness and distraction, however, its information content drops sharply at high levels of mental stress. In addition, there were cases when the driver fell asleep with his eyes open. It is also possible to use a head position sensor.

The first studies of mental tension using portable devices were conducted in the USSR in 1971 and were based on the registration the skin-galvanic reaction of the driver and oculography. The first indirect DAMS was patented by "Nissan" in 1977 [1]. However, in connection with the introduction of anti-lock braking system (ABS) in 1978 and other active safety systems, it did not receive due attention. The development of DAMS and active safety systems has long been parallel and independent of each other. Only 30 years later, Volvo introduced the first serial DAMS, which was called Driver Alert Control (DAC), and consisted of a video camera that monitored the trajectory of the vehicle and its position on the road, as well as a steering wheel speed sensor. In the second decade of the 21st century, it was understood that the synthesis of control systems gives a synergistic effect to improve road safety [2]. An integrated system, such as a preventive motion control system (PMCS), can prevent more accidents than each system individually. DAMS has become part of this complex.

2. Problems of modern DAMS

The main reason for the lack of effectiveness of active safety systems is a fragmented approach to the review of processes in the car. A modern DAMS must interact with other active safety systems (or other PMCS modules). If the driver’s aggressive state is detected, it is advisable to limit the fuel supply by acting on the automated engine control system, and if the driver faints, to stop the vehicle within the lane with help of the lane-keeping assist and collision avoidance system [3–5].

Initially, DAMS included the following main functions:
1. Prevention of falling asleep with the help of sound, visual, and tactile signals.
2. Alarm signal when driver's distraction.
3. Warning by signals from temperature sensors inside the cabin when overheating above + 27 °C, which reduces the driver’s ability to quickly and accurately assess the traffic situation, increases reaction time, leads to dull attention, and increases the number of errors.
4. Checking for alcohol intoxication with the possibility of displaying recommendations on the display and forced engine blocking.

However, no one even tries to count how many accidents and, moreover, emergency situations occur due to aggressive or dangerous driving [6–8]. Aggressive driving style is manifested as follows:
1. Sharp acceleration and braking, abrupt releasing the clutch.
2. The excess of the estimated speed in corners with a given curvature or when performing the lane-changing maneuver.
3. Speeding when moving over bumps.
Dangerous driving is characterized by the intentional creation of critical or emergency situations, including failure to provide priority.

A technical solution to reduce the number of the aforementioned cases is especially actual for the following reasons:

1. Aggressive driving by public transport drivers (buses, taxis) often leads to micro-injuries of the passengers' musculoskeletal system that no one records.
2. The safety of transported goods, especially fragile and liquid.
3. Comfort of passengers carried by private transport.
4. Increased durability of the vehicle chassis.

Therefore, modern DAMS should be supplemented with the following functions:

1. Assessment of driving style in terms of comfort and safety.
2. Checking the adequacy and mental state of the driver, assessing his danger.
3. Checking the driver’s readiness to take control with the possibility of performing a minimum risk maneuver or automatic stop when driving on a vehicle with a high level of automation [9, 10].
4. Remote monitoring of the physiological and mental state of the driver through the intelligent transport system (ITS) [11].

3. CIDAC

One of the elements of modern DAMS should be a Comprehensive Integrator of Driver's Aggressiveness and Comfort (CIDAC), which forms the so-called “driver behavior profile” and implements the aforementioned functions using the following evaluation parameters:

1. Total acceleration and jerk (the first time derivative of acceleration) in three axes.
2. The number of cases of violation of the high-speed mode, driving to a prohibitory traffic signal, determined by either a system for recognizing traffic signs and traffic signals [12], or ITS.
3. The number of responses of various active safety systems.

CIDAC belongs to the group of indirect DAMS, that is, it evaluates the driver’s behavior based on indirect indicators [13, 14].

The purpose of CIDAC is to increase the safety of freight and passenger transportation and the durability of the chassis of vehicles by reducing longitudinal, lateral and vertical overloads. In accordance with this, CIDAC solves three problems:

1. The limitation of longitudinal acceleration during acceleration and braking.
2. Improving the stability of curvilinear motion by limiting lateral acceleration, predicting the trailer jerk by angular speed of the steering wheel.
3. Prediction of the behavior of the trailer suspension along the first axle of the tractor.

CIDAC has a double character of action:

1. Informative and training.
2. Preventive due to interaction with other modules of PMCS.

For professional drivers of buses and commercial vehicles, it is possible to provide a penalization system for aggressive driving style on the part of the trucking company according to the integral indicators of acceleration and jerk.

4. Application of jerk for determination of aggressive driving style

As experimental studies have shown, the loss of passenger stability in the subway car is most likely at the time of acceleration change, that is, under the action of jerk [15]. Jerk is widely used in astronautics and in rail transport to assess human overloads. When designing highways, jerk is used to calculate transition curves [16]. Vertical jerk has long been used to assess the vehicle ride [17]. The use of longitudinal jerk to assess the smoothness of gear shifting is justified [18, 19]. Similarly, we can evaluate the impact of the lateral jerk during curvilinear movement. At the same time, it is advisable to use instantaneous jerk in the algorithms of active safety systems, and the accumulated (total) jerk can serve as an integral criterion for assessing the overloads acting on the driver, passengers and cargo. Studies show that the most difficult case for passengers is overload on all three axes at the same time.
In case of alternating overload when calculating jerk, it is necessary to add two acceleration amplitudes modulo (fig. 1), for example, 0.5g–(−0.5)g=1g.

![Figure 1. The dependence of jerk on the nature of acceleration](image)

Two typical situations can be distinguished, covering most of the possible cases of curvilinear motion:

1) "U-turn" maneuver.
2) "Lane changing" maneuver.

The task is to tell the driver which trajectory is the best for passengers and cargo in terms of reducing lateral overloads. To do this, it is advisable to use the following motion parameters: the final speed of the maneuver, the total time of the maneuver, the integral acceleration along three axes, the average acceleration and the accumulated jerk.

There are three ways to perform the “U-turn” maneuver: with early, neutral and late apex, as well as two special cases – with shutter speed and with an additional turn of the steering wheel. The U-turn maneuver has two phases:

1) entrance to the turn (from the start of the steering wheel to the trajectory apex);
2) exit from the turn (from the trajectory apex to the return of the steering wheel to the neutral position).

At a constant speed, the most comfortable by jerk is neutral apex. Offset apex in any direction increases jerk. Acceleration does not depend on apex.

With equally slowing motion, the late apex is the most comfortable for acceleration, which allows the driver to find a balance between reducing lateral acceleration at the entrance due to the expansion of the trajectory, and at the exit due to the reduced speed. However, the smallest jerk is observed at neutral apex, since the acceleration between the phases does not change. The least comfortable, both by acceleration and jerk, is an early apex.

In the case of braking at the entrance and acceleration at the exit, neither acceleration nor jerk depend on the method of passing the turn, however, the final speed of the maneuver comes to the fore. The maneuver time does not depend on the apex, but depends only on the distance traveled and the average speed.

The lane changing maneuver has a different number of phases on the steering wheel and on the path. The former phases are:

1) entrance (steering wheel to the left);
2) counter-movement (steering wheel to the right);
3) exit (steering wheel left to the neutral position).

The latter phases are:

1) entrance (before the inflection);
2) exit (after bending).

When performing "lane changing", the trajectory has an inflection, where the increment of the lateral coordinate changes sign, therefore, there are two apexes.

As experimental studies have shown, an early kink when performing the lane changing maneuver is preferable. The fact is that when the steering wheel is counter-running, a “suspension bounce” occurs, the jerk from which folds with the side jerk, increasing the likelihood of buckling – skidding or tipping over. To date, there is no mathematical model that adequately describes this phenomenon.

"Lane changing", as a rule, is performed either at a constant speed, or when engine braking, or coasting. When “lane changing”, the values of the radii affect the length of the maneuver.

Vertical jerk is very indicative of assessing the aggressiveness of the driver when moving over road irregularities, for example, artificial. However, with a decrease in vertical overloads, it is necessary not only to limit the speed, but also to take into account its value at which resonant vibrations of the sprung masses occur [20, 21]. Longitudinal jerk can help train the driver to gently engage the clutch.

On-board diagnostic is widespread nowadays [22–24]. The selected parameters can also be used to diagnose shock absorbers and clutch in order to detect their wear or malfunction (fig. 2). Based on this data, the PMCS or the autonomous control system can make recommendations for replacement of those.

![Figure 2. Application of jerk for testing dampers and clutch](image)

5. Construction of CIDAC

In order to justify the link between the evaluation parameters and the driving style, the authors have invented a new on-board device. The device construction includes (fig. 3): housing 1; display 2; signal lamps 3, 4, 5; set-up buttons 6, 7, 8, 9; power lamp 10; port for MicroSD-card 11; power connector 12; toggle switch 13. Inside the housing 1 we placed the Arduino controller and a three-axis accelerometer (fig. 4).

The device is portable and supposed to be mounted on the dash-board inside the cabin in the driver’s field of view in accordance with the image of the axes on the housing 1. For the device to work correctly, the X axis must coincide with the longitudinal axis of the vehicle, the Y axis with the transverse axis of that, and the Z axis should be vertical.

The signal lamp 10 informs that the device is turned on. The device is connected to the power source through a cable, which is inserted into connector 12. After turning on the toggle switch 13, a self-test is performed, including the following items:

1. Checking the presence of a MicroSD-card in the slot 11.
2. The signal lamps 3, 4, 5 briefly (for 1 second) turn on to check their serviceability.
3. The horizon is determined to exclude errors in the installation of the device (manually with showing the current installation angles on the display or automatically, taking into account the deviation of the initial coordinates).

![Figure 3. CIDAC, general external view](image)

**Figure 3.** CIDAC, general external view: 1 – housing; 2 – display; 3, 4, 5 – signal lamps of an overload on axes X, Y, Z respectively; 6 – button SETUP; 7 – button UP; 8 – button DOWN; 9 – button MODE; 10 – power lamp; 11 – port for MicroSD-card; 12 – power connector; 13 – toggle switch

![Figure 4. CIDAC, internal structural scheme](image)

**Figure 4.** CIDAC, internal structural scheme

During the diagnosis, the power lamp 10 is in a blinking mode, then the device enters the recording mode, and the lamp 10 is lit continuously. During movement, the signal lamps 3, 4, 5 light up when the specified threshold acceleration values are exceeded along the X, Y, Z axes, respectively. Thus, the driver is taught to drive gently applying the method of scientific observation [25, 26].
The device is configured as follows. Button 9 is used to select the display mode between MAX and AVE. In the MAX mode the maximum acceleration values for the last 1...2 s are displayed, in the AVE mode a running average over the last 1...4 s are shown.

The transition to the setting of threshold values at which the signal lamps light up, and the selection of the adjustable axis is carried out by pressing the button 6. The display shows the current threshold values of accelerations on each axis, while the editable value flashes. The setting is made with buttons 7 and 8 in increments of 0.05 g. After completing the settings, the menu closes automatically when inactive for 5 s or by pressing the 9 button.

When the toggle switch 13 is turned off, the readings are reset to zero, and the data recorded during the last session is saved in a separate file on the MicroSD-card inserted in the slot 11.

6. Conclusion
The following problems need to be solved while working with CIDAC:

1. Initial determination of the horizon.
2. Removing sensor noise (normalization).
3. Selecting the optimal differentiation step using the moving average function (balance between accuracy and false response). The differentiation step significantly affects values of jerk.
4. The choice of threshold values and critical values. At threshold, the signal lamps should turn on; at critical, PMCS should be automatically triggered.

CIDAC setup is quite a subtle task, since the range of acceleration fluctuations along all axes during normal vehicle movement lies within 0.1...0.3 g, and during normal landing of a plane the vertical overloads do not exceed 0.5...0.6 g. Meanwhile, when jumping, a person develops acceleration in excess of 1 g.

The use of CIDAC will increase not only the safety of cargo and passenger transportation, but also passenger comfort and cargo integrity, while providing a training effect for the driver, increasing his skill level, and on-board diagnostics of suspension and transmission elements.

References
[1] Yanagishima T 1977 Patent US 4017843
[2] Malinovsky M, Vorobyev A and Zabudsky A 2018 Interaction of subjects having different control paradigms in a common transport space Transportat. Res. Procedia 36 472–9
[3] Ivanov A M, Shadrin S S, Kristalny S R and Popov N V 2019 Possible scenarios of autonomous vehicles' testing in Russia IOP Conf. Ser. Mater. Sci. and Engineer. 534(1) 012001 DOI 10.1088/1757-899X/534/1/012001
[4] Ivanov A M, Kristalny S R, Popov N V, Toporkov M A and Isakova M I 2018 New testing methods of automatic emergency braking systems and the experience of their application IOP Conf. Ser. Mater. Sci. and Engineer. 386(1) 012019 DOI 10.1088/1757-899X/386/1/012019
[5] Dygalo V, Salykin E and Kotov V 2019 Methods of development and adaptation of engineering microprocessor engine control unit in real time to ensure the possibility of research work in various modes Int. Conf. on Industr. Engineer., Applicat. and Manufact. 8743053 DOI 10.1109/ICIEAM.2019.8743053
[6] Pegin P and Pegin O 2018 A method to assess accident psychological severity in drivers Transportat. Res. Procedia 36 562–6
[7] Azemsha S, Kapski D and Pegin P 2018 A method for assessing the automobileization impact on population morbidity Transportat. Res. Procedia 36 18–24
[8] Chubukov A, Kapitanov V, Monina O, Silyanov V and Brannolte U 2017 Simulation of regional mortality rate in road accidents Transportat. Res. Procedia 20 112–24
[9] Malinovsky M, Vorobyev A and Pakhomov S 2018 Social aspect of anthropogenic adaptation to autonomous vehicles Transportat. Res. Procedia 36 480–6
[10] Sidorov K M, Yutt V E, Grishchenko A G and Golubchik T V 2018 Practical implementation of
the concept of converted electric vehicle with advanced traction and dynamic performance and environmental safety indicators *IOP Conf. Ser. Mater. Sci. and Engineer.* 315(1) 012026 DOI 10.1088/1757-899X/315/1/012026

[11] Zhankaziev S 2017 Current trends of road-traffic infrastructure development *Transportat. Res. Procedia* 20 731–739 DOI 10.1016/j.trpro.2017.01.118

[12] Dygalo V, Lyashenko M and Potapov P 2019 Ways for improving efficiency of computer vision for autonomous vehicles and driver assistance systems Int. Conf. *Industrial Engineering, Applications and Manufacturing* 8743060 DOI 10.1109/ICIEAM.2019.8743060

[13] Mayboroda O V and Kalenov G K 2010 Increase of active safety of road traffic *Sci. J. of Transportat.* 2 31–7

[14] Majboroda O V 2012 Patent RU 113218 U1

[15] Malinovsky M 2011 Application of jerk in active safety systems *Sci. J. of transportat.* 3 62–6, 48–9

[16] Kostsov A 2018 Results of studies on traffic volume at left-turn exits of grade-separated intersections *Transportat. Res. Procedia* 36 347–51

[17] Dubrovskiy A, Aliukov S, Keller A, Dubrovskiy S and Alyukov A 2016 Adaptive suspension of vehicles with wide range of control *SAE Techn. Papers* DOI 10.4271/2016-01-8032

[18] Aliukov S, Keller A and Alyukov A 2015 Dynamics of overrunning clutches of relay type *SAE Techn. Papers* DOI 10.4271/2015-01-1130

[19] Aliukov S, Keller A and Alyukov A 2017 Vibrations and properties of inertia continuously variable transmissions *Lecture Notes in Engineer. and Computer Sci.* 2 702–6

[20] Keller A V, Gorelov V A and Anchukov V V 2015 Modeling truck driveline dynamic loads at differential locking unit engagement *Procedia Engineer.* 129 280–7 DOI 10.1016/j.proeng.2015.12.063

[21] Keller A, Aliukov S and Anchukov V V 2017 Mathematical model of the truck for investigation of stability and control of movement *Lecture Notes in Engineer. and Computer Sci.* 2 711–6

[22] Revin A, Dygalo V, Boyko G, Lyaschenko M and Dygalo L 2018 Methods of monitoring the technical condition of the braking system of an autonomous vehicle during operation *IOP Conf. Ser. Mater. Sci. and Engineer.* 315(1) 012020 DOI 10.1088/1757-899X/315/1/012020

[23] Dygalo V and Zhukov I 2018 The thermal loading estimation of the friction pairs of a vehicle automated brake system *IOP Conf. Ser. Mater. Sci. and Engineer.* 386(1) 012012 DOI 10.1088/1757-899X/386/1/012012

[24] Solntsev A A, Feofanov S A, Guliy V V 2019 The research of the operation of the lithium-iron-phosphate battery of an electric vehicle in high and low temperatures *Systems of Signals Generating and Processing in the Field of on Board Communications* article № 8706728 DOI 10.1109/SOSG.2019.8706728

[25] Malinovsky M, Solntsev A, Juravleva A and Makovski S 2017 Estimation method of nonresident vehicle fleet inflow influencing road traffic safety in megalopolis *Transportat. Res. Procedia* 20 751–5 DOI 10.1016/j.trpro.2017.01.121

[26] Kotov A and Pospelov P 2017 Engineering tools and methods of estimation of traffic capacity using mobile video monitoring *Transportat. Res. Procedia* 20 347–54 DOI 10.1016/j.trpro.2017.01.044