Archives of
Transport System
Telematics

Volume 7

Issue 4

November 2014

In-vehicle driver behavior monitoring

J. MŁYŃCZAK[a], I. CELIŃSKI[a]
[a] SILESIAN UNIVERSITY OF TECHNOLOGY, ul. Krasińskiego 8, 40-019 Katowice, Poland
EMAIL: jakub.mlynczak@polsl.pl

ABSTRACT
Monitoring of the status and behavior of drivers is important for ensuring traffic safety. The process using SHP (automatic train braking system) and CA (dead man's control system) has been used in railway transport since 1960s. Equipment of similar functionalities is at the stage of research and single implementation projects in road traffic. It seems that monitoring of drivers in both rail and road traffic can be implemented using equipment of the same or similar construction, operating within visible and infrared bands, and in the acoustic spectrum. This article includes a presentation of two universal devices developed by the authors. The planned monitoring systems to be used in road and rail traffic can be similar in terms of equipment used. As regards software, collecting information about behavior and status of drivers (based on functionalities of equipment), the two systems differ.

KEYWORDS: footage processing, human interface and behavior, image recognition

1. Introduction

Monitoring of a physical status and behavior of drivers has attracted increasingly large interest among researchers, not only in the context of traffic safety. Characteristics describing the driver also influence the use of capacity of road transport infrastructure [27],[28]. They can be used to design constructions and distribution of point and line infrastructure facilities. This applies both to rail and road traffic. One could expect that with growing speed in rail transport and gradually exhausting capacity of lines of various categories, research on the influence of driver's behavior on using infrastructure parameters will become increasingly important.

Complex driver's behavior models [1], [9], [27], [28], [29] are implemented in micro-simulation road traffic programs. The models are based on measuring basic features of vehicle movement (speed, acceleration, etc.) and observing parameters of traffic flows, chiefly from the point of view of an external observer. Research on characteristics of vehicles uses functionalities of movement detectors and sensors fitted within a road side. In such a measuring system, the driver is examined indirectly. It is an important simplification of the problem due to technical limitations. In recent years, researchers have focused increasingly often on the interior of a vehicle and driver [4],[7],[8],[11],[13-22],[25],[36]. This approach is supported by the development of new technologies, in particular devices for monitoring visible spectrum and infrared, and the development of methods of image processing (including in motion) [30],[31].

The main area of using our knowledge about driver's behavior is the improvement of traffic conditions and its safety [2],[4],[10],[14],[21]. Vehicle traffic directly depends on a driver's physical and mental status and his behavior. For this reason, the monitoring of a driver himself is the most promising as regards enhancing traffic safety. Driver's behavior and status are primary causes of the majority of traffic threats and incidents [4],[8],[11].

It is worth mentioning that from the point of view of the issue concerned, driver's behavior is not determined as independent variables. Driver's behavior in road traffic (manner of driving) is influenced by fuel price, capacity, weather conditions, communication available over CB network (citizen band) radio, etc. Thus, it is a complex system with many interaction channels, which should be examined in real time using sophisticated methods of data abstraction, processing and analysis. The complexity of the issue is illustrated by research on the impact of fuel prices on driver's attitudes and behavior in road traffic [3],[5],[32]. Track driver's behavior in rail traffic (specific rules, manner of driving) is also influenced by many factors. Much more complicated is the vehicle service.

1.1 Human behavior and health condition

Undoubtedly, physical and mental health of a driver have the most significant influence on traffic safety. The weakest element of even the best designed road and means of transport is a man. It is reflected in formal and legal requirements which need to be met before someone acquires the right to drive a vehicle [33],[34],[35],[40]. An important limitation in this respect is the lack of possibility of having fully and reliable verification of driver's health while driving. Such research can be carried out by authorized people only in organizations having concessions and in the case of examining professional drivers it involves the use of specialist equipment. The research has been conducted in a specific interval (according to authors it was too long considering rapid changes in life of contemporary societies).

It seems that monitoring of the cabin interior has overcome these barriers to a certain limited extent. While examining drivers in the visible spectrum or using mechanical measurements, simplified procedures can be used for controlling of the driver's status. Although the procedures cannot be performed with precision close to medical examination, they can be performed in real time. It is the main advantage of driver's monitoring during their duties [19],[37],[38],[39].

Acquired information about mental and physical health of a driver has complex etiology and is significantly variable in time and space. Considering this rough examination of driver's characteristics almost real time, it may turn out that to be an appropriate approach to the problem discussed in the article.

Driver's behavior can be divided into several basic groups known as attitude components. They include behavioral and emotional components and knowledge. While in traffic, all components play an important role, but only one of them has been subject to examination during travelling (so far). The component comprises a set of features determining verbal and non-verbal behavior of a driver. Colloquially speaking, the examination focuses on those processes which can be seen or heard inside the driver's cabin. This component enables examining driver's extremities, his head, gestures, and mimics. It is also possible to examine driver's eye movement around the traffic scene and inside the vehicle, and sounds he produces. Examination of drivers can be based on monitoring of the vehicle interior (CCTV cameras), eye-tracking systems, elements of active safety systems and almost all kinds of sensors. The article presents several solutions of this sort based on various technologies for examining driver's behavior.

1.2 Human interface

An important aspect of research on driver's behavior is to determine their interaction with onboard equipment in the cabin. Similar issues are analyzed in research and development projects on the HID market (Human Interface Device) [6],[12],[23]. Driver's behavior research should be correlated with the status of onboard equipment operated by the drive, equipment which changes driver's behavior in specific situations. Additionally, studying correlation should also cover operation of the onboard equipment by the driver (individual personal differences in population).

From this point of view, apart from above listed examination of driver's health status and behavior, developing modern and ergonomic dashboards should be a subject of particular interest. In-vehicle driver behavior monitoring enables better adjustment and arrangement of control devises within a dashboard and displayed information. This applies not only to the form of information, but also display time and synchronization with other information [41],[42]. Recently, virtualization of dashboards has become increasingly important. This is supported by a major advancement in manufacturing liquid crystal displays, and recently displays based on graphene. Personalizing control equipment in a vehicle should in principle facilitate operation and thus contribute to improved conditions of driving and increased traffic safety.

2. Purpose of the research

The purpose of the research is to develop systems that provide parametrization and analysis of driver's behavior and status in near real time. In principle, these systems should use various monitoring techniques with the possibility of fitting them in every vehicle. A project has been implemented involving rail-bus SA132 series operated by Koleje Wielkopolskie sp. z o.o., a regional railway operator. A decision was made to use the following driver monitoring systems (rail vehicle driver):

1. CCTV cameras (MORKM, module for observing movements of extremities)
2. eye-tracking glasses (MET, eye-tracking module),
3. ultrasound sensors (MPPM, driver's position module).

The first set was developed in two versions to operate with visible spectrum and independently in infrared. Despite technical differences, all those systems can be used complementarily to each other. For example, a functional limitation of MPPM is distance characteristics of ultrasound sensors (max. range 150÷180 cm). Additionally, comparative tests are planned with the use of equipment by Kinect Microsoft version 1.0 (2.0, when manufacturer makes new SDK libraries available, software development kit)

Initial tests using those measurement systems focus on behavior and status of passenger train drivers. The tests can be easily implemented in any cabin of a mechanical vehicle that enables fitting those measurement systems inside. Similarly, the methods of data acquisition in those systems is identical (regardless means of transport). Major differences between means of transport in different modes reveal themselves at the stage of processing and analyzing data acquired. This, however, extends beyond the area of the article. Below presented are modules developed by the author that are used in research: MORKM, MPPM and MZŚ (environment variables module).

2.1 Hardware

Research equipment prepared to examine drivers consists of four different measurement systems, apart from MORKM, MET and MPPM, an additional system of reading environment variables in the MZŚ cabin (MET has not been described in this article) was used for research. There is one more system used in research (not discussed in article) which is designed for providing inventory of transport infrastructure. The system uses satellite positioning of the vehicle using 4 GPS (global positioning system) devices. The research is synchronized with two real time clocks made to DCF77 standards (integrated with MPPM and MZŚ).

The objective of installing a module for measuring environment variables in the cabin is to correlate characteristics from the module with driver's behavior and status. The following parameters influencing the driver are examined: acceleration, temperature, illumination, noise, etc. it is also possible to monitor other parameters such as pressure in the cabin, driver's pulse, etc.

The MZŚ module is based on a microcontroller Atmega32U4 AVR (operating at f=16 MHz). During driving, the module measures the following in parameters the driver's cabin: temperature, illumination, noise, acceleration of each axle. The research uses simplified measurement of environment variables in one or two points in the cabin – possibly close to the driver's seat. A chart showing the measurement of variables in the driver's cabin and components of the module are presented in Fig. 1.

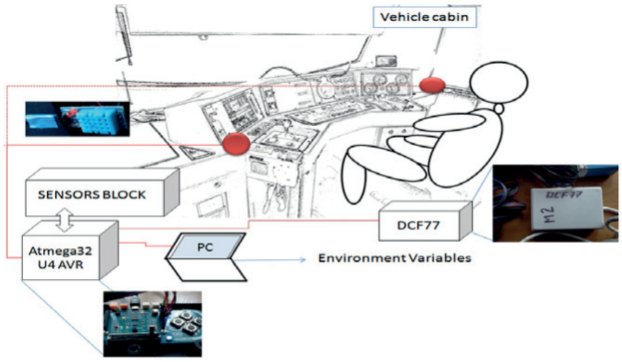

Fig. 1. Measurement system of environment variables module (MZŚ) [own study]

The module enables measuring environment parameters using the following components: acceleration (MMA 7361 LCR 2;1.5g;6g; illumination (FLD00030/VT90N2); noise (microphone PMOF-974P-Q0, and temperature (sensor TMP 36GT9Z; RS 427-351). Basic parameters of environment variables sensors used in the project are presented below: FLD00030/VT90N2, about 300-700 nm (illumination); 12K-36K, MMA7361; ±1.5g, ±6g; 800 mV/g @ 1.5g (acceleration), PMOF-974P-Q; 20-16000 Hz; 120dB S.P.L; S.N ratio 60 dB (noise frequency), TMP 36GT9Z; –40°C do +125°C; ±2°C (temperature).

2.2 Monitoring in visual and infrared band (MORKM)

The research uses a system of 5 to 9 CCTV cameras operating simultaneously. The driver's picture is recorded in several video files. Each camera registers a different space section in the driver's cabin. One camera registers an area of driver's head, two cameras are mirrored and register movements of upper extremities and upper body, and another one registers movement of legs. The module includes another camera fitted to ceiling lining in the driver's cabin to register manipulations performed by the driver with his hands on the dashboard.

Fig. 2. MORKM module (left, in laboratory), test vehicle (right) [own photo]

Fig. 2 (left) shows the MORKM module operating in the laboratory. In the right side of the figure, we have the driver's cabin in track bus SA132 series.

2.3 Monitoring in ultrasonic band (MPPM)

MPPM module is an independent measurement system. The module comprises 7 ultrasonic sequential sensors based on the ATMEGA microcontroller. The module acquires data from 7 position sensors at the rate of 4 readouts per second from an individual sensor. Reading of values recorded in particular sensors takes less than the reaction time of a track vehicle driver (0.39-0.77 second) [43],[44]. MPPM module supports MORKM and its calibration at the stage of data analysis. The system based on ultrasonic sensors might be used for interpreting data from both systems: MET and MORKM.

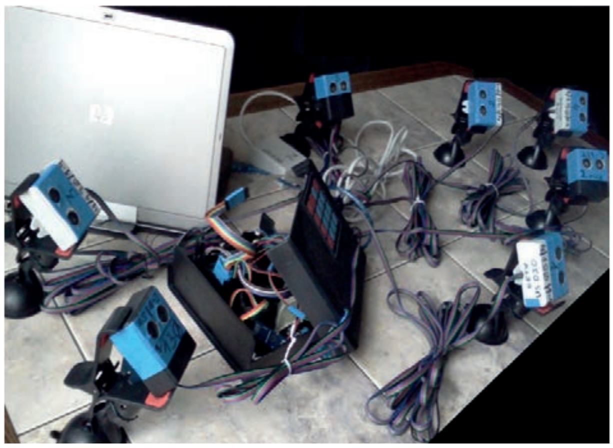

Fig. 3. Ultrasonic sensors module (MPPM), laboratory [own photo]

Fig. 3 presents the MPPM module prepared to work. The project uses ultrasonic sensors of different class (from HC-SR04 to SDM-IO). Below presented are parameters of sensors used: <15 degrees (detection angle), precision of projection: 0.2-0.3 cm ±1%, range of scanning distance 0-150-200-400-500-700 cm, depending on sensor's type and class (in practice characteristics of popular ultrasonic sensors enable measuring at distances from 20 cm to 150 cm). The range is sufficient for measuring activities performed by a track vehicle driver.

3. Software

Modules presented provide information about movements performed by the vehicle driver in the cabin. Each second, the MPPM module generates from 3 to 4 lines of data while recording distances between the driver and each of n sensors (precision about 2 cm). In practice, by multiplying the number of controllers, it is possible to mount more sensors in the cabin. It is possible to control movement in 15 measurement zones with frequency of 4 Hz (frequency can be locally extended to 30 Hz) for two MPPM systems. Processing data from the MPPM module is based on analyzing matrix A of (n x m), where m -number of sensors, and n - multiple observation time. An appropriate design of the system enables measuring distances in at least two planes, vertical and horizontal, which enables building a module of pseudo 3D functionality. In such a case, analysis applies to matrix A' of (n x m x l), where l is a vertical coordinate of a sensor or set of sensors controlled by one microcontroller.

In the MORKM system, a film registered from each of 5÷9 cameras provides dynamic content of matrix B which registers in elements bij movement in a plane perpendicular to the focal length. In practice, the dimension of matrix B, and x j is determined at the stage of processing the video material produced in the vehicle cabin. At the stage of processing data, a movement detection network is declared (similarly to movement detection zones in monitoring systems). The distribution of cameras in the cabin enables building pseudo 3D matrixes B' which undergo further analysis. One of the cameras controls the driver's face zone and it also provides information as regards the position of eyes, mouth and characteristic elements situated within the area of the face. This provides for further processing and analysis of mimics and pantomime registered within the face zone. Further research will concentrate on checking the possibility of tracking driver's eye sight using the same method (support for MET module). An example of a software for analyzing data using the MORKM module is presented in Fig. 4.

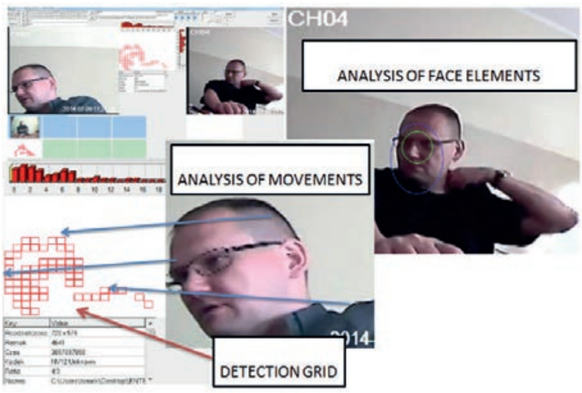

Fig. 4. Software for analyzing data obtained using MORKM module [own study]

Fig. 4 presents decoding of frames into movement parameters registered in particular cells of the movement detection matrix B. The right side of Fig. 4 presents method of determining characteristic points within the face zone of the object monitored.

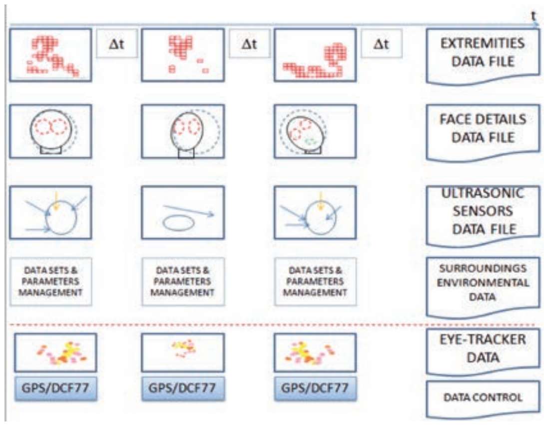

Fig. 5. Diagram analysis [own study]

Fig. 5 shows a schematic representation of few decoding process: frames, face details, driver location, GPS and time data into different and complex patterns data. Patterns that are registered in particular frames of the footage, from different cameras, places and time in driver's cabin. The figure shows six processes is done using the acquisition of information (two of them, MET and GPS location, were not discussed in this article). Patterns are stored in numerical form allowing their further treatment.

3. Conclusion

Based on analyzing test data we may conclude that a rough assessment of the driver's status and behavior is possible real time. The analysis of the picture and data from ultrasonic sensors provides valid information about driver's movements taking place in the cabin. The MORKM module provides information about momentary position of driver's face parts. Such information is correlated with the readout of data regarding physical location of transport infrastructure elements (separate module, not presented in this article, based on GPS signal acquisition). While analyzing and comparing data we may determine relations between driver's behavior, movement parameters at a given stretch, and activities performed by the driver in response to information received. The system is in its development phase and still requires further research as regards retrieving information on recognition of patterns. Research findings will be presented in consecutive publications.

Bibliography

[1] LEUTZBACH, W.:Introduction to the Theory of Traffic Flow. Springer-Verlag. Berlin (1988)

[2] BURGESS, M.: Contrasting Rural and Urban Fatal Crashes, NHTSA Technical Report DOT HS (Department of Transportation. NHTSA (2005)

[3] GRABOWSKI, D., MORRISEY, M.: Do Higher Gas. Taxes Save. Econ. Lett 90 (2006)

[4] KWEON, Y.J, KOCKELMAN, K.: Driver Attitudes and Choices: Speed Limits, Seat Belt Use, and Drinking-and-Driving, Jour. of Transportation 45/3 (2006)

[5] LAWSON, R., RAYMER, L.: Testing the Alchian–Allen Theorem: A Study of Consumer Behavior in the Gasoline Market, Economics Bulletin 4/35 (2006)
[6] LASALA, K.P.: Human Interface technology, Journal of the Reliability AC (2000)
[7] MIKOLAJETZ, A., et. al.: Curve navigation, identifying driver behavior with the driver perfor., V Int. Driving Symposium (precedings),
[8] DINGUS, T., et. al.: The 100-Car Naturalistic Driving Study, NHTS Adm (2006)
[9] WIEDEMANN, R.: Simulation des Verkehrsflusses. Univ. Karl, Karlsruhe (1974)
[10] VAN BEURDEN, E., et. al.: Heavy episodic drinking and sensation seeking in adolescents as predictors of harmful driving and celebrating behaviors: implications for prevention. Journal of Adolescent Health (2005)
[11] SHOPE, J.T., RAGHUNATHAN, T.E., PATIL, S.M.: Exam. trajectories of adolescent risk factors as predictors of subsequent high-risk driving behav. J. of Adolesc. Health (2003)
[12] NORMAN, D. A.: The design of future things. Basic Books, New York (2007)
[13] DAVEY, J., et. al.: An application of the Driver Behaviour Questionnaire.. Transport. Research P. F: Traffic Psychology and Behav.10 (2007)
[14] PARKER, D., et. al.: Behavioural character. and involvement in different types of traffic accid. Accident Analysis 27 (1995)
[15] ABERG, L.: Rimmo, P.: Dimens. of aberrant driver behav. Ergonomics 41 (1998)
[16] WOUTERS, P.I, BOS, J.M.: Traffic accident reduction by monitoring driver behavior with In-Car data rec., Accident Analysis and Prevention 32 (2000)
[17] HUTTON K.A: Mod. driver behave. with passing. feedback, Transpor. Res., 257 (2001)
[18] RANNEY T.A. at all: Driver Behavior Driving During Visual-Manual Secondary Task Performance: Occlusion Method Versus Simulated, NHTSA (2013)
[19] REIMER, B., et. al.: The use of heart rate in a driving simulator as an indicator of age-related differences in driver workload, Advances in Transportation Studies (2006)
[20] KAYSI, I. A., ABBANY, A. S.: Modeling aggressive driver behavior at unsignalized intersections, Accident Analysis and Prevention 39 (2007)
[21] BARHAM A.J, P. BLACK, I.: Factors influencing the probability of an accident at a junction. Accident Analysis and Prevention, 34 (2002)
[22] RECARTE, M. A., NUNES, L. M.: Mental workload while driving: Effects on visual search, discrimination, and decision making. Journal of Exp. Psych. Applied 9 (2003)
[23] VERPLANK, B., SAPP, C., MATHEWS, M.: A course on controllers. Proceedings of the 2001 conference on New Interfaces for Musical Expression (NIME'01) (2001)
[24] ENGSTRÖM, J., JOHANSSON, E., ÖSTLUND, J.: Effects of visual and cognitive load in real and simulated motorway driving. Transport. Research (F) (2005)
[25] KUTILA, M. H.,et. al.: Driver cognitive distraction detection: Feature estimation and implementation. Proceedings of the Institution of Mechanical Eng. Journal of Automobile Engineering 221 (2007)
[26] TAKEDA, et. al.: In-Vehicle Corpus and Signal Processing for Driver Behavior, DSPinCars, Springer (2007)
[27] CHODUR, J.: Funkcjonowanie skrzyżowań drogowych w warunkach zmienności ruchu, Monografia: Inżynieria Lądowa, Politechnika Krakowska (2007)
[28] Highway Capacity Manual. Transportation Research Board, Washington, D.C. 2010.
[29] HELBING, D., TREIBER, M.: Derivation of a fundamental diagram for urban traffic flow, European Physical Journal B 70 (2003)
[30] BOVIK, A.C.: Handbook of Image and Video Processing, Academic Press (2010)
[31] PARKER, M., DHANANI, S.: Digital Video Processing for Engineers: A Foundation for Embedded Systems Design (2013)
[32] NARVON, D.: The Paradox of Driving Speed: Two Adverse Effects on Highway Accident Rate. Accident Analysis and Prevention 35 (2003)
[33] Rozporządzenie Min. Zdrowia z dnia 8 lipca 2014 r. w sprawie badań psychologicznych osób ubiegających się o uprawnienia do kierowania pojazdami, kierowców oraz osób wykonujących pracę na stanowisku kierowcy, Dz. U. 2014 poz. 937 (2014)
[34] Rozporządzenie Ministra Zdrowia z dnia 7 stycznia 2004 r. w sprawie badań lekarskich kierowców i osób ubiegających się o uprawnienia do kierowania pojazdami (2004)
[35] Załącznik nr 2 do rozporządzenia Ministra Infrastruktury i Rozwoju z dnia 10 lutego 2014 r. w sprawie licencji maszynisty (Dz. U. poz. 211) (2014)
[36] YALE, S.H., et. al.: Neurologic Conditions: Assessing Medical Fitness to Drive, Clin. Med. Res. 1(3) (2003).
[37] LIN, C., et. al.: Development of On-Line Diagnostics and Real Time Early Warning System for Vehicles, Sensors for Industry Conf. (2005)
[38] ZHANG, C, et. al.: Portable diagnostic devices for identifying obstructive sleep apnea among commercial motor vehicle drivers: considerations and unanswered questions. Sleep 35 (2012)
[39] TIPPIN, J., SPARKS, J., RIZZO, M.: Visual vigilance in drivers with obstructive sleep apnea. J Psychosom Res. 67 (2009)
[40] FLISEK, A. (red.): Kodeks drogowy C.H. BECK (2014)
[41] http://www.autonews.com/article/20140217/OEM06/302179994/h (accessed: 18.07.2014)
[42] WEINBERG, G., HARSHAM, B., MEDENICA, Z.: Investigating HUDs for the Presentation of Choice Lists in Car Navigation Systems. In Proc. of Driving Asses. 2011 (2011)
[43] KOTERBA J., PALUCH R.: Obciążenie fizyczne i psychiczne maszynistów elektrowozów, http://ergonomia.ioz.pwr.wroc.pl/download/ (accessed; 10.07.2014)
[44] WOOLLER, J.: The measurement of driver performance. Ergonomics 15 (1972)
[45] BUST, P.D.: Contemporary Ergonomics 2008: Proceedings of the International Conference on Contemporary Ergonomics (CE2008), Nottingham (2008)