analysis of emotional states, facial expression,
heart rate estimation, driving safety

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SIMULTANEOUS ANALYSIS OF DRIVER'S PHYSIOLOGICAL AND BEHAVIOURAL PARAMETERS UNDER THE ASPECT OF TRANSPORT SAFETY

The article presents an analysis's attempt of the emotional and physiological state of the driver while driving a vehicle. This approach takes into account the correlation of biomedical parameters with the fuzzy classification of facial expression. Based on the results of the experiment, carried out in the real road conditions, driver's emotional states were determined and identified and then combined with the easily measurable indicators of cardiovascular system.

1. INTRODUCTION

A huge number of accidents happens every year. It is being estimated that at least 90% of them are caused by the driver [13]. During driving many stimulations affect the person behind the steering wheel, which have an impact on his physiological and emotional state. As a matter of fact the police statistics in Poland include fatigue and drowsiness as an accident cause, but the police estimates this state basing rather on intuition and experience than on facts. The accident participants are also not willing to admit that they drove under limited psychomotoric abilities. Because of the mentioned reasons in statistics the share of traffic accidents are these in which the driver was exhausted or sleepy is so small. However, it seems that it is nothing but fatigue which is an often reason of car crashes. Conducted research shows, that even 20% of traffic accidents are caused by a sleeping driver [6][10]. This is why it is so important to analyse the driver's emotional state, particularly dangerous states like drowsiness or stress.

2. RESEARCHES ON DRIVER PSYCHOPHYSIOLOGICAL STATE ANALYSIS

Researches on the estimation of the driver's psycho-physiological state are conducted using two main measurement methods:

– estimation of the driver's state basing on his outward features,
– estimation of the driver's state basing on biomedical measurements.

The driver's psycho-physiological state can be evaluated on such outward features as face or its parts. Thanks to the driver's eye observation (eye closing, frequency of blinking or the activity of the eye ball) the driver's fatigue and his concentration on driving can be estimated [8]. For eye's observation mainly digital cameras are used, particularly the ones that use infrared light, because they allow to observe eyes also at night. In laboratories the EOG measurements are also used but they can be easily affected by noise like head motion.

The change in facial expression allows to estimate the driver's emotional state, which has an influence on the probability of causing a dangerous situation on the road. Some emotional states indicate also the fatigue, so their detection would be a good complementation of the eye tracking system. The driver's face image can be processed by on-line algorithms or evaluated by specialists in laboratories in order to detect dangerous states. The automatic detection of emotional state base on the position of some characteristic points like eye corners, mouth corners or eyebrows. Another method is to create meshes of the face in different emotional states and comparing them with the mesh created basing on the current face image [2]. This approach is very effective but the system has to be trained.

Biomedical measurements, in laboratories as well as in real situations, can be used for very accurate estimation of the driver's psycho-physiological state. Among many different methods the most popular is the EEG [8] which provides detailed information about the driver's state. However, this measurements are conducted only in laboratories rather than during driving. This results from the fact that for the EEG relatively many sensors are needed (19 according to ICFN's recommendation), which are placed around the skull and therefore are a source of the driver's movements limitations. In real situation different biomedical measurements are used, which are simpler but still they provide enough information about the driver's state. The examples of such measurements are ECG, GSR or muscle activity MEG [1], [9], [7]. Basing on ECG and pulse it was shown that during monotonous driving and fatigue the heart rate can decrease even to 7 beats per minute [8]. A high level of stress can also lead to dangerous situation on the road. Therefore, it is important to monitor the stress level in order to warn the driver against potential risk, which he creates for other people and for himself.

In our research we focused on combining both methods (outwards features and biomedical measurements) in order to fully model the driver's psycho-physiological and emotional state. Similar approach can be found in [1], but this research was

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conducted using the simulator. Basing on the literature [3], [4] and our previous researches [11], [12] driver facial expression and pulse were chosen to be used. It seems that this combination is sufficient for a full analysis of the driver's state.

3. DRIVER'S EMOTIONAL CONDITIONS DETERMINATION METHOD

The proposed method for driver's emotions determination bases on analysis of two independent measurement paths:

– driver's face video registration (facial expression),
– cardiovascular system encourages registration (heart rate).

In order to register the driver's face we used a typical webcam with resolution of 640x480 pixels and frame rate 15 fps. The camera was fixed directly opposite the driver, at the distance of 1 meter. The second measurement was done by using a finger plethysmograph (analysis of the infrared light transmitted through driver's finger). Due to processing time of the video data, the method was limited to facial expression analysis in time intervals indicated by the heart rate distinct changes.

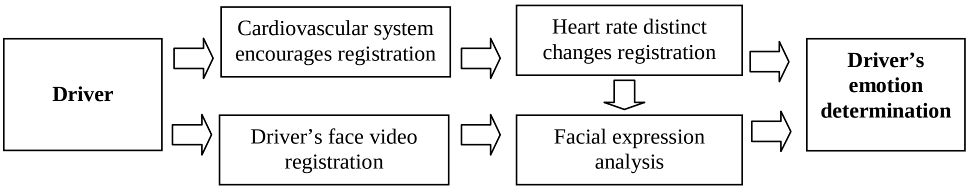

Fig. 1. Scheme of driver's emotions state evaluation system

3.1. HEART RATE ANALYSIS

The used plethysmograph registered amplitude of the infrared light in the function of time. In order to reduce noise and wandering baseline the filtration of the signal was made. We used a high-pass filter set at 0.5 Hz and low-pass set at the value of 5 Hz. The results of pre-filtering are shown on the Fig. 2.

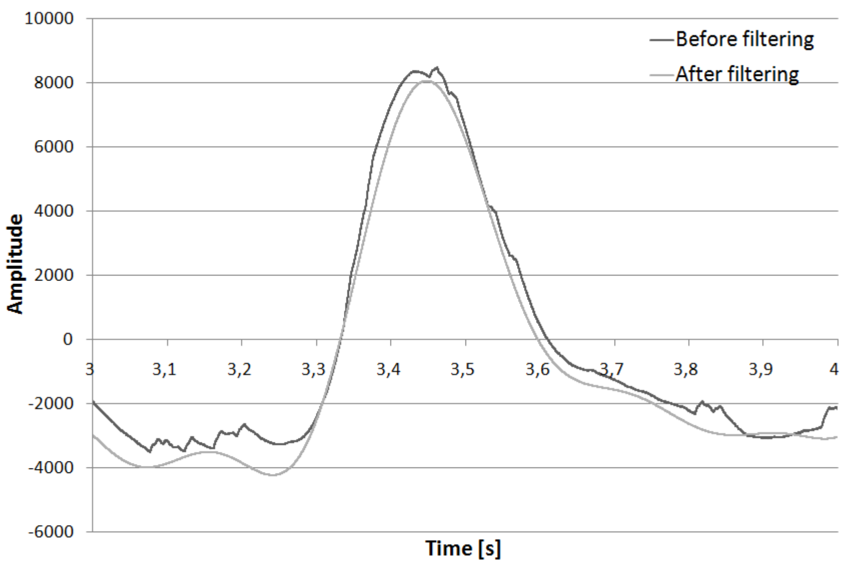

Fig. 2. Part of pulse graph before and after filtering

On the pulse graph we estimated peaks as the extremum point in which:

$$f'(t_n) \cdot f''(t_{n+1}) < 0 \quad and \quad f''(t_n) < 0 \tag{1}$$

where: $f(t_n)$ -amplitude of pulse in time t_n .

Knowing the time position of the peaks the heart rate was computed:

$$HR = \frac{60}{tp_{n+1} - tp_n} \tag{2}$$

where: tp_n -time position of the n peak.

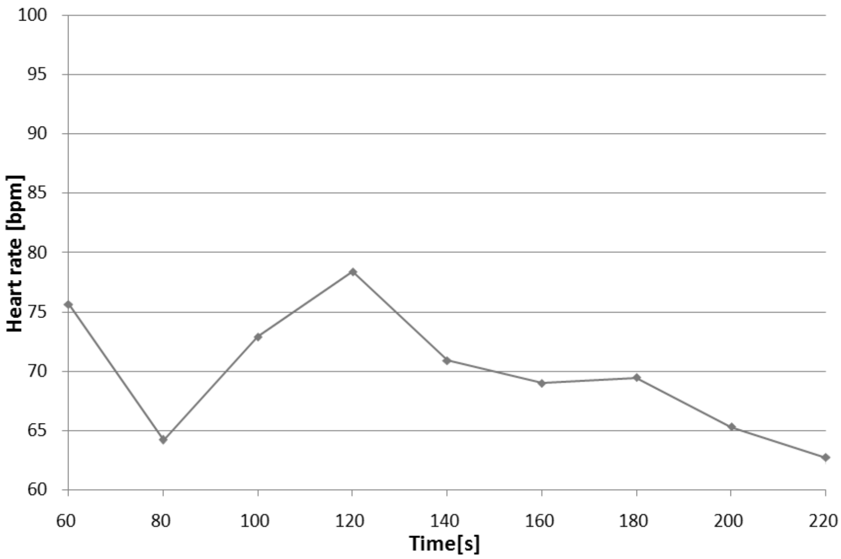

Fig. 3. Heart rate graph

Next, the average value of HR in 20s intervals was estimated. Figure 3 shows example of designated graph. The points in which graph has local extrema were treated as heart rate distinct changes.

3.2. FACIAL EXPRESSION ANALYSIS

From the registered data we chose the most characteristic images and, according to researches [5], emotion were divided into six basic states (Fig. 4): anger, disgust, sadness, fear, satisfaction, surprise:

Fig. 4. Basic driver emotional states

The next operation was creating the model of the face and indicating the points which could particular create the facial expression (Fig. 5). On the model the Euclidean distance between points (percent value - related to head height and width) and also curvature of eyebrows and mouth (reciprocal of the radius of the arc formed by 3 points) were analysed.

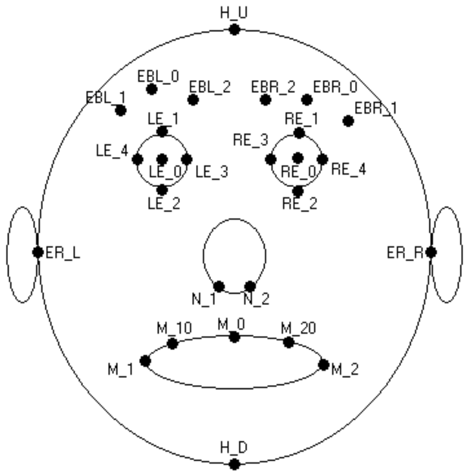

Fig. 5. Block scheme of chosen points for driver's emotions state evaluation system

Detailed analysis of the relative points position clarified eight characteristic indicators of each emotional state. In the table 1 the particular indicators with the value for different emotion are presented. The values were divided into three groups: low (white cell), average (grey cell) and high (black cell).

Table 1. Indicators of driver's facial expression

Indicator	Type	Points	Anger	Disgust	Sadness	Fear	Satisfaction	Surprise
Eye closure [%]	Left	LE_1-LE_2	3,10	2,88	4,76	5,94	4,42	5,78
	Right	RE_1-RE_2	2,61	2,35	3,90	6,51	4,42	5,78
Distance from eyes to eyebrows [%]	Left	LE_0-EBL_0	9,13	7,98	9,09	9,13	10,18	12,00
	Right	RE_0-EBR_0	8,70	8,45	8,23	10,50	10,18	12,44
Distance from eyes to mouth [%]	Left	LE_4-M_1	35,22	31,92	36,80	36,07	33,63	36,44
	Right	RE_4-M_2	34,78	35,68	35,50	38,81	33,63	36,89
Mouth curvature [px^{-1}]	Left part of upper lip	M_1-M_10-M_0	0,048	0,063	0,041	0,044	0,036	0,047
	Right part of upper lip	M_2-M_20-M_0	0,036	0,035	0,034	0,030	0,036	0,041

As it can be seen in emotions like anger and disgust eyes are almost closed and eyebrows are situated low. In the case of disgust there is a clear difference between curvature of left and right part of upper lip and distance between eyes and mouth. In sadness and satisfaction eyes are half open, however in satisfaction distance from eyes to mouth is clearly lower, what is a result of rise mouth corners. Surprise and fear are characterised by wide open eyes. Surprise is also designated by high rise eyebrows**.**

4. RESULTS

The experiment took place on the public, local road, in the favourable road conditions. The ride lasted about 20 minutes and in this time driver covered a distance of 18 km. In the Fig.6 the heart rate of the driver in 20 second intervals from 60 to 300 second of the drive is presented.

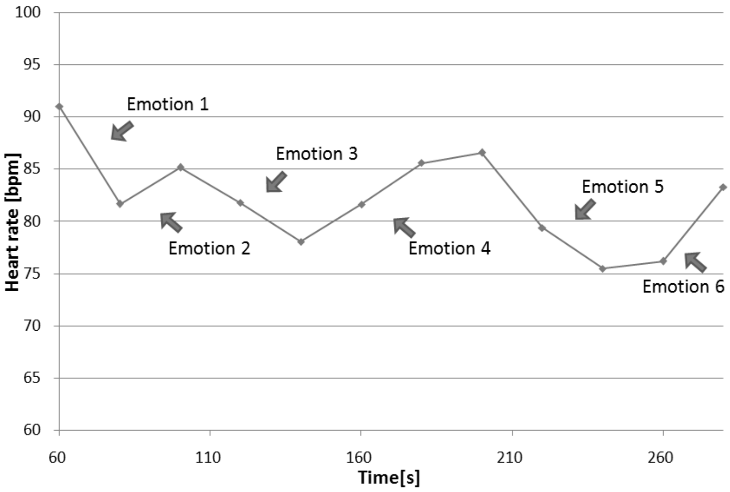

Fig. 6. Driver's heart rate graph registered in the real road conditions

On the graph we estimated six points in which the pulse reached local extrema. We researched the facial expressions before and after this distinct changes occurred. From the registered data six most characteristics faces were chosen (Fig.7).

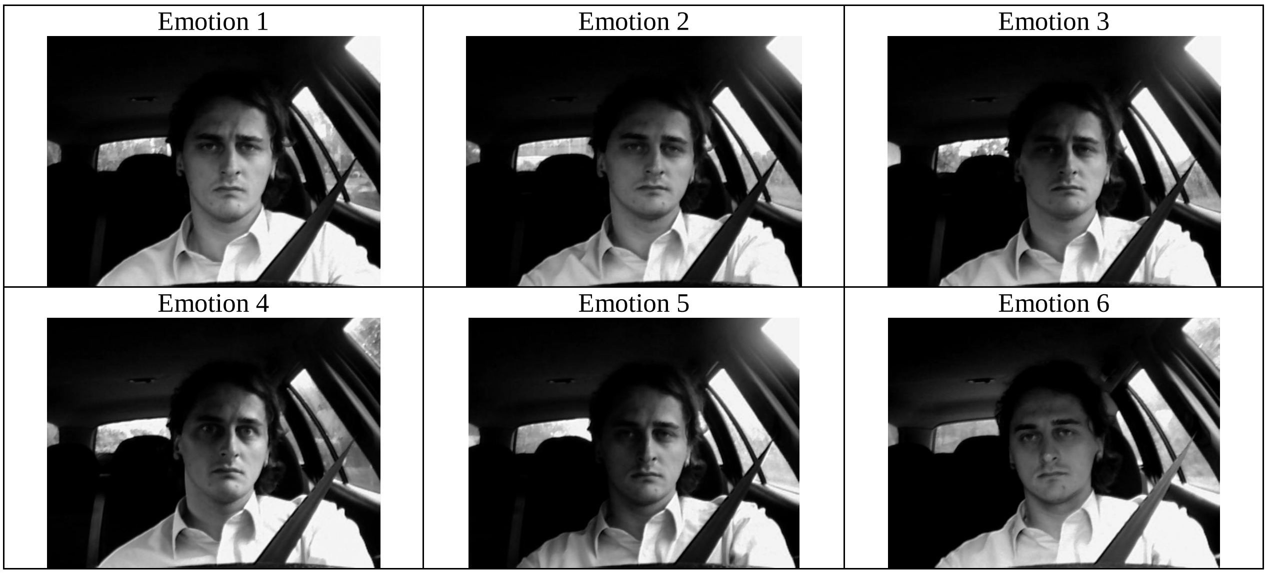

Fig. 7. Driver's facial expression registered in the real road conditions

As shown in table 2 each image was analysed and basic emotion indicators were estimated.
The value of indicators allows to distinguish the following emotions:

- emotion no.1 – sadness,
- emotion no.2 – satisfaction,
- emotion no.3 – sadness,
- emotion no.4 – surprise,
- emotion no.5 – sadness,
- emotion no.6 – satisfaction.

Table 2. Indicators of driver's facial expression registered in real road conditions

Indicator	Type	Points	Emo. 1	Emo. 2	Emo. 3	Emo. 4	Emo. 5	Emo. 6
Eye closure [%]	Left	LE_1-LE_2	5,42	4,89	5,29	5,90	4,26	5,69
	Right	RE_1-RE_2	3,79	4,04	4,37	6,42	4,46	5,42
Distance from eyes to eyebrows [%]	Left	LE_0-EBL_0	9,82	11,56	9,94	11,91	9,91	10,14
	Right	RE_0-EBR_0	9,17	10,33	9,62	11,36	9,09	10,52
Distance from eyes to mouth [%]	Left	LE_4-M_1	36,17	33,56	38,46	37,84	37,73	33,64
	Right	RE_4-M_2	36,17	33,22	38,46	35,59	36,82	36,41
Mouth curvature [px^{-1}]	Left part of upper lip	M_1-M_10-M_0	0,032	0,024	0,029	0,030	0,037	0,027
	Right part of upper lip	M_2-M_20-M_0	0,044	0,037	0,032	0,049	0,033	0,020

Comparing the heart rate graph with the facial expression analysis it can be seen that emotions 1,3 and 5 (sadness) occurred with the decrease of the pulse, while emotion 2,6 (satisfaction) and 4 (surprise) with increase of the heart rate. In case of surprise, pulse radically increased to 86 beats per minute and stayed at the high level for 20 seconds.

5. CONCLUSIONS

It is hard to expect that the driver will keep an equally good psycho-physiological state during the whole journey. Excessive faith in ones perfection, familiar also to wise and well-educated people, often leads to overestimation of the abilities for driving safely. It results in mistakes, and their consequence, fortunately with relatively small probability, are road events and accidents. This statistical function is affected by objective factors (intensity of road traffic, road condition, vehicle technical state etc.), which stay beyond the current driver's influence zone. The problem is rather that the driver does not perceive his own errors or he disregard their significance. The likelihood of making mistakes in road traffic can not be measured, except the permanent driver monitoring which by the way is scientifically interesting. But it is difficult to imagine that in every present vehicle the George Orwell's vision comes true (for which many dreamily miss), because it is rather expensive and the basic element of the 21st century humanism is money. The object that is going to avoid observation cannot be monitored, especially when motivated by subjectivism and so-called stress, takes a risk higher than acceptable by speeding or overtaking in place where it is forbidden. Deliberately violation of traffic regulations is probably a derivative of low technical culture and it needs time and comprehensive education to minimize the problem. The punishments for intentional offences suggested by media look like training the living being basically by means of penalties system. The educational system in the range of transport education in our reality is one of many weak links and the technical culture is in a rather poorly state owing to short period of real motorization in our country. One of the possible variants is a monitoring acceptable by the driver, which will evaluate the current driver's psycho-physiological condition and effectively show when the condition is getting worse. Directing this multi-criterion optimisation analysis on facial expression in association with selected, easily measurable indicators of cardiovascular system encourages, as the experiments presented in this paper has shown, to elaborate the assumptions of the driver's early-warning system.

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