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Evaluation of Statistical Metrics by Using Physiological Data to Identify the Stress Level of Drivers

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Abstract. In this study, an efficient and easy implementation metrics to determining stress level of drivers is proposed. For the evaluation, data have been obtained from Stress Recognition in Automobile Drivers database in the PhysioNet databank. Evaluations have been completed by using the available segment based arrays of electromyography (EMG), foot based galvanic skin response (Foot GSR), hand based galvanic skin response (Hand GSR), heart rate (HR) and instantaneous respiratory rate (IRR) derived from respiration by using peak detection algorithm. Comparisons of overall mean values of statistic metrics obtained by using EMG, Foot GSR, Hand GSR, HR and IRR showed that all of these signals and metrics can be used to identification of drivers with different physiological driving conditions.

Keywords: automobile driver, stress level, electromyography, heart rate, respiration rate, galvanic skin response.

1. Introduction

Biological signals express the condition of the physiological systems providing significant metrics indicating the dynamics of the internal states in human body [1]. Driver's stress level can be measured by using the data derived from biological signals. For a driving process, data must be task related, gathered continuously and without interfering to the driver's driving [2]. Information obtained by this way can provide a continuous measuring to specify the traffic and road conditions that affect the drivers. The information can be used to detect drivers' stress by using in-vehicle electronic systems so that the driver's decision-making abilities can be improved [3].

Healey and Piccard conducted one of the most cited studies in this context. In this method, physiological data were collected and analyzed to evaluate driver's stress level during real world task. The study showed that heart rate (HR) and Galvanic Skin Response (GSR) recordings are the most correlated to driver stress [4]. Ahmet Akbas concluded that Instantaneous Respiratory Rate (IRR) and average number of Contraction/Minutes (CPM) metrics can be used to determine stress level of drivers [5]. Mandeep Singh and Abdullah Bin Queyam concluded that Mean HR and Mean Hand GSR are the two statistical features related changing traffic conditions [6]. Another study studied by Mandeep Singh and Abdullah Bin, 8 features obtained from Electrocardiography (ECG), Hand GSR, Foot GSR, Electromyography (EMG) and HR recordings were classified by using Artificial Neural Network (ANN). Accuracies of this work are changed between 77.5% and 88.75% [7].

The remaining of the paper is organized as follows: obtained data for the evaluation are briefly described in section 2. Methodology, feature selection are introduced in section 3. Experimental results are summarized and described in section 4. Finally, conclusion and suggest future work that could result from paper are given in section 5.

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2. Materials

Data have been obtained from Stress Recognition in Automobile Drivers database in the PhysioNet databank [8]. Physionet is a web-based library of physiologic data and analytic software sponsored by the US National Institutes of Health. The database, contributed to PhysioNet by its creator, Jennifer Healey, contains a collection of multiparameter recordings from healthy volunteers, taken while they were driving on a prescribed route including city streets and highways in and around Boston, Massachusetts [4]. In total, 16 records contain a complete experiment, were taken from healthy driving-licensed drivers, with durations of 65 to 93 minutes. General placements of physiological sensors with respect to the automotive system are shown in Figure 1. In this study, totally 10 group of those 16 recordings could be used for evaluations of driver's stress levels. For that reason, remaining 6 datasets may not be helpful to find the correct markings and to determine the transient times between the driving segments through the whole recording.

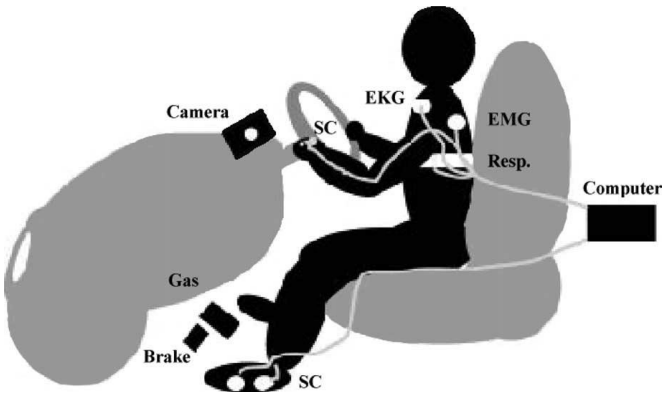

Fig. 1: Placement of physiological sensors (4).

Data consist of ECG, EMG, Foot GSR, Hand GSR, HR and Respiration signals. ECG was sampled at 496 Hz, EMG was sampled 15.5 Hz, Respiration, Foot GSR and Hand GSR were sampled at 31 Hz, and HR signal derived from ECG with 31 Hz. A sample 10 sec recording of 'drive11' has been shown in Figure 2. List of the time intervals for different driving segments for each of the drives are shown in Table 1.

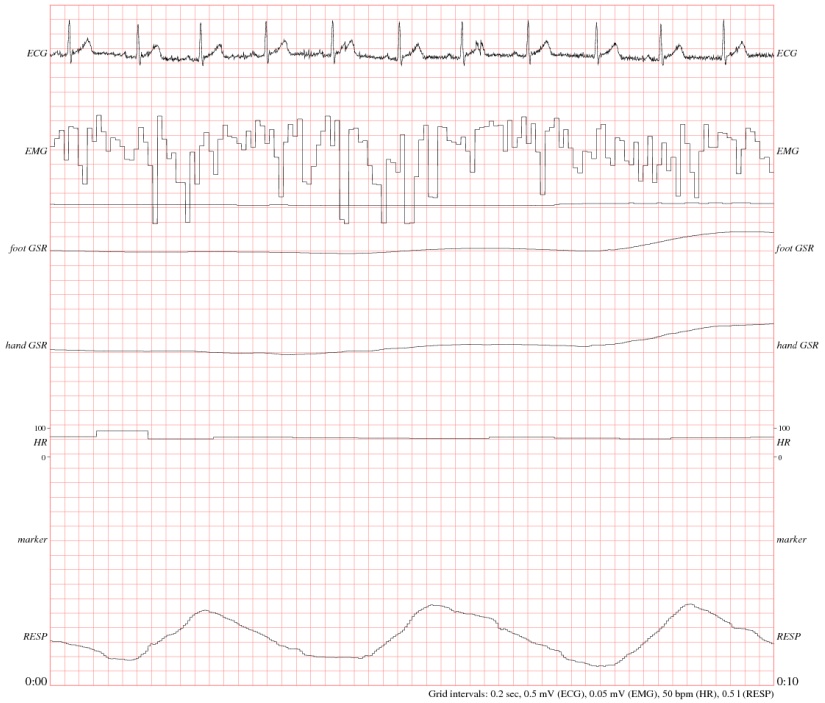

Fig. 2: A sample 10 sec recording of 'drive11'.

3. Methods

The mean, median, variance, standard deviation, quartiles and interquartile range to the segment based data arrays have been calculated for HR, HSC, FSC, EMG and IRR derived from respiration signals. A peak detection algorithm has been used to determine the peaks of the respiration signals to derive IRR [9]. Intervals between the sequential peaks of the respiration signal are measured in the form of the time units of milliseconds and transformed to the IRR (Breath per minute, Bpm).

Table 1: Time intervals of the 7 driving segments of available datasets (NA: Not available).

	initial rest	city drive 1	highway drive 1	city drive 2	highway drive 2	city drive 3	final rest
drive05	15,1	16,0	7,7	6,1	7,6	15,0	15,8
drive06	15,0	14,5	7,3	6,5	7,6	12,3	15,0
drive07	15,0	16,2	11,0	9,8	7,6	10,2	15,0
drive08	15,0	12,3	7,2	9,5	7,6	13,4	15,1
drive09	15,7	19,2	8,5	5,2	7,1	13,2	NA
drive10	15,0	15,3	8,7	5,3	7,0	12,1	14,8
drive11	15,0	15,8	7,4	7,1	7,0	11,7	15,0
drive12	15,0	13,4	7,6	6,5	8,1	11,7	15,0
drive15	15,0	12,5	7,2	6,0	6,8	12,1	15,0
drive16	15,0	16,1	7,1	5,1	6,8	13,9	NA

In probability and statistics, mean refer to a central value of a discrete set of numbers: specifically, the sum of the values divided by the number of values. The median of a finite list of numbers can be found by picking middle of the arranged observations from lowest value to highest value. Variance specifies measurement of the spread between numbers in a dataset. Variance is calculated by taking the differences between each number in the set and the mean, squaring the differences and dividing the sum of the squares by the number of values in the set. Standard deviation is a measure of the dispersion of a set of data from its mean. It is calculated by squaring root of variance. In statistics, the quartiles of data values are the three points that divide the data set into four equal groups. Each group contain a quarter of the data. The first quartile (Q1) is defined as the median of the lower half of the data set. The second quartile (Q2) is the median of the data. The third quartile (Q3) is the median of the upper half of the data set. Interquartile range (IQR) is the difference between the upper (Q3) and lower (Q1) quartiles. The entire segment based mean statistical parameters related to the EMG (mV), Foot GSR (μS), Hand GSR (μS), HR (bpm) and IRR (Bpm) arrays have been calculated for low, medium and high stress corresponding to rest, highway and city driving conditions, for each driving. Obtained results are given in Table 2 according to the evaluations.

Table 2: Mean statistics of HR, Foot GSR, Hand GSR, HR and IRR of all City, Highway and Rest segments.

		Mean	Median	Var	Std	Q1	Q2	IQR
EMG	City	1,69	1,29	3,54	1,85	0,82	2,02	1,20
	High	1,40	1,16	2,05	1,32	0,78	1,70	0,92
	Rest	0,86	0,83	0,40	0,57	0,62	1,02	0,40
FOOT GSR	City	7,70	7,45	3,51	1,72	6,44	8,79	2,35
	High	6,41	6,21	1,32	1,07	5,59	7,03	1,44
	Rest	4,34	4,26	2,98	1,45	3,05	5,37	2,32
HAND GSR	City	10,92	10,70	3,89	1,94	9,57	11,94	2,36
	High	9,72	9,42	2,06	1,38	8,75	10,30	1,55
	Rest	7,02	6,75	3,31	1,45	5,83	7,88	2,05
HR	City	82,53	79,80	160,16	12,26	74,90	87,90	13,00
	High	78,19	76,00	106,58	9,84	72,20	81,20	9,00
	Rest	71,87	70,50	92,42	9,20	66,50	75,10	8,60
IRR	City	19,06	19,07	20,25	4,48	16,34	21,92	5,59
	High	19,47	19,25	12,36	3,47	17,48	21,35	3,87
	Rest	15,09	15,12	7,38	2,65	13,59	16,72	3,13

According to results given in Table 2, percentages of statistics of the driving segments have been calculated relative to each other. Obtained results are given in Table 3.

Table 3: Comparison of mean statistics of HR, Foot GSR, Hand GSR, HR and IRR between City and Highway, City and Rest, Highway and Rest segments.

		Mean	Median	Var	Std	Q1	Q2	IQR
EMG	City / High	21,08	10,95	73,25	40,34	6,13	19,25	30,29
	City / Rest	98,19	54,54	785,65	221,74	32,22	98,20	201,13
	High /Rest	63,68	39,29	411,20	129,25	24,58	66,20	131,12
FOOT GSR	City / High	19,98	20,01	164,51	59,96	15,09	25,00	63,51
	City / Rest	77,15	75,30	17,54	18,93	111,03	63,76	1,54
	High /Rest	47,65	46,08	-55,56	-25,65	83,36	31,01	-37,90
HAND GSR	City / High	12,36	13,51	88,06	40,34	9,38	15,84	52,28
	City / Rest	55,53	58,30	17,28	33,83	64,18	51,36	15,00
	High /Rest	38,42	39,46	-37,64	-4,64	50,09	30,66	-24,49
HR	City / High	5,55	5,00	50,27	24,60	3,74	8,25	44,44
	City / Rest	14,83	13,19	73,30	33,21	12,63	17,04	51,16
	High /Rest	8,78	7,80	15,32	6,91	8,57	8,12	4,65
IRR	City / High	-2,09	-0,97	63,88	28,88	-6,54	2,67	44,23
	City / Rest	26,30	26,08	174,25	68,82	20,22	31,11	78,40
	High /Rest	29,00	27,30	67,35	30,99	28,63	27,71	23,69

4. Results

According to the results given in Table 2, EMG, Foot GSR, Hand GSR and HR are well correlated with low, medium and high stress level, thus increasing stress level has led to the increasing statistics of them. According to the results of the evaluation of IRR, most significant changes related with stress level have been observed at calculation of variance, in Table 2. Considering all the results in Table 2, variance is observed to be more significant than other measurements. According to the results given in Table 3, variance of foot GSR has the best percentages among comparisons of city and highway driving, variance of EMG has the best percentages among comparisons of city and rest, and finally, variance of EMG has the best percentages among comparisons of highway and rest segments. Considering all the results in Table 2 and Table 3, variance is better discriminative statistic measurement than others.

5. Conclusions

In this study, an efficient and easy implementation metrics to determining stress level of drivers is proposed. For the evaluation, drivers' bio-signal datasets obtained from Physionet Databank were used. Evaluations have been completed by using 7 statistic measurement of EMG, Foot GSR, Hand GSR, HR and IRR signals. Experimentation in this study showed that such signals and metrics can be used to identification of drivers with different physiological driving conditions. Broadly thinking, the present features because of its simplicity, such a design can be integrated the future car technology for automatic detection of stress level of drivers. In future studies, different feature extraction methods on EMG, Foot GSR, Hand GSR, HR and IRR will be implemented.

6. References

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