Detection of Stress Level of Automobile Drivers using ECG and EMG Signals

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Abstract – *In the past few decades, there was a steep increase in road accidents and also loss of life was experienced due to increase in the driver's mental stress. Thus stress level detection is very important in automobile drivers. In this paper, a method is proposed to detect stress level using features extracted from biomedical signals such as ECG and EMG signals. These signals were taken from "Physionet Database" and the results are obtained using MATLAB Simulation Software. The extracted features showed correlation with the stress level of automobile drivers, with the high accuracy of 78.57% for 60 seconds of the signals and 92.85% for 240 seconds of the signals.*

***Key Words*: Signal Processing, ECG, EMG, Stress Detection, Automobile Driver, MATLAB.**

1. INTRODUCTION

Driving could be a complex task which needs full concentration and an important balance between the alertness and a relaxed attitude [1]. Stress and powerful emotions can affect this balance whether or not they result from the driving task itself, or some unrelated matters. The work of operating transportation system vehicles in urban centers is also among the foremost stressful and unhealthy modern occupations.

According to survey conducted by Cigna TTK insurance, about 89% of India's population stricken by stress, as compared to the worldwide average of 86%. A survey conducted by Ford Motor Company about Causes of Stress in the Indian car drivers states that most of the drivers in India suffer from stress due to congested traffic. About 63% drivers feel stress due to traffic jams, while 56% of the Indian drivers suffer from the stress due to improper management of parking. 45% drivers fear of getting into an accident while 37% drivers fears due to increasing fuel prices.

An ECG can be defined as a biological signal which represents the electrical activity of the heart associated which is with oscillation. It can be measured as a potential difference using special electrodes placed on different areas of the chest and limbs [2]. Heart rate can give an appropriate state of the human stress. Many studies have proven the connection between the HRV (heart rate variability) and the stress level [3]. Feature extracted from the ECG signal for the proposed method in this paper are R-peaks and Average Heart Rate.

An EMG signal is the one of the most significant biomedical signals that demonstrates stress of a person. The EMG signal is random in nature. Feature extracted from the ECG signal for the proposed method in this paper is ZCR (Zero Crossing Rate). When a driver suffers from the low stress, the action potential propagates a chemical reaction that creates the relaxation of muscle fibres. Hence get low ZCR value. While when muscles are in contracted condition, ZCR value becomes higher.

2. LITERATURE REVIEW

The proposed method states the stress level detection of different automobile drivers under different traffic conditions. Different approaches used by various researchers are tabulated as follow:

Table -1: Various approaches by other researchers

References	Algorithm used	Physiological signals used	Populations used
Picard & Healey (2000)[4]	Linear Discrimination Algorithm	ECG, EMG, SC (Skin Conductivity), Resp.	3 experienced drivers
Karthik S, Sathiya A, Suganthi N (2014)[5]	SVM (Support Vector Machines)	ECG,EMG	14 individuals
Barreto& Zhai (2006)[6]	SVM (Support Vector Machines)	BVP, GSR, PD	32 individuals
Singh R. R. & Banerjee R.(2013)[7]	LRNN	EDA, HRV, RSP signals	19 individuals

The various researchers previously used various features are vocal inflection changes [8], blood-glucose levels, video recordings of facial expressions and posture gesture changes [9] and other bodily changes [10] [11]. But video recordings make data acquisition expensive and it's also has its own limitations. In the proposed method, features extracted from the biomedical signals in order that they become more robust and reliable.

3. METHODOLOGY

Figure 1 shows the block diagram of the proposed system.

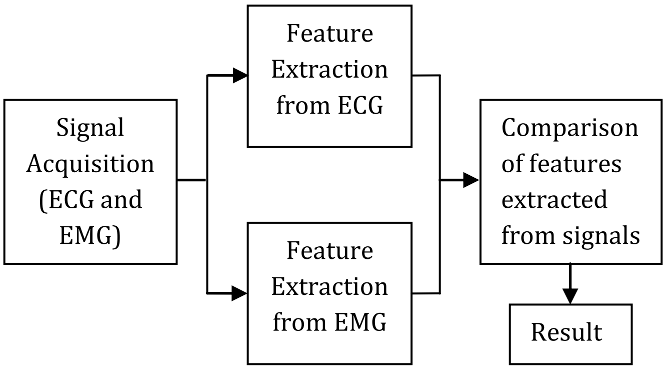

Fig -1: Block Diagram of Methodology

3.1 Signal Acquisition

The signals used in this paper were taken from the "Physionet Database" [4]. The ECG and EMG signals were obtained using electrodes which are connected to the drivers while they were driving. Lead II electrode configuration was used to collect the ECG Signal in order to increase the amplitude of the R waves and also to decrease the amplitude of the artifacts. The EMG signals were collected by putting the physiological sensors on the shoulder muscles. ECG signal was sampled at frequency 496Hz and EMG signal was sampled at frequency 15.5Hz by using Flex comp A-D converter. Data acquisition was done for 14 drivers.

3.2 Feature Extraction from ECG Signal

For the feature extraction of ECG signal, first preprocessing of the signal must be done. In the preprocessing, low frequency noise components are removed by shifting the signal into frequency domain and then equating low frequency components to zero. Again the signal is shifted back to time domain and then to find the maxima (i.e. r-peaks) window filter is used. Here, a classic peak and valley filter is used. With the help of sampling frequency, calculate the window size. Now to find the maximum value (R peak) compare amplitude of each sample with next sample. After that small values are removed and significant values of R-peak are stored.

Heartbeat rate (beats/second) can be calculated by using formula with the help of detected R peaks:

$$\text{Rate} = 60 * \text{sampling rate} / (\text{R-R Interval})$$

Feature extraction of ECG signal is done using algorithm described in the flowchart as follow:

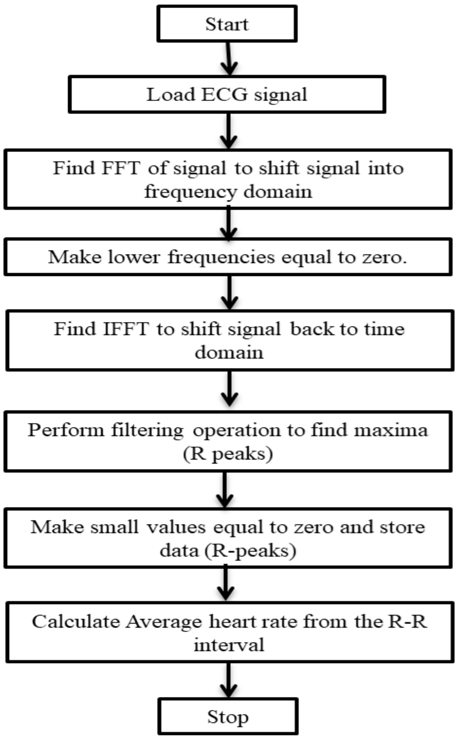

Fig -2: Algorithm for Feature Extraction from ECG Signal

3.3 Feature Extraction from EMG Signal

Feature extraction of EMG signal is done using algorithm described in the following flowchart:

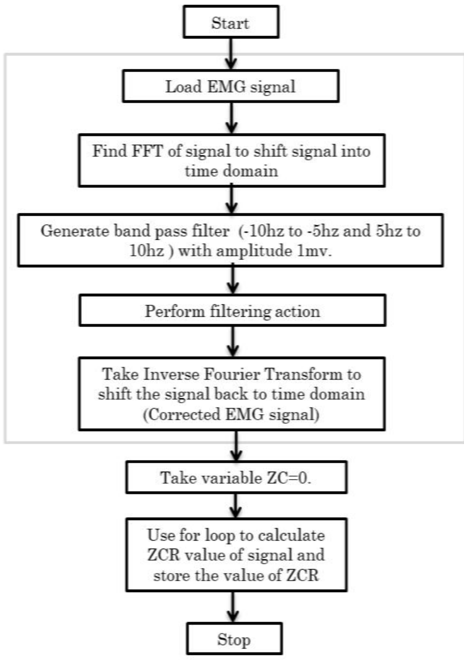

Fig -3: Algorithm for Feature Extraction from EMG Signal

For the feature extraction of EMG signal, first preprocessing is done in order to remove the noise. For renovation of noise from the signal, convert the signal into the frequency domain and perform filtering action using band-pass filter as illustrated in figure 3. Again convert the signal back to time domain for the feature extraction. In the proposed method, Zero Crossing Rate (ZCR) of EMG signal is used as important feature in order to detect the stress level of drivers. It is the rate at which signal crosses zero axis i.e., rate at which sign changes from positive to negative and negative to positive. ZCR is calculated using formula stated below:

$$ZCR = \frac{1}{T}\sum_{t-1}^{T} | s(t) - s(t-1)|$$

3.4 Comparison of Features extracted from Signals

Comparison of the features extracted from the signal is done in order to detect the stress level of the driver whether it is high or low. The algorithm for the comparison is described in the following flowchart:

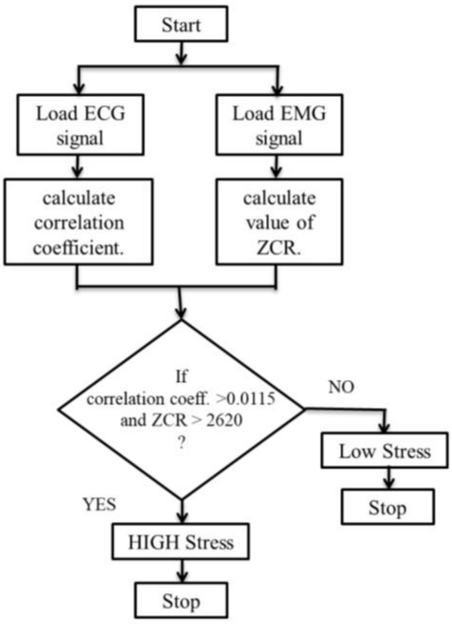

Fig -4: Algorithm for Comparison of the features

As illustrated in the figure 4, for the comparison between the feature extracted from the ECG signals Correlation coefficient is calculated and compared with the threshold value to determine whether the signals falls under the category of high stress or low stress. Correlation coefficient is calculated using formula stated below:

$$r = \frac{\sum_m \sum_n (A_{mm} - \bar{A})(B_{mm} - \bar{B})}{\sqrt{(\sum_m \sum_n (A_{mm} - \bar{A})^2)(\sum_m \sum_n (B_{mm} - \bar{B})^2)}}$$

For the comparison between the feature extracted from the EMG signals, ZCR value of each signal is compared with the threshold value to detect the stress level of the driver.

4. OBSERVATION AND RESULTS

The results were obtained by simulating entire experiment using MATLAB. For the detection of the stress level using proper approach, set of ECG and EMG signals were taken from Physionet Database.

Fig. 5, 6, 7 illustrates the detailed feature extraction of ECG signal. Fig. 8, 9, 10 illustrates detailed waveforms for the feature extraction of EMG signals.

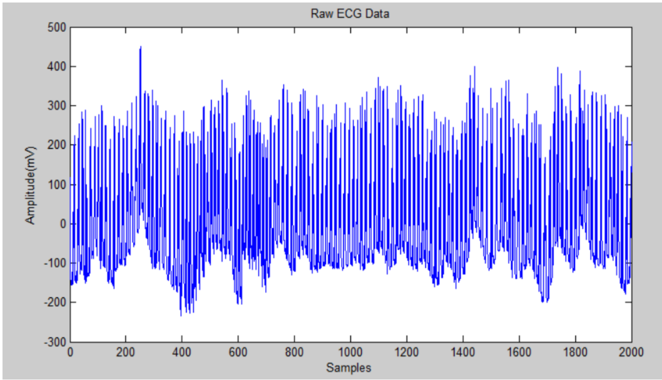

Fig -5: Waveform of Raw ECG Signal

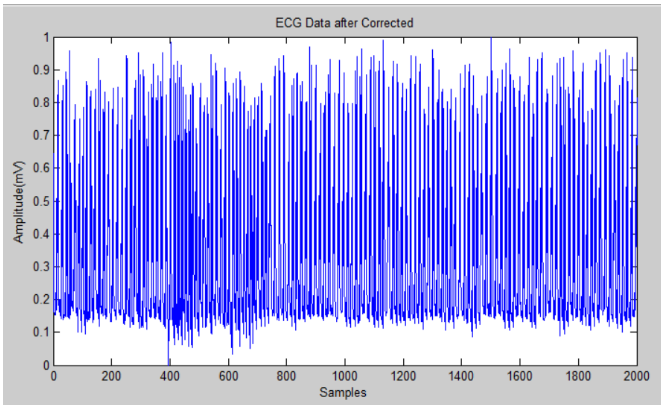

Fig -6: Waveform of Corrected ECG Signal

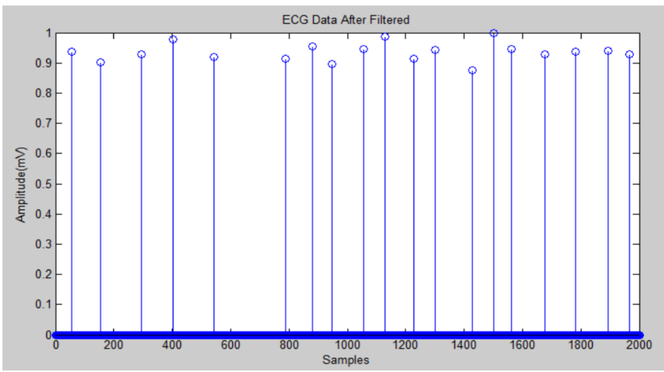

Fig -7: Waveform of Filtered ECG Signal (R-peaks detected.)

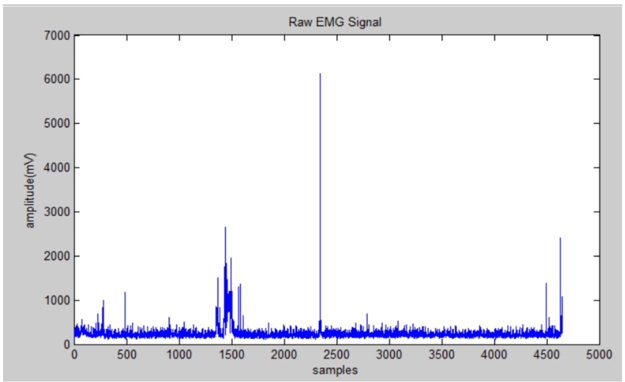

Fig 8-: Waveform of Raw EMG Signal

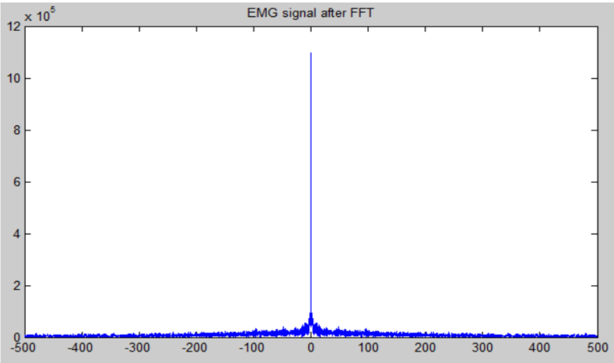

Fig -9: Waveform of EMG Signal after FFT

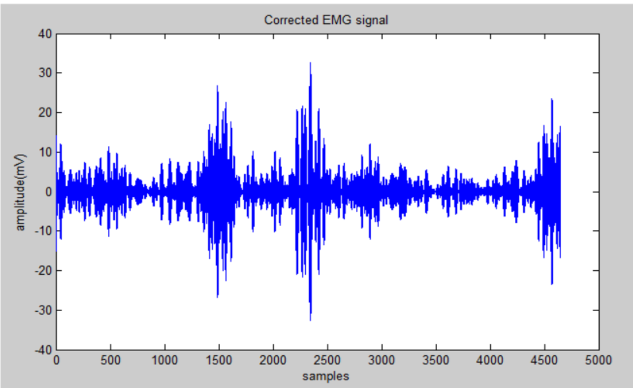

Fig -10: Waveform of Corrected EMG Signal

Fig. 11, 12 illustrates screenshots of the stress level detected in drivers using MATLAB software.

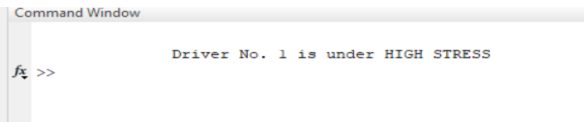

Fig -11: Screenshot of High stress signal detected

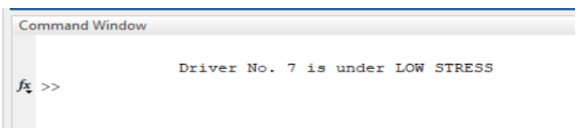

Fig -11: Screenshot of Low stress signal detected

The features extracted from ECG signal are: R peaks, Average heart beat rate, Correlation coefficient and the features extracted from EMG signal is zero crossing rates. Table 2 shows results of 4 drivers for 2325 samples while table 3 shows the results for 9300 samples.

Table -2: Result Table (for 60 seconds/2325 samples)

Driver No.	Average Heart Beat Rate	Correlation Coefficient	Zero Crossing Rate	Stress Level
02	117.7520	0.0815	1373	HIGH
07	83.8794	-0.0081	1330	LOW
12	85.8369	-0.0080	1315	LOW
14	105.5409	-0.0092	1337	HIGH

Table -3: Result Table (for 240 seconds/9300 samples)

Driver No.	Average Heart Rate	Correlation Coefficient	Zero Crossing Rate	Stress Level
02	106.8984	0.0169	5434	HIGH
07	81.9868	-0.0081	5192	LOW
12	86.7688	-0.0084	5269	LOW
14	113.3737	0.0024	5313	HIGH

To evaluate the performance of the proposed method accuracy parameter is used. The degree of closeness of measurements of a quantity to that of its actual (true) value is termed as Accuracy. As calculated accuracy to detect the stress level of drivers using 2325 samples is 78.57%, while using 9300 samples is 92.85%.

5. CONCLUSION AND FUTURE SCOPE

The stress level of the automobile driver was detected with high accuracy of 78.57% for 60 seconds and 92.85% for 240 seconds. Hence, with the large number of samples high accuracy can be obtained. The correlation between the stress level and features extracted from ECG and EMG signal was also proved. The proposed method in this paper can help to increase driver's safety.

In the future, the proposed method may be used for developing machines which may respond intelligently to driver behavior like automatic management of in-vehicle information systems such as radios, cell phones, and on-board navigation aids. Some examples of this might include mobile phone calls might be diverted to voice mail.

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