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Special Issue

A Feed Forward Neural Network with Particle Swarm Optimization based Classification Scheme for Stress Detection from EEG Signals and Reduction of Stress Using Music

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Abstract

Modern people tend to have more stress due to lots of things happening in their life which needs to be handled by them alone. Stress is a more serious threat which would lead to dangerous cause such as diabetes, heart disease, cancer and mental disorder. These problems can be reduces by finding the common pattern and risk factors associated between the stress factors. In this research analysis, a novel method is introduced in which it focus on finding the serious cause and effects mental stress. This is done by analysing the Electroencephalogram (EEG) signals in which feature selection and classification would be carried out. These EEG signals have been gathered from the multiple persons to predict the mental workload stress variation. Anticipating higher performance with reduced error rate and improved accuracy, this analysis has been carried out by using Feed Forward Neural Network with Particle Swarm Optimization (FFNN-PSO). Before prediction, EEG signals would be pre-processed to improve the quality of the signals obtained. In pre-processing stage power line noise and ocular artifacts would be removed by using digital band-pass filter. Then, the Power Spectral Density (PSD) based features are extracted. At last, the stress level is categorized as low, medium and high by with FFNN-PSO. If high stress, next music are hear or chant and this statistical examination is conversed in the course of the performance analysis. The experimental outcomes demonstrate that the anticipated FFNN-PSO

accomplished higher performance in terms of accuracy of 93.25%, sensitivity of 92.14%, and specificity of 97.52%contrast to the existing stress detection and classification algorithms with EEG signal.

Key Words: Human brain, stress detection, stress reduction, PSD, music, FFNN-PSO.

1. Introduction

Human stress is developed by various emotional things in their life. The varying challenges and tasks undertaken by human would lead to high mental pressure which might cause various issues. The major health issues occurred on humans due to high mental pressure is heart disease, stroke, and high blood pressure. These problems might lead to dangerous threats such as human's death. Stress might also affect the personal relationship matters such as mood changes, productivity variation, personal relationship breakup, life quality and so on. Thus it is required to predict the mental stress level in the effective manner to avoid the harmful threats happening on the humans.

The mental stress level of humans can be categorized into levels such as positive stress/joy and negative stress/depression .Mostly humans would suffer from the negative stress which might affect their regular activities by creating hyper tension and make them feel frustrated.

The nervous system of humans contains two parts namely central and peripheral. Here Autonomous Nervous System (ANS) which is reason for the mental stress can be found in the peripheral part of nervous system. This ANS is reason for generating the negative physiological thinking such as stress, tension, anxiety and depression. This is can be identified by various biological factors of humans such as Blood Pressure level (BP), (BVP),Galvanic Skin Response (GSR), Skin Temperature (ST) and EEG signals measurement .If there is more variation found in these factors then it can be concluded that those corresponding persons are under mental stress due to reflect of nervous system variation. EEG signal factors would also varied in its performance under different environment consideration such as noisy working environment, high workload, improper sleep and family issues. These factors would generate negative emotions of humans which need to be analysed well for the proper treatment.

There are various research methods has been introduced earlier to perform feature selection and classification efficiently to predict the stress level of humans very accurately. Thus the proper treatment can be ensured. These processes would be carried by concerning the stress related factors in mind. Feature extraction can improvement classification performance of EEG signal prediction by selecting more reliable features. Fuzzy K-Nearest Neighbour (FKNN) classifier is a one of the human stress prediction methodology introduced to perform better by adapting the behaviour of Finite Variance Scaling (FVS). However evaluation of F-KNN method based stress prediction leads to reduced accuracy rate by involving more false positive rate. Discrete Wavelet Transform (DWT) is a most famous technique utilized by different application to perform feature extraction process in the well-definedmanner. This can be further optimized by hybridizing it with the EEG Asymmetry method which can lead to accurate feature selection outcome by finding unique

pattern of human stress .These ideas have not been taken over by any previous research method where the variation of beta band would indicate the variation in mental workload. KNN classification method proves that prediction of stress level during human listening music provides positive results.

The main contribution of this research paper is to introduce the novel protocol namely mental stress elicitation protocol which is implemented and evaluated for its performance to predict the mental stress level. Figure 1 illustrates the overview of mental stress recognition system using EEGsignal. Mental stress prediction system can be carried out in four steps which is denoted as follows: i) Data gathering protocol, ii) Pre-processing dataset iii) Feature extraction and iv) classification. These steps are explained in detail as follows:

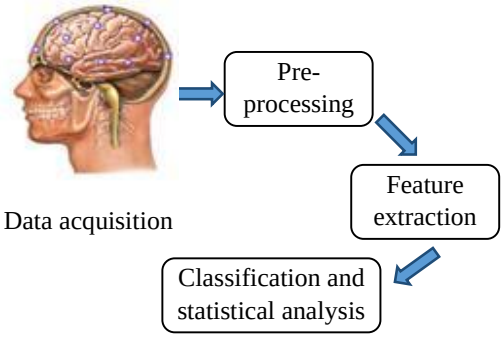

Figure 1: Overall Steps of Proposed Work Analysis

EEG signal acquisition: Brain activity recognition is the more difficult process which requires continuous monitoring of brain activities. The electric signal measured from the electrodes cap of EEG signal might varies based on human response which would be digitized for further processing later.

Pre-processing: The main goal of this steps is to increase the qualityof the electric signals measures without loss of information which is ensured by introducing the digital band pass filter.

Feature Extraction: It is the process of finding the characteristics features about the brain electro signal variation which is done by using Power Spectral density (PSD)

Classification and statistical analysis: The main contribution of this research method is to find the variation level between the stress level and rest state by processing EEG signals gathered from the multiple source sights. The stress level has been classified by using FFNN-PSO and the stress is solved by using religion mantras. This classification scheme is classified the stress and non-stress people. The simulation results conclude that the proposed FFNN-PSO attained better performance compared than existing algorithms.

The following deals with the sections are arranged as: which section 2 discusses some existing researches based on EEG signal stress classification. Section 3

explains the proposed FFNN-PSO based classification and the performance results are discussed in section 4 and finally, this work is concluded.

2. Related Works

Here, some existing mental stress classification schemes have been discussed. ChetanUmale et al., [12] attempted to predict the human stress level by analysing the characteristics of EEG signals. Initially authors havepre-processed the EEG signals by using different algorithms namely DCT and DWT. After pre-processing classification of the pre-processed signals are done by using algorithms namely LDA, Naive bias and ANN. This work analysis the different algorithms in terms of its behaviour to predict the human stress level from the EEG signal and concluded with the better algorithm.

Mantri et al., [13] try to predict the mental stress level in the accurate manner. Author gained knowledge from the various previous research methodologies which are introduced earlier for the detection for the human stress level. The proposed research method would first gather the EEG signal data detailed from the different human brain functionality. From these gathered signals, feature extraction is done by using different methodologies such as PCA and ICA. After feature extraction, data classification is done to categorize the input signal as “stressed” and “relaxed” by using different classification techniques namely SVM, K means. The overall evaluation of the research method proves that the proposed research method can accurately classify the input EEG signals in the efficient manner.

Verona et al., [14] analysed the behaviour of the hemisphere of humans to predict the variation between the stressed people and non-stresses peoples. They have concluded that the people more stress would have more activity in front hemisphere of brain than people with no stress [20]. As like that, Hayashi et al. also tried to find the activity of brain by foreseeing right frontal brains. From this analysis it can be concluded that the EEG signals are capable of predicting the measure of human stress level without concerning about the variation present inn humans.

Vanitha and Krishnan [15] introduced correlation based technique for the detection of stress level by finding the correlation range between the various students EEG signals. Initially the measure EEG signals would be pre-processed to remove the noises and artefacts present in the signals. After pre-processing relevant features are extracted using Hilbert Huang Transform (HHT). These extracted features are then categorized into stress level or non-stress level by using hierarchical support vector machine. These analyses are carried out in real time using brain waves.

Begum and Barua[16] introduced hybridized technique to predict the stress level from the EEG signals. Authors adapted Multivariate Multi-scale Entropy Analysis (MMSE) technique to perform the data level fusion. After fusion data

classification is performed by using case based reasoning technique. The overall evaluation carried out proved that the EEG sensor based classification can lead to accurate and efficient stress level prediction. This system can be used for the health monitoring application to improve the performance outcome.

Pandiyan&Yaacob [17] introduced the statistical features and principal component analysis (PCA) technique for the extracting and using the more useful informative features from the EEG signal dataset. This work utilizes EEG signal dataset which is created by gathering the signals from ten subjects (i.e. consists of 6 males and 4 females). This is done in Mental Arithmetic Test (MAT) stimuli. This dataset would be first pre-processed which will filter the input EEG signal into four frequency bands namely delta, alpha, theta and beta. This is done by using the elliptic bandpass filter. These extracted features would be classified into different classes namely Low (i.e. Level 1), Medium (i.e. Level 2) and High (i.e. Level 3) using K-Nearest Neighbours (KNN) classifier. The performance evaluation of this research method confirms that the proposed research method leads to have increases classification accuracy rate than the existing research methods.

Zoshket al. introduced Fast Fourier Transform (FFT) to extract the optimal features from the database, thus the classification accuracy can be improved to 83%[18]. This algorithm also filters the EEG signals into four frequency bands such as delta, theta, alpha and beta. The evaluation of the research method proves that the proposed method can increase the fatigue detection outcome ratio than the existing research method [19]. This method used DWT technique to extract the features from the EEG signals for the accurate result. These features would then be fed into the KNN classifier which will classify the features into disgust, happy, surprise, fear and natural with classification accuracy of 83.26% [7].

3. Proposed Methodology

Feed Forward Neural Network with Particle Swarm Optimization (FFNN-PSO)

In this section, an effectual FFNN-PSO based stress classification has been discussed. Also, the step by step process has been explained.

System Overview

Figure 2considers the design of presented scheme. The objective of this presented scheme is to reduce the human stress after sensing the stress by using EEG signals. The main aid of this is to examine accurately estimated the human stress and classify the human stress level. The stress has been evaluated by using the EEG characteristics and stress level of human (i.e. stress or relaxed mode). This stress levels are classified by using FFNN-PSO classification scheme. If high stress is monitored, then next music of subject’s choice are played and this statistical examination is conversed in the course of the

performance analysis. The step by step process has been discussed in given below subsections.

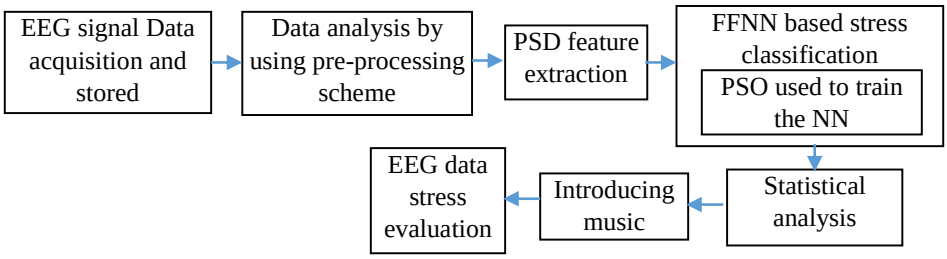

Figure 2: FNNN-PSO based Stress Classification and Reduction Procedure

EEG Data Analysis

The EEG signals are gathered from five humans and it is omitted during categorization process due to presence of artifacts in those images. These artifacts are generated by various reasons such as eye movement and blinks, muscle movement and so on. The signals with the artefacts value more than 100 μV would be rejected for the further processing. Thus filtering is done before processing EEG data. This filtering task would divide the EEG signal into five frequency bands such as Delta (1 - 4 Hz), Theta (4 – 8 Hz),Alpha (8 – 13 Hz), Beta (13 – 30 Hz) and Gamma > 35 Hz bythe EEG frequency band analysis. Here beta signal is found to be more efficient signal with corresponding variation which can lead to accurate classification rate. Here spectral power density is utilized to calculate the mean power of EEG signals and hamming window distance is calculated by using the power spectral density. Here window size is fixed as 256 with 50% overlapping and then FFT length is fixed as 1024. The situation that are considered while measuring EEG signals are listed as follows:

- Relax: The signal is measures when the volunteer are sitting in the relaxation mode. It was done for two minutes (i.e. 30sec x 4 trails).
- Music's: The signal is measures when volunteers are sitting in the relaxation mode and hearing songs out. This was also done for two minutes (i.e. 30sec x 4 trails) hearing or chanting.
- Stress signal: Here signals are measured when volunteers are sitting in the place where the high pitch noise presence. Noises are varied during examination. It is also done for two minutes (i.e. 30sec x 4 trails).

Pre-Processing

Pre-processing is used to eliminate the noises present in the signals which are done by fixing frequency variation between 0.5 to 30 Hz in real time. This frequency limit can avoid the noises generated from both main source and other sources.

PSD Feature Extraction

After pre-processing, feature extraction is done on the signals using the one of the AR method namely PSD method is a kind of parametric modern spectrum estimate method. It is a random process which is used to predict the different

kind of phenomena present in the frequency signals. This method is a linear prediction based technique which attempts to find a final outcome from the knowledge of previously defined outcomes [20]. There are numerous algorithms proposed earlier for the measurement of AR method parameters such as Yule-Walker, Burg, Covariance and Modified Covariance. In the proposed research method, Yule-walker scheme is adapted to assure the better outcome even in case of long data sequence presence. The main constraint that needs to be taken in mind when utilizing this method is model order prediction. So that, the error can be avoided during run time. This selected order would be utilized during performance evaluation which can lead to better method selection. In this work model degree is selected as 15 for EEG.

After accomplishment of PSD estimation from the signals gathered, feature selection is done. In this work, 11 features were extracted in terms of time and frequency domain EEG signal. These features were selected from the corpus defined in [21] and it is listed as follows:

1. Relative Powers of frequencies in alpha band.
2. Relative Powers of frequencies in theta band.
3. Power of theta band or power of alpha band.
4. Power of alpha band in related epoch/power of alpha band in previous epoch.
5. Relative Powers of frequencies in 12-14 Hz (for spindle detection).
6. Mean value of the EEG signal in time domain.
7. Skewness of the EEG signal in time domain.
8. Kurthosis of the EEG signal in time domain.
9. Sum of Powers of frequencies in 0.5-2 Hz.
10. Sum of Powers of frequencies in delta band (0-4 Hz).
11. Sum of Powers of frequencies in 2-6 Hz.

FFNN-PSO based Stress Classification

After feature extraction process, those would be fed into the FFNN classifier to perform prediction process. This classifier would predict the EEG signals as three classes namely low, medium and high. FFNN consists of input layer, hidden layers and output layer. This structure is given in figure 3. In the training process, FFNN would identify the weight values for the submitted input values. This weight value would be updated in each iteration based on variation between outcome obtained and the expected outcome. This will be done until it reaches minimum error value. This error value optimization is done by using PSO algorithm.

Particle Swarm Optimization (PSO)

PSO is optimization approach which is based on biological behaviour of birds searching for food. In this method, random population would be generated initially whose main goal is to identify the optimal search place in which more food found. Here particle in the population is referred as candidate solution which would consist of their own memory p. In PSO, n numbers of particles are

taken initially$where\ i\ =\ 1, 2, \ldots, n$. These particles would locate the optimal location with more food during search process. This is ensured by updating the velocity and location of the particles in each phase based on their local solution and global solution. Here global best solution is updated based on values of local best solution. Based on the values of local best and global best values, neighbourhood particles have been updated. This update is done by considering the fitness values evaluated for each particle (i.e. features).

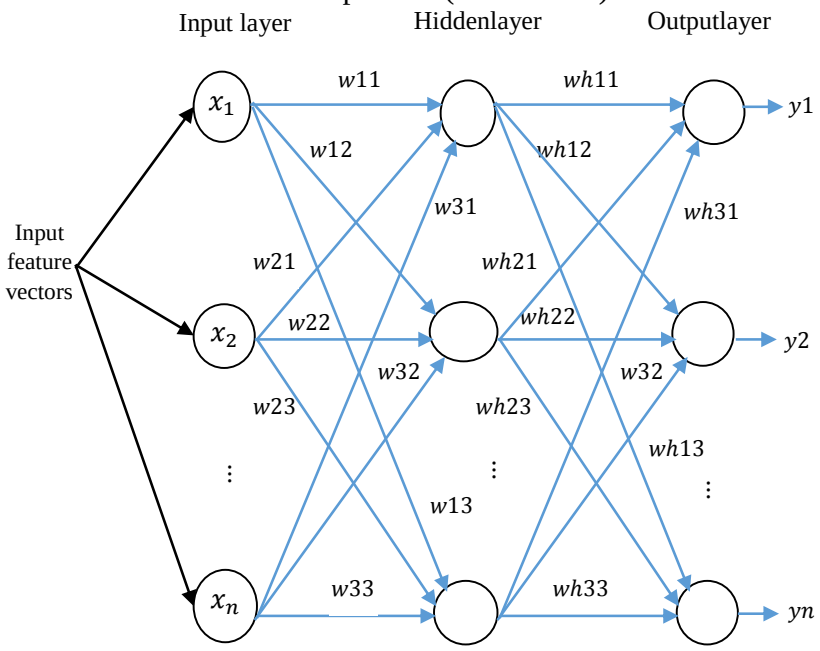

Figure 3: Process of FFNN

In this work, weight values of FFNN are considered as the particles and the total number of weights generated is taken as dimension. Input layer and output layer weight matrix is represented as W^{ih} and W^{ho}respecitvely. And position is taken as $p_i = \{p_i^{[ih]}, p_i^{[ho]}\}$ and velocity of $i^{th}$is considered as $v_i = \{v_i^{[ih]}, v_i^{[ho]}\}$ and so on. The calculation procedure of these particles is given as follows:

$$v'^{[ih][ho]}_k = v_k^{[ih][ho]}(m,n) + \frac{\left\{\alpha\beta\left(p_k^{[ih][ho]}\right) + ba\left(p_b^{[ih][ho]} - w_k^{[ih][ho]}\right)\right\}}{t} \quad (1)$$

$$w'^{[ih][ho]}_k = w_k^{[ih][ho]} + v_k^{[ih][ho]} \quad (2)$$

Where m, n→row and columns values of matrix, a, b → positive constants, t → time step which is taken as random values between 0 and 1, $v'^{[ih][ho]}_k$and $w'^{[ih][ho]}_k$→ updated velocity and weight values.

k^{th} particle fitness evaluation procedure is given as follows:

$$f = \frac{1}{N}\sum_{i=1}^{N}\left[\sum_{j=1}^{o}\left(t_{ij} - p_{ij}\right)^2\right] \quad (3)$$

Where t_{ij}→target output ,p_{ij}→predicted outputand N → number of training samples.

The stress level can be categorized accurately by using this proposed algorithm FFNN-PSO. If the volunteers are suffered with high or average level stress then they will be offered with music played in background. The stress level is reduced slowly by initially playing the mantras. Subsequent to the novel EEG information of patient, leads to the manipulation of subject's novel stress indices value. Novel stress indices value will evaluate with old stress indices value for presenting the stress of patient is low or high.

4. Results and Discussion

Based on the distinctiveness of the dataset, two foremost parameters should be measured when choosing the classifier is curse of dimensionality and bias variance substitution. Curse of dimensionality is that the amount of training information desirable to present high-quality outcomes rises exponentially with the aspect of the feature vectors, while bias-variance substitution is distinctiveness of classifier towards elevated bias with low variance.Here, the proposed stress classification method of FFNN-PSO performance has been evaluated and the results are compared with state-of-the-methods like Relevance Vector Machine (RVM), Support Vector Machine (SVM) and Linear Discriminant Analysis (LDA) by using EEG signal. Initially, stress indices value has been evaluated for analysis the EEG signal. Then, the performance are analysed in terms of classification accuracy, sensitivity and specificity.

Stress Level

In the stress recognition system, initial step is to measure and find the index value of volunteer stress level. It would be once completion of data gathering process. Once the data is gathered, stress indices of individual volunteers would be identified. This would be measured for both cognitive data and the physical data. This value would be taken as threshold value for the further processing of stress prediction. This is calculated because each volunteer would have varying EEG signal frequency based on their health impacts. This can be adapted by calculating the threshold stress index for individual volunteer. This research work measures individual stress indices (SI) for the finding the stress level of individual volunteers. Here graph construction procedure is used for the analysis process of gathered data. This graph would indicate stress level individual volunteer.

In figure 4, stress index value comparison has been given in two stages. It is used to indicate the variation present between different stress indices value. This graph represents the stress level before noise and after noise. It can be proved that the stress would be higher in case of presence of noise in the environment.

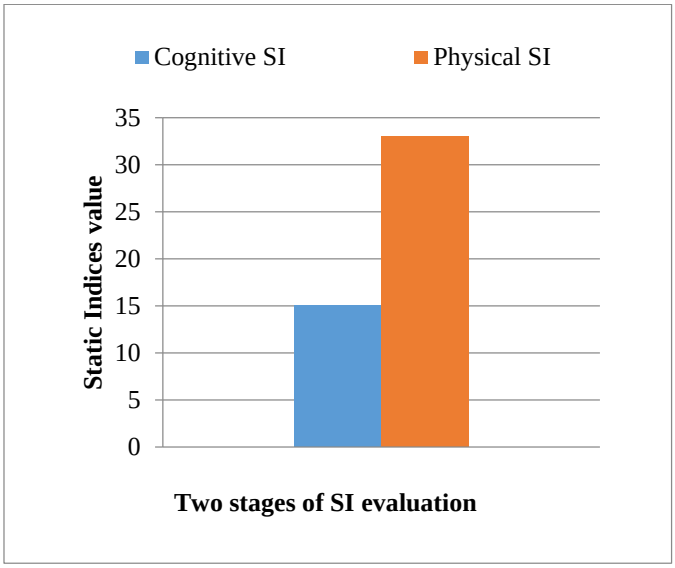

Figure 4: Stress Indices Values for Two Stages

After prediction of stress level of humans, it is required to update the stress index value based on the previous stress index values. This can be used to know the variation between the stress levels in different stages.

In figure 5, Stress index value is compared in the graphical format in three stages. Those stages are before task load, after task load, and after recovery. From this comparison it can be concluded that the stress index value after recovery would be lesser than other stages.

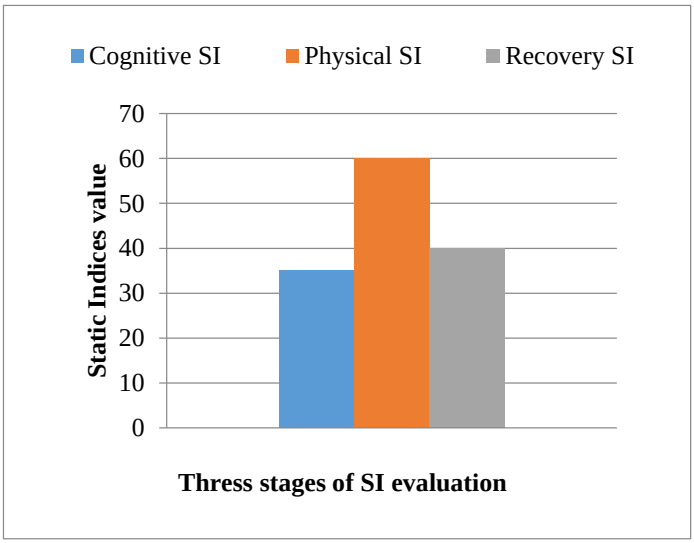

Figure 5: stress indices for three stages

Stress Rate Performance Comparison

Music is a kind of technique that can relief human from the high stress or

depression by relaxing their mood. It would help more for the aged peoples by relaxing their mind. Different music based on their behaviour can made ease of stress level reduction process. Figure 6,7 and 8 shows the stress rate value by using EEG signal based on time. These all predicts the stress and no stress rate by using EEG signal, when hearing noise and music's. As well as, when chanting the music, the stress level is measured. It's clearly shows, the stress level is less, when hearing and chanting music compared than to hearing noise. So, only the presented system has been focused to reduce the stress by using music's (i.e. traditional or classic).

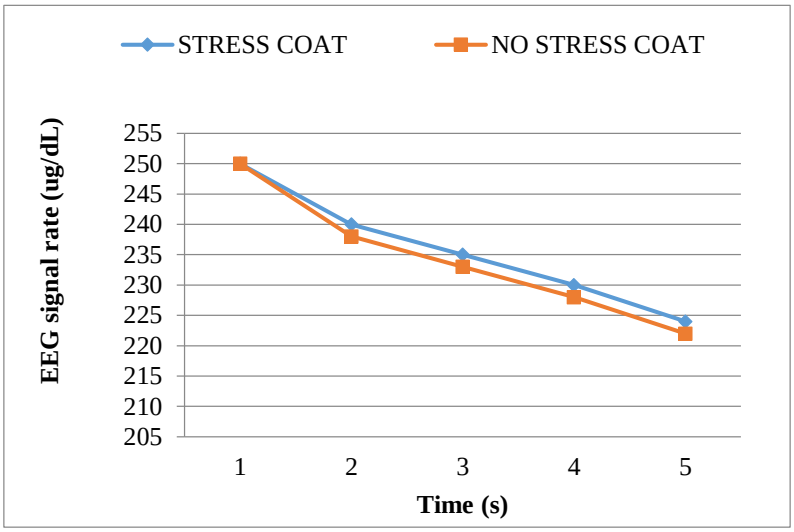

Figure 6: Stress Coat on Listening to Noise

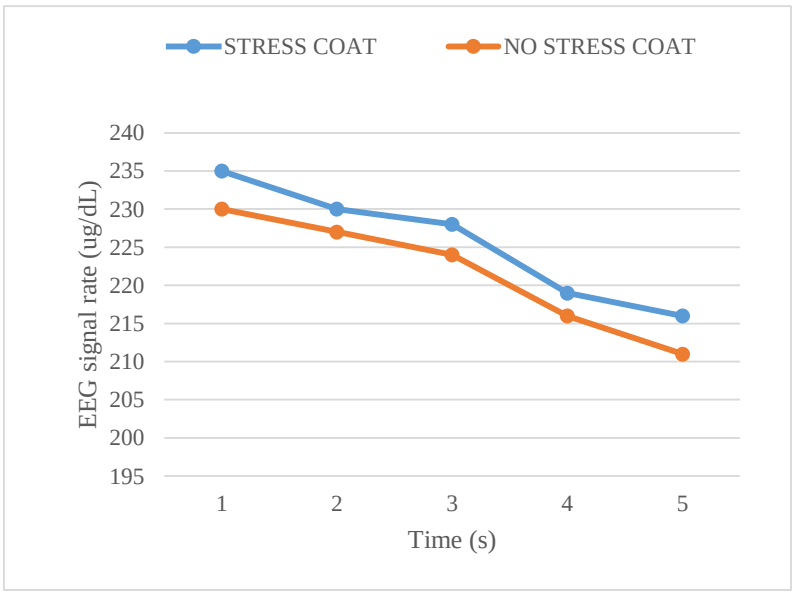

Figure 7: Stress Coat on Listening to Traditional or Classical Music

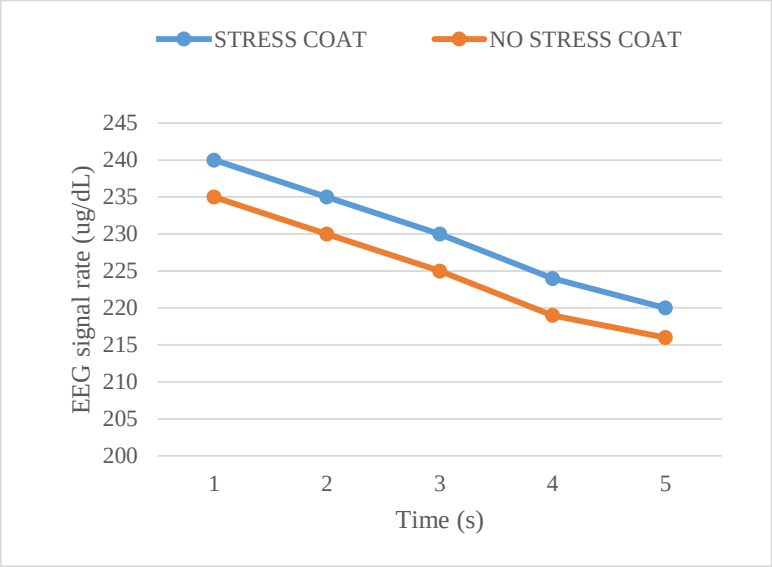

Figure 8: Stress Coat on Listening to Heavy Metal Music

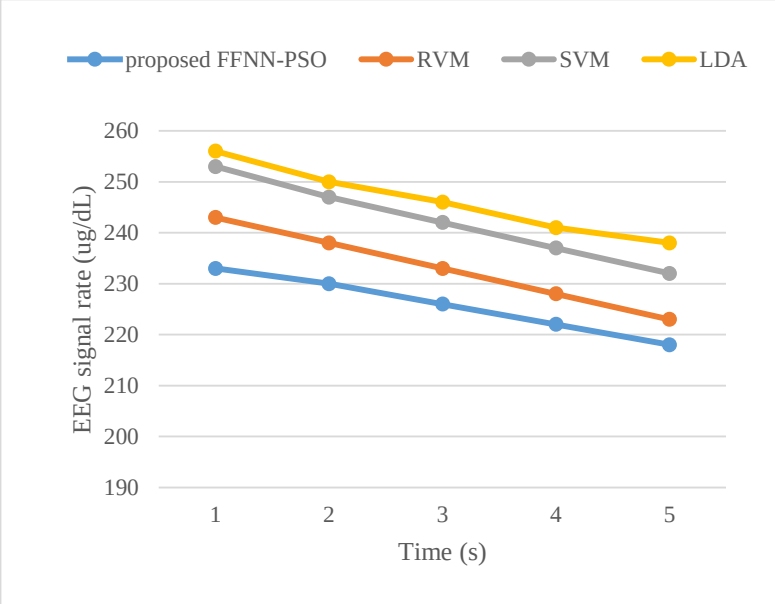

Figure 9: Stress Rate Analysis between Classification Schemes

In above figure 9 it shows the stress level among various classification schemes. It shows, the proposed FFNN-PSO attained less stress compared than existing schemes due to hearing and chanting music.

Accuracy, Sensitivity and Specificity Comparison

In figure 10it shows the overall performance comparison of accuracy, sensitivity and specificity for proposed FFNN-PSO and existing RVM, SVM and LDA. It shows the classification accuracy of proposed scheme attained high compared than existing schemes, due to the efficient pre-processing and

effectual classification by using FFNN with PSO. Then, the sensitivity of proposed FFNN-PSO attained high compared than others, due to less false negative errors, as well as the specificity is also high compared than others, due to the high true positive rate. When, the number of subjects increased means, the performance of proposed also increased. The proposed FFNN-PSO attained accuracy of 93.25%, sensitivity of 92.14%, and specificity of 97.52%. The numerical evaluation is showed in table 1.

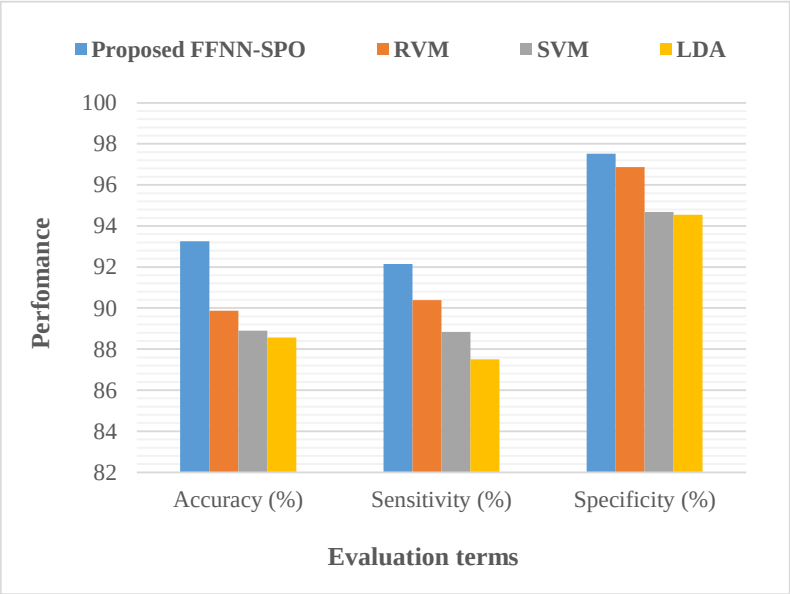

Figure 10: Overall Performance Comparisons among All classIfications Schemes

Table 1: Precision, Sensitivity and Specificity Performance Comparison for all Classifiers

Classifiers	Accuracy	Sensitivity	Specificity
Proposed FFNN-PSO	93.25%	92.14%	97.52%
RVM	89.87%	90.38%	96.87%
SVM	88.90%	88.84%	94.68%
LDA	88.56%	87.51%	94.54%

5. Conclusion

In this work, Feed Forward Neural Network with Particle Swarm Optimization (FFNN-PSO) based classification scheme has been presented for stress level classification and music introduced for reducing the stress level. In this process, at first, the EEG signal has been acquired and then pre-processed by using a digital band-pass filter for improving the image quality. Then, the PSD based features has been extracted for improving the classification performance. Finally, the features are classified by FFNN-PSO. In FFNN process, to attain minimum error the PSO is applied. The experimental outcomes demonstrate that the presented FFNN-PSO accomplished higher performance in terms of accuracy of 93.25%, sensitivity of 92.14%, and specificity of 97.52% contrast to the existing stress detection and classification algorithms with EEG signal due

to the effectual feature extraction and classification. In future, the neural network based some other classification schemes will focus with effectual swarm intelligence algorithms as well as focus some features like Gray Level Different Statistics (GLDS), Statistical Feature Matrix (SFM) and improve the accuracy.

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