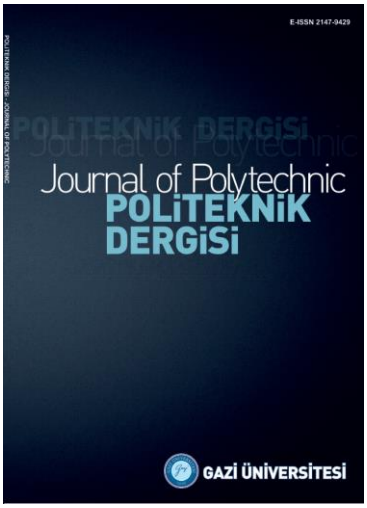

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EEG, EMG and ECG based determination of psychosocial risk levels in teachers based on wavelet extreme learning machine autoencoders

Dalgacık aşırı öğrenme makinesi otomatik kodlayıcılarına dayalı öğretmenlerde EEG, EMG ve EKG tabanlı psikososyal risk düzeylerinin belirlenmesi

***Yazar(lar) (Author(s))**: Dönüş ŞENGÜR*

ORCID: 0000-0002-8786-6557

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EEG, EMG and ECG based Determination of Psychosocial Risk Levels in Teachers based on Wavelet Extreme Learning Machine Autoencoders

Highlights

- *A novel approach is proposed for the prediction of the psychosocial risk levels of the teachers*
- *The proposed approach is based on two-level extreme learning machines (ELM). In the first level, an extreme learning machine autoencoder (ELM-AE) is considered for data augmentation. The autoencoder structure is employed to obtain an approximate reconstruction of the input dataset*

Graphical Abstract

The proposed method is composed of two-level ELM. In the first level ELM, the input is reconstructed by using WELM-AE structure. In WELM-AE, the input is reconstructed by using an ELM model where the wavelet kernel is used.

Figure. The illustration of the proposed method

Aim

In this study, a novel approach, which is based on data augmentation and data classification, is proposed for the prediction of the psychosocial risk levels of the teachers.

Design & Methodology

A two-level ELM is developed in order to detect the psychosocial risk levels in Teachers. In the first level, an ELM-AE is used for data augmentation. The autoencoder structure is employed to obtain an approximate reconstruction of the input dataset. In the second level, wavelet kernel based ELM is adopted for classification purposes.

Originality

Wavelet extreme learning machine autoencoder (WELM-AE) model is developed and used for data augmentation. The output weights of the ELM are calculated by using the Schur decomposition for efficient convergence.

Findings

The experimental works showed that the data augmentation is important and efficient in training of the ELM. In addition, wavelet kernels increased the performance of the ELM classifier.

Conclusion

The obtained results showed the superiority of the proposed approach. The conventional machine learning approaches were also used in experiments for performance comparisons. The comparison showed that the proposed method outperformed the other methods.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Dalgacık Aşırı Öğrenme Makinesi Otomatik Kodlayıcılarına Dayalı Öğretmenlerde EEG, EMG ve EKG Tabanlı Psikososyal Risk Düzeylerinin Belirlenmesi

Araştırma Makalesi / Research Article

Dönüş ŞENGÜR*

Firat University, Faculty of Education, Department of Educational Sciences, Elazig/Turkey

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ÖZ

Kutsal bir iş yapan öğretmenler birçok psikososyal riskle karşı karşıyadırlar. Bu riskler genellikle okul yönetimi, öğrenciler ve çevresel faktörlerden kaynaklanabilir. Makine öğrenimi ve veri madenciliği yaklaşımları son zamanlarda sosyal ve eğitim araştırmalarında bir hayli ilgi görmüştür. Bu çalışmada öğretmenlerin psikososyal risk düzeylerini tahmin etmek için veri artırmaya ve veri sınıflandırmaya dayalı yeni bir yaklaşım önerilmiştir. Veri artırma, aşırı öğrenme makinesi tabanlı otomatik kodlayıcıları (AÖM-OK) kullanılarak gerçekleştirilir. Daha spesifik olarak, dalgacık aktivasyon fonksiyonu ileentegre edilen AÖM-OK, DAÖM-OK adı verilen yeni bir yaklaşımın geliştirilmesini sağlamıştır. Veri artırmanın ardından öğretmenlerin psikososyal risk düzeylerinin tahmininde geleneksel bir AÖM sınıflandırıcısı kullanılmıştır. Önerilen yöntemin performans değerlendirilmesi için Elektrokardiyografi (EKG), Elektromiyografi (EMG) ve Elektroensefalografi (EEG) içeren bir veri kümesi kullanılmıştır. Sınıflandırma doğruluğu, değerlendirme ölçütü olarak kullanılmıştır. Tüm kodlamalar MATLAB'de yapılmış ve önerilen yöntemle % 99,9 doğruluk elde edilmiştir. Karar ağaçları (KA), destek vektör makineleri (DVM) ve K-en yakın komşu (KYK) gibi bazı makine öğrenimi teknikleriyle de performans karşılaştırması yapılmıştır. Sonuçlar, önerilen DAÖM-OK ve DAÖM sınıflandırıcısının karşılaştırılan yöntemlerden daha iyi performans gösterdiğini göstermiştir.

Anahtar Kelimeler: Öğretmenlerin psikososyal riskleri, fizyolojik faktörler, tahmin, AÖM, otomatik kodlayıcılar, dalgacık aktivasyon fonksiyonları.

EEG, EMG and ECG based Determination of Psychosocial Risk Levels in Teachers based on Wavelet Extreme Learning Machine Autoencoders

ABSTRACT

Teachers who perform a sacred work are faced with many psychosocial risks. These risks can often be caused by the school administration, the students, and environmental factors. Machine learning and data mining approaches have recently gained much attention in social and educational researches. In this study, a novel approach, which is based on data augmentation and data classification, is proposed for the prediction of the psychosocial risk levels of the teachers. The data augmentation is carried out by using an extreme learning machine autoencoders (ELM-AE). More specifically, the wavelet activation function is incorporated into the ELM-AE to develop a novel approach called WELM-AE. After data augmentation, a traditional ELM classifier is used in the prediction of the psychosocial risk levels of teachers. A dataset, which contains physiological factors, namely Electrocardiography (ECG), Electromyography (EMG), and Electroencephalography (EEG), is used to evaluate the performance of the proposed method. Classification accuracy is used as the evaluation metric. All coding is carried out in MATLAB, and a 99.9% accuracy score is obtained with the proposed method. A performance comparison is also carried out with some machine learning techniques, namely decision trees (DT), support vector machines (SVM), and K-nearest neighbour (KNN). The results show that the proposed WELM-AE and ELM classifier outperform the compared methods.

Keywords: : Psychosocial risks of teachers, physiological factors, prediction, ELM, autoencoders, wavelet activation functions.

1. INTRODUCTION

Psychosocial risks and stress in work life, which significantly affect the health of individuals, are two important issues in occupational health. The concept of the psychosocial risk is defined as the interaction between the job content, organization, management, and other organizational and environmental conditions and employee abilities and requirements [1]. Teaching, which

**Sorumlu Yazar (Corresponding Author)*
e-posta : dsengur@firat.edu.tr

exhausts the teachers both mentally and physically, is an important job in public. Teachers generally come across many psychosocial risks that are caused by either the school management or the students' attitudes.

As the literature is reviewed, it is seen that there are many factors, which affect the psychosocial risks of the teachers [2-4]. Souto et al. [2] investigated psychosocial factors associated with the development of job-related distress in the specific professional context of higher education teachers. Authors aimed to determine which dimensions of psychosocial risk were associated with work-related distress. Jemeļjanenko et al. [3] proposed a freamwork to investigate various methods researched by other authors on how to manage risk, analyze the causes of these risks, and make recommendations on how to deal with psychosocial risks in the education sector. Heredia et al. [4] explored the adaptation and validation of "CoPsoQ-Istas 21" in the Ecuadorian environment. The research was applied on 435 university professors to determine the level of psychosocial affect they were exposed to in their context. The research indicated that 72% of the professors who participated had a high level of exposure.

Authors generally intended to determine these factors and their interactions [5- 7]. Recently, there have been some works where the data mining approaches were used for the prediction of the psychosocial risk levels of the teachers. Mosquera et al. [5] used hill climbing and support vector machines (SVM) for prediction of the psychosocial risk levels of the teachers in Colombian public schools. To this end, a database was constructed that was collected from 5340 teachers. And 95% of the performance was reported by the authors. Ekici et al. [6] used various machine learning approaches, namely decision trees (DT), linear discriminant, SVM, k-nearest neighbor, and ensemble approaches for prediction of the psychosocial risk levels of the teachers. The authors used the dataset that was shared by [5]. The authors reported a 97.4% correct classification rate with SVM, where cubic and Gaussian kernels were considered. Viloria et al. [7] used three machine learning approaches, namely SVM, Naïve Bayes (NB), and genetic algorithm (GA), to determine the level of psychosocial risks for university lecturers. Experiments revealed that the SVM approach had achieved a 96.34% accuracy score for prediction.

In this paper, a novel approach is proposed for the prediction of the psychosocial risk levels of the teachers. The proposed approach is based on two-level extreme learning machines (ELM). In the first level, an extreme learning machine autoencoder (ELM-AE) is considered for data augmentation. The autoencoder structure is employed to obtain an approximate reconstruction of the input dataset. As wavelet kernel is considered in ELM-AE structure, we call the whole approach as wavelet extreme learning machine autoencoder (WELM-AE). The second level ELM is used for prediction of the psychosocial risk levels. In both ELM levels, instead of using the Moore-Penrose inverse in the calculation of the output layer weights, the Schur decomposition is employed due to its efficiency. A dataset that contains physiological factors such as hearth rate (ECG), skin electro-dermal activity (EMG), and electromyography (EEG) is used in experiments. The dataset contains 480 samples and five attributes. Holdout cross-validation test and classification accuracy are used in the experiments. The experimental works show that the proposed method is quite efficient in the prediction of the psychosocial risk grades of the teachers. The obtained prediction accuracy is 99.9%.

The main contributions of this paper are as following.

1-) Wavelet extreme learning machine autoencoder (WELM-AE) model is developed and used for data augmentation.

2-) The output weights of the ELM are calculated by using the Schur decomposition for efficient convergence.

The remainder of the paper is as following. The next section introduces the traditional background theories such as ELM and WELM-AE. Section 3 briefly introduced the proposed method. The experimental works and the obtained results are represented in Section 4. In Section 5, the conclusions are represented

2. BACKGROUND THEORIES

2.1. Hypotezis

As mentioned in the introduction section, psychosocial risks and stress in work life significantly affect the health of individuals. Various parameters can be used to determine these risks. In this study, the answer of the question "Can physiological signals namely EEG, ECG and EMG be used to determine the psychosocial risk levels in teachers by using machine learning techniques ?" is investigated. To this end, a dataset which covers EEG, ECG and EMG quantities and a novel approach based on machine learning are used.

2.2. Extreme Learning Machine (ELM)

The extreme learning machine (ELM) is a well-known supervised neural network model that contains a single hidden layer [8, 9]. In ELM, the input-output relationship is guaranteed by randomly assigning of the input weights, and hidden layer biases and the output weights are calculated by using Moore-Penrose inverse in one forward pass. Due to its simple structure, its learning ability is extremely fast and efficient.

Given the input-output training pairs $\{(x_i, y_i)|x_i \in R^w, y_i \in R^L\}_{i=1}^N$, where N is the size of the training dataset, w denotes the number of input features, and L represents the number of class labels, respectively. The hidden layer output matrix H of size $N \times K$ is then defined as;

$$H = \begin{bmatrix} g(a_1^T x_1 + b_1) & \dots & g(a_K^T x_1 + b_K) \\ \vdots & \ddots & \vdots \\ g(a_1^T x_N + b_1) & \dots & g(a_K^T x_N + b_K) \end{bmatrix}_{N \times K} \quad (1)$$

a_j and b_j denote the input weights and biases of the jth ($1 \leq j \leq K$) hidden layer neuron where K is the number of neurons in the hidden layer and g denotes the activation function. The output weights β is calculated by using the Moore-Penrose inverse (H') as given;

$$\beta = H'Y \tag{2}$$

where Y denotes the labels of the input features. To ensure a stable solution, β can be calculated by using the following formulation;

$$\beta = \left(\frac{I}{C} + H^T H\right)^{-1} H^T Y \tag{3}$$

where C is a positive integer.

2.3.Wavelet Extreme Learning Machine Autoencoder (WELM-AE)

AE, which is based on two parts, namely encoder and decoder, is an unsupervised learning method where the input data are also used as output data [10]. In the encoder part, the input data are projected to the hidden layer, and in the decoder part, an approximation of the input data is obtained. In the AE concept, the input X_(N×w) is initially encoded to a higher-level space and then an approximation of the input X_(N×w)' is obtained by using the encoded input X. Figure 1 shows the structure of one hidden layer AE architecture.

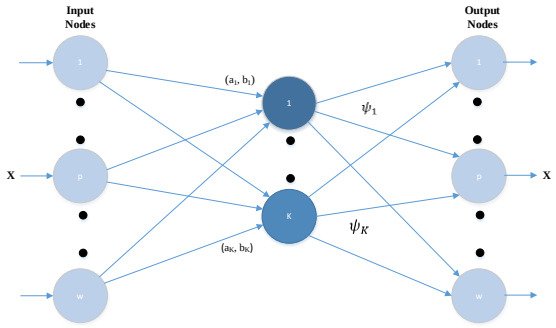

Figure 1. The architecture of the WELM-AE

As seen in Figure 1, the architecture of the AE is quite similar to the ELM structure, and thus, by using the ELM algorithm, the output of the AE can be easily obtained. By using the wavelet kernel ψ, the hidden layer output matrix H_ψ of size $N \times K$ is re-defined as;

$$H_\psi = \begin{bmatrix} \psi(a_1^T x_1 + b_1) & \dots & \psi(a_K^T x_1 + b_K) \\ \vdots & \ddots & \vdots \\ \psi(a_1^T x_N + b_1) & \dots & \psi(a_K^T x_N + b_K) \end{bmatrix}_{N \times K} \tag{4}$$

The Morlet wavelet kernel function is defined as [11];

$$\psi(t) = \cos(1.75t) e^{\left(-\frac{t^2}{2}\right)} \tag{5}$$

Similar to the ELM algorithm, the output weights β of the WELM-AE is calculated by using the Schur decomposition as given [12];

$$\beta = H_\psi^{Schur} X \tag{6}$$

The Schur decomposition of a square matrix H_ψ is defined as;

$$Q\, H_\psi^{Schur} Q^{-1} = H_\psi \tag{7}$$

where Q is the unitary matrix and H_ψ^{Schur} is an upper triangular matrix, which is called a Schur form of H_ψ. Thus, the output of the WELM-AE is obtained by;

$$X = H_\psi^{Schur} \beta \tag{8}$$

3. PROPOSED METHOD

The schematic illustration of the proposed method is represented in Figure 2. As seen in Figure 2, the proposed method is composed of two-level ELM. In the first level ELM, the input is reconstructed by using WELM-AE structure. In WELM-AE, the input is reconstructed by using an ELM model where the wavelet kernel is used. In WELM-AE structure, the input and output layers contains an identical number of neurons. The Morlet wavelet kernel is considered as activation function of the ELM model. The output of the WELM-AE and the input are concatenated and feed into the second level ELM structure for prediction of the psychosocial risks of the teachers. In both ELM levels, the Schur decomposition is used for calculation of the output weights instead of Moore-Penrose inverse.

4. EXPERIMENTAL WORKS AND RESULTS

The dataset, which was used in experimental works, was collected on public school teachers in the metropolitan area of a Colombian city [4]. Bitalino hardware, which is an easy-to-use, versatile and scalable hardware platform for bio signals acquisition and wireless transmission in real-time, was used to collect the dataset in eight months [13]. A random sample of 480 teachers, who participated voluntarily, was used to collect the physiological quantities, namely hearth rate (ECG), skin electro-dermal activity (EMG), and electromyography (EEG). Dataset was initially normalized into [0, 1] interval. Randomly selected 70% of the dataset was used for training, and the rest 30% was used for testing the proposed method. All coding was carried out by using MATLAB software. The classification accuracy was used for the performance measure of the proposed method. The parameters of the ELM were selected heuristically during the experimental works. The C value of the ELM was set to 1000. The number of the hidden nodes was set to 100 [12-13]. Table 1 shows some obtained results by using various wavelet kernels. The same wavelet kernel was used in both WELM-AE and ELM classifier methods.

Table 1. The obtained results by using various wavelet kernels.

Wavelet Kernels	Accuracy (%)
Gauss wavelet	99.97
Morlet wavelet	99.99
Mexican wavelet	99.98
Shannon wavelet	99.85
Meyer wavelet	99.97

As seen in Table 1, the best accuracy score 99.99% was obtained by using the Morlet wavelet kernel. Mexican wavelet kernel yielded the second best accuracy score, where the calculated accuracy was 99.98%. Gauss and Meyer wavelet functions produced the identical accuracy scores that were 99.97%. Finally, the worse accuracy score 99.85% was produced by the Shannon wavelet function. We also gave the results where the traditional pseudo inverse was used instead of the Schur decomposition. The obtained results were given in Table 2. As Tables 1 and 2 were compared, it was seen that the Schur decomposition was efficient in improving the obtained results.

Table 2. The obtained results by using various wavelet kernels

Wavelet Kernels	Accuracy (%)
Gauss wavelet	99.95
Morlet wavelet	99.97
Mexican wavelet	99.94
Shannon wavelet	99.81
Meyer wavelet	99.94

We further compared the obtained result with the traditional machine learning approaches, namely DT, SVM, and KNN. The MATLAB classification learner tool with a default setting was used in the implementation of the mentioned methods. The comparison results were given in Table 3. As seen, the proposed method outperformed the compared methods. SVM and KNN approach produced a 99.3% accuracy score, and DT produced a 98.3% accuracy score, respectively.

Table 3. Performance comparison of the proposed method with some machine learning methods

Method	Accuracy (%)
DT	98.3
SVM	99.3
KNN	99.3
Proposed method	99.9

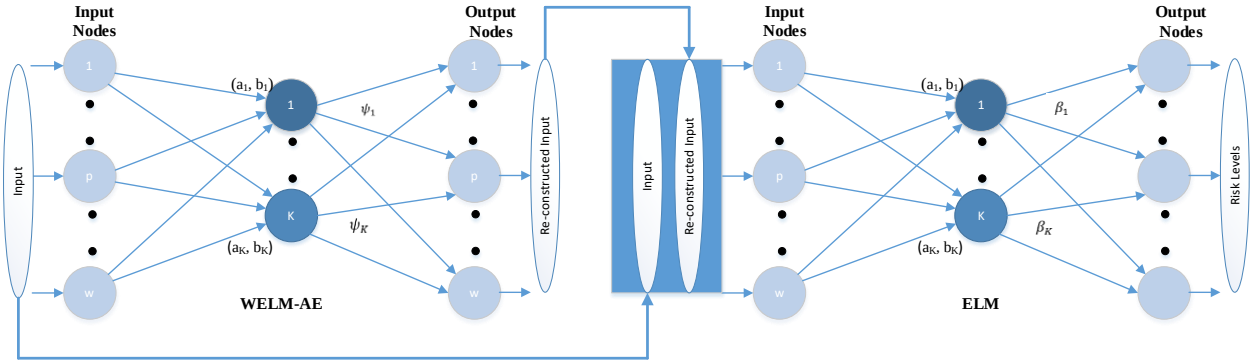

Figure 2. The illustration of the proposed method

5. CONCLUSIONS

In this paper, a novel approach was proposed for prediction of the psychosocial risk levels of the teachers. In the proposed approach, a two-level ELM scheme was used for efficient prediction. In the first ELM level, the WELM-AE was developed for data augmentation, and in the second ELM, the prediction was carried out. Schur matrix decomposition was considered in ELM structures for output weights calculations. A dataset that contains physiological factors such as ECG, EMG, and EEG was used to evaluate the performance of the proposed method, and the obtained results showed the superiority of the proposed approach. The conventional machine learning approaches were also used in experiments for performance comparisons. The comparison showed that the proposed method outperformed the other methods.

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DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Dönüş ŞENGÜR: The author conceived and worked to achieve this work**.**

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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