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Intelligent human emotion recognition based on elephant herding optimization tuned support vector regression

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ABSTRACT

The ability to recognize emotional states of people surrounding us is an important portion of natural communication as emotions are fundamental factors in human decision handling, interaction, and cognitive procedure. The primary intention of this paper is to present an approach that uses electroencephalography (EEG) signals to recognize human emotions. This work targets emotional recognition in terms of three emotional scales; valence, arousal and dominance. EEG raw data were pre-processed to remove artifacts, discrete wavelet transform (DWT) was applied for features extraction. Moreover, support vector regression (SVR) is combined with Elephant herding optimization (EHO) to predict values of the three emotional scales as continuous variables. Multiple experiments are applied to evaluate prediction performance. EHO was applied in two stages of optimization. Firstly, to fine-tune regression parameters of the SVR. Secondly, to select the most relevant features extracted from all 40 EEG channels and eliminate ineffective and redundant features. To verify the proposed approach, results proved EHO-SVR ability to gain relatively enhanced performance measured by regression accuracy of 98.64%. Therefore, SVR is introduced in this paper as a better technique for predicting emotions as quantifiable continuous variables rather than classifying emotions into discrete emotional values.

1. Introduction

Human emotions are vital for human machine interaction (HMI) and affective computing. Some emotional examples are happiness, sadness, surprise and anger. Recently, there are many research efforts focusing on brain activity analysis, where subjects experience different emotional states. The ability to realize emotional states of people is an important part of natural communication. Currently, considering how much machines are involved in our lives, realizing human emotions by machines has been a research trend in brain computer interfacing (BCI) and advanced HMI. A reliable system for emotion recognition is a vital requirement to cope with the evolution of HMI. such system is required to grant good recognition performance, artifact tolerance, and adaptation to practical applications. In past years, a number of research efforts have been introduced in the field of emotion recognition [1].

With regards to EEG-based emotion recognition, various techniques have been proposed such as support vector regression (SVR), neural networks (NN), K-nearest neighbor (k-NN) and fuzzy systems. However, there have been significant findings proved that SVR is a superior regression technique in the field of emotion recognition based on EEG signals [2]. However, all regression techniques depend on a set of regression tuning parameters and kernel functions. According to what can be demonstrated from the experimental results in [3], regression performance can be significantly affected by such parameters. In [4], authors have proposed an emotion regression approach applying supervised learning and Bayesian classifier. Feature extraction stage employed fast Fourier transform. Then feature selection was achieved through the application of correlation coefficients.

Several studies [5,6] have employed feature extraction, regression and classification. In this section, we review few research efforts which explore EEG feature extraction and regression problem in the domain of human emotion to detect emotion based on different classifiers. Brain emotional system is considered the

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substrate for emotion-related processes, EEG can expose intrinsic information on their task. Research on how EEG activity is related to emotions have created a lot of attention [7]. Furthermore, lots of studies have concentrated on the issue of asymmetric activation of the encephalic hemisphere. Also, Davidson et al. [8], stated that positive and negative emotions are related to relative left and right frontal EEG activities respectively. Baumgartner et al. [9], have pointed out that happy conditions are related to an extension to the left hemisphere, in contrast with unfavorable emotional conditions. In addition to research on asymmetrical activation of the encephalitic hemisphere, event-related potentials have also been utilized to study the association with EEG signals and human emotion.

The remainder of this paper is drawn as follows; literature review is introduced in Section 2. Section 3 presents a review of materials and methods used in this paper. In Section 4, research methodology is illustrated including EEG data, feature extraction, feature selection, emotion classification approach. The results of emotion detection are provided in Section 5 and at the end, Section 6 concludes the paper providing discussions on issues regarding the proposed approach and future work.

2. Literature review

The comparison among different studies in terms of machine learning techniques is not an easy task. Most studies comprise different preprocessing, features processing, experiment environments and other variations. However, such factors strongly affect the performance of a classification model. EEG data classification and regression have been the target of many research efforts under different machine learning techniques [10]. Some examples are K-Nearest neighbor (KNN), support vector machine (SVM) and artificial neural network (ANN) [11]. According to an extensive survey carried out by Rani et al. [12], KNN is one of the most widely used techniques for classifying EEG data and in the same context Rani et al., strongly supports SVM and recommend it for accurately classifying EEG data. According to experimental results in [13], SVM provides effective and promising results for classifying EEG data. Also, ANN was stated to have the ability to accurately classify EEG data in [14], authors also stated that ANN would be more useful when a small number of electrodes are used. Eventually, these techniques were found to be employed in most of the empirical studies we have found and were considered suitable for EEG data classification according to the results. Therefore, KNN and SVM are considered the most common among classifiers with the highest attained accuracy which is our main interest in this work. Several methods have been successful when applied to develop classification models from physiological indices. However, it is still important to find an appropriate method for EEG data to attain uniformity in various aspects of emotion selection, data collection, data processing, feature extraction and feature selection. Table 1 summaries some techniques applied in the same area of EEG-based machine learning.

Table 1
Summarization of previous studies on the classification techniques and the accuracy (Ac).

Studies	Classifier	Accuracy	Remark
[15]	SVM	90.72%	Calculated power difference among 12 symmetric pairs of electrodes using EEG signals from different sources EEG signals from different sources, applying Fourier transform.
[16]	SVM	62.07%	Dimensionality Reduction, and normalization approaches were applied.
[17]	SVM	63%	Identifies three emotional states using EEG Signals.
[18]	SVM	73%	Identifies two emotional states of a person using an emotion understanding system
[19]	SVR-GA	87.30%	Three classifiers such as SVR-GA, Multinomial (NB) and Ensemble On-line Sequential Extreme Learning Machine that learn different aspects of the emotion dataset samples are used.
[20]	SVM-based	86%	Proposed moth-flame optimization (MFO) approach.
[1]	SVM-based	91.77%	Linear Discriminant Analysis (LDA) is applied.
[11]	KNN	83.33%	KNN is applied.
[21]	ANN	90%	ANN-based method is applied.
[22]	NN	99%	Radial basis function neural network (RBFNN) is proposed.
[23]	PNN	99%	Probabilistic neural network (PNN) and Genetic algorithm (GA) is proposed.

With its remarkable generalization performance, support vector machine (SVM), firstly designed for pattern recognition by Vapnik [24] for classification purposes, has gained extensive applications in regression estimation (in which it is called SVR) and is thus introduced to time series forecasting/prediction problems. SVR is compared with multiple other models and shows superior forecast performance [25,26]. In the same context, important to point that proposed results express regression accuracies for emotional states as continuous variables which is more valid and accurate than other techniques proposed in literature that targeted regression of emotional values as discrete classes. Also, they suffer from low efficiency and computation time limitations as shown in Table 1. To overcome such drawbacks, SVR was applied in this work as a more efficient regression technique.

Thus, due to the nature of the EEG dataset applied in this work and the aims of this study to recognize human emotions from the EEG dataset, SVR is regarded the most suitable machine learning technique. Therefore, the major goal of this work is to realize an efficient predictor to perform further robust and precise approach in emotion recognition from EEG signals to improve the obtained accuracy that has been achieved in previous studies based on swarm intelligence (SI) [27]. This paper applies elephant herding optimization (EHO) [28] to optimize SVR parameters and select the most relevant features from input data set. In this paper we relied on SVR to recognize the emotional states of subjects as continuous variables, and we consider this as accuracy achievement over previously proposed classification techniques that clusters emotional values in discrete classes such as SVM and NN.

3. Materials and methods

Next paragraphs discuss the most vital techniques applied in this work and the targeted data set.

3.1. EEG dataset description

This research was established based on a dataset that was published under the name of (DEAP), short for a database for emotion analysis using physiological signals [29,30]. It was established for the purpose of human effective states analysis and detecting emotional indications that could be extracted during human-computer interaction which could lead to proper machine response. Emotional scales have been widely discussed in research. Russell introduced the valence-arousal scale [31] that was widely applied by researchers to quantify emotional states. The circumplex model that models any emotional state as a point in two dimensions (valence and arousal) presented in [32] which is visualized by Fig. 1.

In this scale, an emotion is described in two dimensions with horizontal and vertical axes representing arousal and valence values respectively. This as well as dominance as a third significant emotional scale. Data is multi-modal in nature that encompasses EEG signals and peripheral physiological signals for a number of