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Classification of Motor Imagery EEG Signals using Adaptive Neuro-Fuzzy Inference System Trained by Particle Swarm Optimization

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Brain-computer interfaces (BCI) applications have experienced an increasing attention during the last decade [1]. Among the main procedures of EEG based BCI systems, including preprocessing, feature extraction and classification, the last step (classification) is one of the most challenging in the realm of BCI, due to the highly stochastic nature of EEG signal. Several linear classifiers such as linear discriminant analysis (LDA), linear support vector machine (SVM) and non-linear classifiers such as neural networks and adaptive neuro-fuzzy inference systems (ANFIS) have been proposed to classify EEG signals and each of them has shown to be efficient on different kinds of EEG features like P300, visual evoked potentials (VEP) and sensorimotor rhythms (motor imagery signals). Among them, ANFIS due to its strength, originating from both neural network and fuzzy inference systems, seems to have the potential to be used as a robust classifier for motor imagery EEG signals [2]. ANFIS is conventionally trained by a dataset that uses neural network based methods and measures such as backpropagation and least square estimation to adjust fuzzy rules' parameters. On the other hand, particle swarm optimization (PSO) which is an evolutionary optimization technique, has shown to be an effective method for optimization [3]. Thus, in this study we investigated training an ANFIS classifier using PSO instead of backpropagation which is conventionally used for ANFIS training. We used dataset III of the BCI competition 2003 database which comprises 3 channel (C3, Cz, C4) EEG recordings of 280 nine-second trials of left and right hand motor imagery with 140 trials of training and another 140 trials of test data. Then, we applied continuous wavelet transform and student's t-test to extract eight features from each trial with 4 features from each alpha [8-13 Hz] and beta [18-25 Hz] frequency bands. A full description of the feature extraction methodology has been described in our last study [2]. Next, we trained an ANFIS classifier by PSO using Matlab®. We first created a fuzzy inference system (FIS) by subtractive clustering. Then created a swarm of 10 particles, each held a collection of 125 parameters to be used for fine tuning of fuzzy membership functions of the created FIS. Afterwards, all swarm members were evolved for 100 epochs and finally the particle with the best fit function were selected as the winner and the ANFIS parameter were replaced by the winner particle's members. We compared the results of ANFIS-PSO classifier with 3 other classifiers (Traditional ANFIS, LDA and SVM) as benchmark classifiers which were fed by the same features of the training and test data.

Classifier	Accuracy (Training Data)	Accuracy (Test data)
ANFIS-PSO	85.7 %	79.3 %
Traditional ANFIS	80.0 %	81.4 %
LDA	82.9 %	85.7 %
SVM	85.7 %	82.9 %

Table 1: Comparison of the accuracy of four classifiers

As detailed in Table 1, the ANFIS-PSO and SVM classifiers achieved the highest accuracy in classifying training data (85.7 %), which outperformed the traditional ANFIS trained by backpropagation. However, when classifying the test data, the traditional ANFIS performed slightly better than ANFIS-PSO, with LDA achieving the highest accuracy. In summary, it has been demonstrated that PSO is suitable for ANFIS training as a classifier for motor imagery EEG signals, with an accuracy comparable to that of other more common classifiers such as LDA, SVM and conventional ANFIS.

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