Different Dimensionality Reduction Methods for Classification Different Hand Motions Using Energy Wavelet Packet Backpropagation Neural Network

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Abstract: In this paper different dimensionality reduction (DR) methods were implemented to classify eleven hand motions. Multilayer perceptron neural network (MLPNN) with backpropagation (BP) learning method was implemented to recognize the extracted feature vector (FV) of surface electromyographic (sEMG) signal. The highest achieved classification accuracy was 94% by implementing MLPNN classifier and using principle component analysis (PCA) projection method based on: /RMS-EWPC/ features combination and /SampEnt-RMS-MYOP-DASDV/ features combination. Where (RMS) is root mean square, (EWPC) is energy of wavelet packet coefficients, (SampEnt) is sample entropy, (MYOP) is myopulse percentage rate and (DASDV) is difference absolute standard deviation value. In order to improve the pattern recognition rate, artificial bee colony- multilayer perceptron neural network (ABC-MLPNN) was implemented instead of back propagation learning algorithm. An obvious improvement of the average accuracy rate was achieved by 2% when using the hybrid proposed method.
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Keywords: feature projection; pattern recognition; feature extraction; wavelet packet analysis; artificial intelligence; backpropagation algorithm; neural network; artificial bee colony.

1. Introduction

EMG has been used for diagnosis of neurological and neuromuscular problems, in the field of assistive technology and rehabilitation engineering. The usage of a forearm sEMG signal to classify different types of hand motions has become a challenging topic for many researchers (Boostani and Moradi, 2003; Subasi, 2012; Xu and Ping, 2012). The sEMG signal is a bioelectrical signal detected from the skin surface that is generated by the electrical activity of the muscle fibers during contraction or relaxation. The EMG signal is stochastic and has complicated nature and it is difficult to quantify and interpret the processed signal (Duhan et al., 2011). An example of sEMG generated by one volunteer performing clarified in (Figure 1).

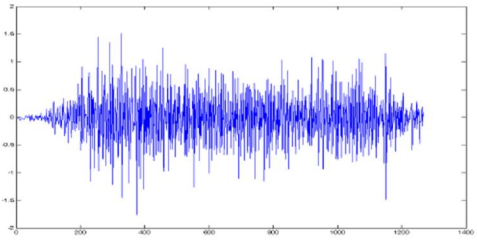

Figure 1. Shows 1267 points-window of acquired sEMG signal for one subject performs open hand motion collected using sEMG signal recording equipment (AD Instrument's Power Lab 4/25 T).

In the following section of the manuscript, we present some of the recent works related to wavelet analysis, neural network and pattern recognition.

Yang et al. (Yang et al., 2012) had succeeded to construct a real time handwriting recognition system able to recognize Arabic numbers and lowercase letters. The average achieved classification rate was above 90%. Englehart et al. (Englehart and Hudgins, 2003) proposed a control myoelectric signals of four classes based on wavelet transform to classify four different hand motions with relatively low response time. Sebelius et al. (Sebelius et al., 2005) established an EMG pattern recognition system based on artificial neural network (ANN) to classify seven hand movements. Kuo and Landgrebe (Kuo and Landgrebe, 2004) proposed nonparametric weigh feature extraction of EMG to improve the performance of linear discriminant analysis method. Arif et al. (Arif et al., 2012) proposed a conceptual method counting of people in the crowd using surveillance visual camera. They extracted features from foreground pixel area for different segmentation. Feature vector of the extracted features was introduced to neural network. The achieved classification accuracy was above 96%. Hu and Ren (Hu and Ren, 2006) proposed an algorithm to extract features from sEMG signal to distinguish forearm supination (FS) and forearm pronation (FP). They found that wavelet packet entropy (WPE) is an effective method in comparison to wavelet packet transform (WPT) to extract the feature from sEMG

signal. A feature extraction method was proposed by Tsai et al. (Tsaia et al., 2014) using the short-time Fourier transform ranking feature to determine multi-channel EMG signals. They found that the proposed STFT-ranking feature is less affected by variation in EMG signals. They succeeded to achieve accuracy rate more than 90%. Karimi (Karimi, 2011) extracted the standard deviation of wavelet packet coefficients of sEMG and proposed genetic algorithm to optimize the work of artificial neural network.

The remainder of this manuscript is divided into five sections. The first describes the experiment and method. The second gives an introduction about the extracted feature vector and dimensionality reduction methods. The third section presents the classification algorithm that was used in this research study and gives a description about the proposed pattern recognition system. The fourth presents and discusses the results obtained from the experiment, and the final section presents our proposed hybrid model based on ABC algorithm.

2. Material and Methods

Two pieces sEMG signal recording equipment (AD Instrument's Power Lab 4/25 T) were used. Twelve hand-dominant healthy subjects (Ten males and two females, aged from 20 to 38 years) without any neuromuscular disorders participated in this experiment. Disposable moisture Ag/AgCl electrodes were used to obtain the sEMG signals from the surface of the skin. Band-pass filter and notch filter were used to eliminate the noise. Due to the different sizes of the forearms and muscles of the different subjects, the determination of the electrode placements required experience (Al Omari et al., 2014).

This research work was conducted only by individuals with the appropriate ethical and scientific education, training and qualifications (all of them are students enrolled in Jiangsu University). One of the factors that affect muscle tension is muscle fatigue. If the contraction of a muscle is sustained with sufficient force for a long enough period of time, the conduction velocities of the action potentials along the muscle fibers begin to decelerate and the muscle starts to respond less frequently. In order to prevent muscle fatigue, the subject requested to get a rest for a few minutes after performing a complete sequence.

3. Feature Extraction

The myoelectric signal should be mapped into a smaller dimension vector that called feature vector (FV) before introducing it to a classifier, due to the large amount of recording data and randomness of sEMG signal (Oskoei and Hu, 2007). In this research we proposed a novel method to classify eleven hand motions; five features were extracted from the collected EMG signals: Sample entropy (SampEnt), root mean square (RMS), myopulse percentage rate (MYOP), and difference absolute standard deviation value (DASDV) and energy of wavelet packet coefficients (EWPC).

Wavelet analysis shows a robust performance in the filed of myoelectric pattern recognition (Al Omari et al., 2014). Wavelet transform represents a more flexible approach with a variably sized window. The wavelet packet method is a generalization of wavelet decomposition, which offers a better frequency resolution of decomposed signal. In the last decade, wavelets packet analysis become very popular and has many applications in different fields (Zhou et al., 2014; Pavez and Silva, 2012; Peng et al., 2013; Ates and Tamer, 2009; Morsi and El-Hawary, 2009).

In previous research work, we found that the performance of a classifier is improved through the implementation of more than one feature (Al Omari, Guohai, Hui and Congli, 2014). In this study two combination features FC1 and FC2 were constructed in order to improve the quality of the extracted feature vector, which leads to high classification accuracy. FC1 represents / RMS-EWPC/, while FC2 represent /SampEnt-RMS-MYOP-DASDV/.

The next step, the constructed feature vector was introduced to dimensionality reduction algorithm; five feature projection methods were tested: neighborhood preserving embedding (NPE), linear discriminant analysis (LDA), principle component analysis (PCA), fuzzy linear discriminant analysis (FLDA) and independent components analysis (ICA).

4. Multilayer Perceptron Backpropagation Neural Network

Data mining is a technique for analyzing data to extract the hidden predictive information from large databases. Different levels of analysis are available through decision trees, artificial neural networks, and swarm intelligence. Data mining had many applications in the fields of image processing, medicine, industry, and security. The biological neuron has served as the inspiration for the artificial neuron. A biological neuron consists of three main components: dendrites, cell body and axon. Extensive studies have been carried out on artificial neural network (ANN). In this study, for classification step, multilayer perceptron (MLP) neural network with backpropagation learning method was employed for classification of motions. The main concept of the backpropagation algorithm is based on reducing the difference between actual and expected results (the

error) through learning process, until the networks learn well.

Our ultimate target is to construct a robust myoelectric recognition system that will classify unknown patterns with the with highest classification accuracy. In total, we have (2200) EMG subset from twelve subjects. The MATLAB computational software was used to extract the features from the sEMG signal and for the classification procedure. The data divided to (20%) for training data, (20%) for validation, and (60%) for test. The whole procedure is clarified in (Figure 2).

5. Results

1- PCA shows more robust performance than NPE, LDA, FLDA and ICA. The best achieved result accuracy rate was 94% by employing feature combinations FC1, FC2 based on PCA.

2- Form experimental result, it is clear that the performance of FLDA and ICA better LDA. The feature combination FC1 gave accuracies of 89% and 86% for FLDA and ICA respectively using MLPNN classification method.

3- The result achieved using NPE is far from that achieved by the others methods. However, for the future work, it is not recommended to implement NPE when using MLPNN as a classification method. These results are visually shown in (Figure 3).

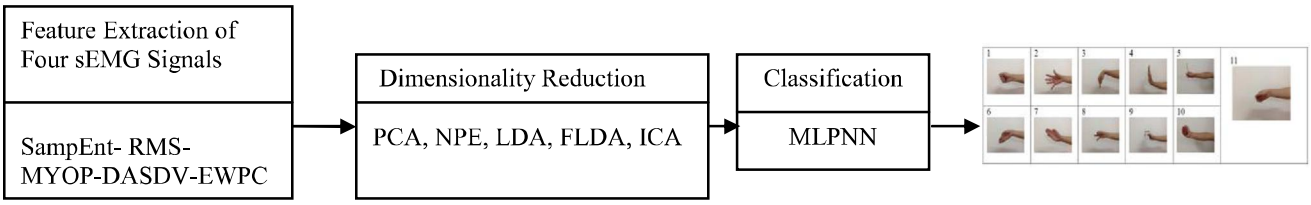

Figure 2. Flow diagram showing the key elements of the sEMG pattern recognition system. Four sEMG signals were collected from two data acquisition systems, and then FV was extracted from the recorded signals. In the next step, different dimensionality reduction methods were implemented. Then BPNN was employed to recognize eleven hand motions.

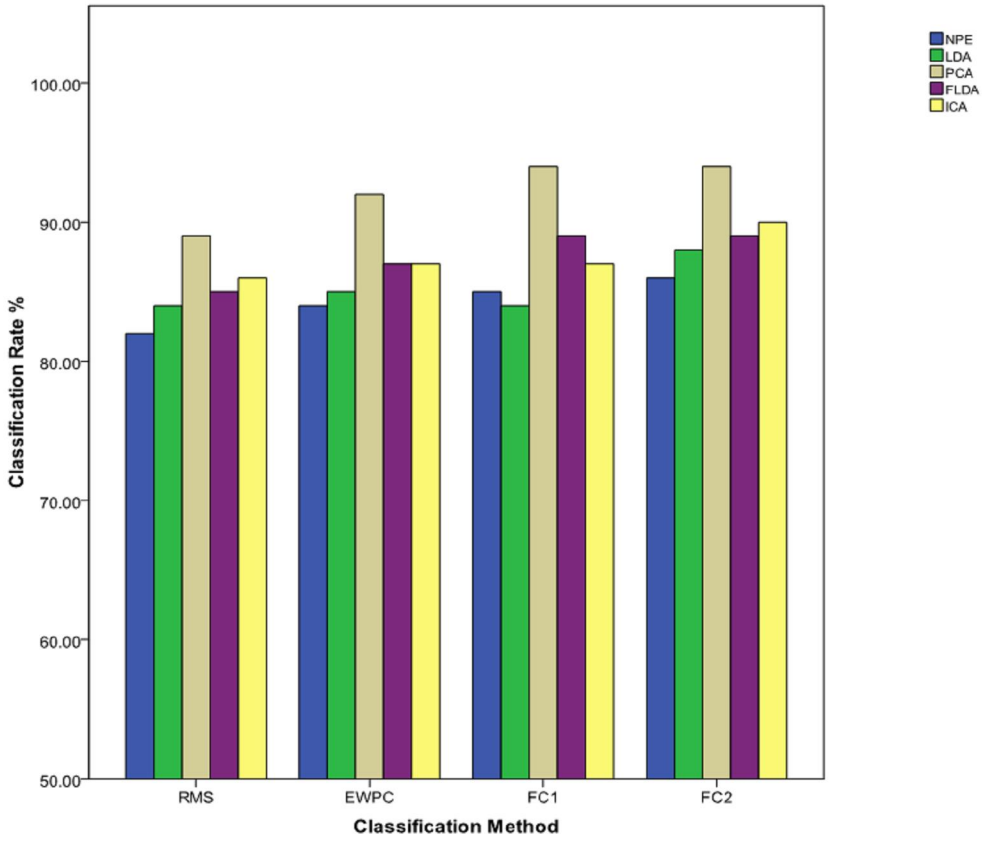

Figure 3. Average classification rates using the MLPNN classifier with different dimensionality reduction method

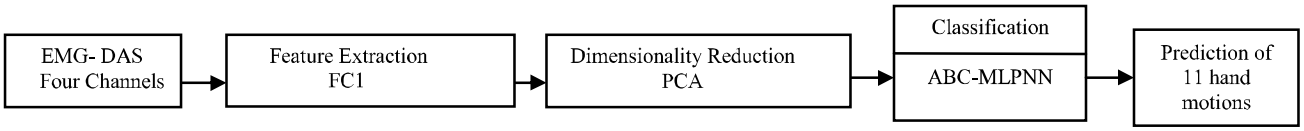

Figure 4. Shows the proposed EMG-pattern recognition system that consists of four stages. Data acquisition system (DAS), feature combination (FC1) based on RMS and EWPC extracted features, principle component analysis for dimensionality reduction (PCA), and artificial bee colony- multilayer perceptron neural network ABC-MLPNN.

6. Proposed ABC-MLPNN Algorithm

One disadvantage of using BP learning algorithm is that it can be easily trapped on local minima. That leads to increase in weights, training time, and the number of nodes.

Artificial bee colony (ABC) algorithm is proposed as learning method to overcome the weak point caused by backpropagation algorithm and to improve a learning algorithm. ABC algorithm is very simple, flexible in comparison to other intelligent artificial algorithms like genetic algorithm (GA). More details about this algorithm is furnished in Karaboga literatures (Karaboga, 2005; Karaboga and Basturk, 2007). The proposed myoelectric control system based on ABC optimization method is clarified in (Figure 4). The output layer of ABC-MLPNN consists of eleven nodes (reflect different hand motions).

Our experimental results show that there is an improvement in the terms of classification accuracy achieved by the proposed ABC-MLPNN classification system. The ABC-MLPNN yielded an overall accuracy of 96% on (2200) signals collected from twelve subjects (ten males and two females).

7. Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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