EMG SIGNAL CLASSIFICATION USING WAVELET TRANSFORM AND FUZZY CLUSTERING ALGORITHMS

Yücel Koçyiğit yucel@ehb.itu.edu.tr

Mehmet Korürek korurek@ehb.itu.edu.tr

İstanbul Technical University, Faculty of Electrical & Electronics Engineering, Department of Electronics and Communication Engineering, Ayazaga, Istanbul, Turkey

Keywords: Surface electromyographic signal, wavelet transform, fuzzy clustering, dimensionality reduction..

Abstract

The electromyographic (EMG) signals can be used as a control source of artificial limbs after it has been processed. The objective of this work is to achieve better classification for four different movements of a prosthetic limb making a time-frequency analysis of EMG signals which covers a feature extraction tools in the problem of the EMG signals while investigating the related dimensionality reduction and fuzzy classification.

I. INTRODUCTION

The electromyographic (EMG) signal observed at the surface of the skin is the sum of thousands of small potentials generated in the muscle fibers. This signal can be used as a control source of artificial limbs after it has been processed.

The classification problem may be divided into the stages of feature extraction, dimensionality reduction, and pattern classification. Different features have been used for classification of EMG signals for upper limb in several papers: Time domain features, autoregressive (AR) coefficients, cepstral coefficients , wavelet transform coefficients. In addition, different classification methods have been used in this topic: artificial neural networks, fuzzy logic.

EMG signals are nonstationary and have highly complex time-frequency characteristics. Consequently, these signals can not be analyzed using classical methods such as Fourier transform. Although the short time Fourier Transform can be used to satisfy the stationarity condition for such nonstationary signals, it suffers from the fact that the performance depends on choosing an appropriate length of the desired segment of the signal. To overcome such problem, Wavelet Transform was used as a feature extraction method and has been widely used in signal analysis [1].

Fuzzy logic systems are advantageous in biomedical signal processing and classification. Biomedical signals are not always strictly repeatable, and may sometimes even be contradictory.One of the most useful properties of fuzzy logic systems is that contradictions in the data can be tolerated. Furthermore, using trainable fuzzy systems, it is possible to discover patterns in data which are not easily detected by other methods, as can also be done with neural network [2].

In this study, the feature vectors were extracted by discrete wavelet transform. Because of high dimension of feature vectors at the extraction stage, the success of classification can be achieved by employing suitable dimensionality reduction methods which is Principal Component Analysis (PCA) outperform WT features. Fuzzy clustering algorithms which are Fuzzy c-means (FCM) and Possibilistic c-means (PCM) and fuzzy K-nearest neighbor classifier (FKNN) were used to classify the feature vectors. After the membership values of each feature vector to all of the classes were computed by FCM and PCM during the training, FKNN assigned the new feature vector to one of the classes by computing its membership values to the classes.

II. METHODOLOGY

PCA

Principal component analysis is a strategy used to summarize the properties of multivariate analysis in a set of data patterns. It is a linear transformation method often used for feature extraction or data compression. PCA, also known as the Karhunen-Loeve transformation in communication theory, maximizes the rate of decrease of variance. From the perspective of statistical pattern recognition, the practical value of principal components analysis is that it supplies an effective method for dimensionality reduction. The number of coefficients needed for effective feature representation can be reduced. On the other hand, it discards those terms that have small variances and retains only those terms that have large variances .

FCM & PCM

Clustering has long been a popular approach to unsupervised pattern recognition [3]. Fuzzy clustering has been shown to be advantageous over crisp (or traditional) clustering in that a total commitment of a vector to a given class is not required in each iteration.

The FCM and its derivatives have been used very successfully in many applications, particularly those (such as pattern classification and image segmentation) in which the final goal of the task is to make a crisp decision. The FCM uses the probabilistic constraint that the memberships of a data point across classes must sum to 1. This constraint came from generalizing a crisp C-partition of a data set, and was used to generate the membership update equations for an iterative algorithm based on the minimization of a lest-squares type of criterion function. The constraint on memberships used in the FCM algorithm is meant to avoid the trivial solution of all memberships being equal to 0, and it does give meaningful results in applications where it is appropriate to interpret memberships as probabilities or degrees of sharing.

The main motivation behind the possibilistic approach to clustering was to address the problems associated with the constraint on the memberships used in the fuzzy clustering algorithms such as the fuzzy c-means (FCM) [3]. As pointed in [4], the constraint causes the FCM to generate memberships that can be interpreted as degrees of sharing but not as degree of typicality. Thus, the memberships in a given cluster of two points that are equidistant from the mean (prototype) of the cluster can be significantly different and memberships of two points in a given cluster can be equal even though the two points are far away from each other. This gives rise to poor performance in the presence of noise and outliers.

FUZZY K-NEAREST NEIGHBOR

While the fuzzy K-nearest neighbor procedure is also a classification algorithm the form of its results differ from the crisp version. The fuzzy K-nearest neighbor algorithm assigns class membership to a sample vector rather than assigning the vector to a particular class. The advantage is that no arbitrary assignments are made by the algorithm. In addition, the vector's membership values should provide a level assurance to accompany the resultant classification.

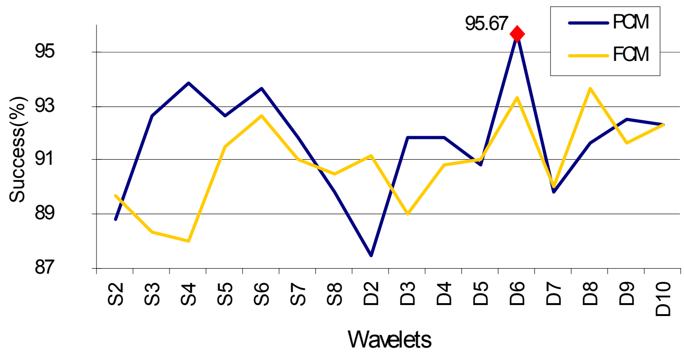
The basis of the algorithm is to assign membership as a function of the vector's distance from its K-nearest neighbors and those neighbors'memberships in the possible classes. The fuzzy algorithm is similar to the crisp version in the sense that it must also search the labeled sample set for the K-nearest.

neighbors. Beyond obtaining these K samples, the procedures differ considerably [5].

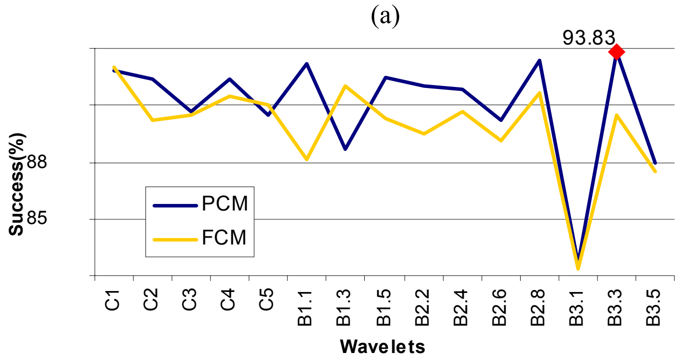
III. RESULTS

Four classes of myoelectric signal patterns were collected, corresponding to flexion/extension of the elbow, and pronation/supination of the forearm. The data were acquired from two channels, located at the biceps and triceps, each pattern consisting of two channels of 256 points, sampled at 1000 Hz. The data were divided into a training set and a test set.

The WT feature vector sets were computed. Subsequently, each feature vector set was subject to dimensionality reduction using PCA, so as not to overwhelm the classifier with high-dimensional data. It is shown in [6] that the application of PCA is critical to the success of the time-frequency-based feature vector sets, and that PCA is clearly superior to other forms of dimensionality reduction. Thirty PCA coefficients were used in the analyses. Also computing mean absolute values of the signal for two channels of each 50 points were added to the coefficients. Finally, each feature vector consisted of forty coefficients.



(a)



(b)

Figure 1: The test feature set classification success for (a) Symlet, Daublet, (b) Coiflet, Biothogonal mother wavelets of varying order.

After the membership values of the feature vectors to the classes were computed by FCM/PCM in training phase, the new feature vectors were assigned to the classes by FKNN in testing phase.

PCM shows significantly improved classification accuracy as compared to FCM in Figure 1.

A Daublet mother wavelet (of order six) yielded better accuracy (95.7%) than a host of other wavelet families of varying order with PCM.

IV. CONCLUSION

Classification of flexion/extension of the elbow and pronation/supination of the forearm was investigated. While WT was adopted as an effective feature extraction technique and PCA was used as a dimension reduction method, FCM/PCM and FKNN used for classification.

REFERENCES

1. K. Englehart , B. Hudgins, P. A. Parker and V. Stevenson (1999). Classification of the Myoelectric Signal Using Time-Frequency Based Representations, *Medical Eng. and Physics*, volume 21, pages 431-438.
2. F.H.Y. Chan, Y.S. Yang, F.K. Lam, Y.T. Zhang, and P.A. Parker (2000). Fuzzy EMG Classification for Prosthesis Control, *IEEE Trans. Rehabilitation Eng.*, volume 8, pages 305-311.
3. R. Krishnapuram and J. M. Keller (1996). Correspondence: The Possibilistic C-Means Algorithm: Insights and Recommendations. *IEEE Transactions on Fuzzy Systems*, volume 4, pages 385-393.
4. R. Krishnapuram and J. M. Keller (1993). A Possibilistic Approach to Clustering. *IEEE Transactions on Fuzzy Systems*, volume 1, pages 98-110.
5. J.M. Keller, M.R. Gray and J.A. Givens (1985). A Fuzzy K-Nearest Neighbor Algorithm. *IEEE Transactions on Systems Man, and Cybernetics*, volume 15, pages 580-585.
6. K. Englehart , B. Hudgins , and P.A. Parker (2001). A Wavelet-Based Continuous Classification Scheme for Multifunction Myoelectric Control, *IEEE Trans. Biomed. Eng.*, volume 48, pages 302–311.