ABSTRACT

In the field of pattern recognition, probabilistic neural networks (PNNs) have been proven as an important classifier. For pattern recognition of EMG signals, the characteristics usually used are: (1) amplitude, (2) frequency, and (3) space. However, significant temporal characteristic exists in the transient and non-stationary EMG signals, which cannot be considered by traditional PNNs. In this article, a recurrent PNN, called recurrent log-linearized Gaussian mixture network (R-LLGMN), is introduced for EMG pattern recognition, with the emphasis on utilizing temporal characteristics. The structure of R-LLGMN is based on the algorithm of a hidden Markov model (HMM), which is a routinely used technique for modeling stochastic time series. Since R-LLGMN inherits advantages from both HMM and neural computation, it is expected to have higher representation ability and show better performance when dealing with time series like EMG signals. Experimental results show that R-LLGMN can achieve high discriminant accuracy in EMG pattern recognition.
INTRODUCTION

Electromyographic (EMG) signals provide information about neuromuscular activities and have been recognized as efficient and promising resources for human-machine interface (HMI) used for the rehabilitation of people with mobility limitations and those with severe neuromuscular impairment. Typically, a pattern recognition process is applied to translate EMG signals into control commands for the HMI, such as powered prostheses and functional electrical stimulation devices (Englehart et al., 2001; Fukuda et al., 2003; Hudgins et al., 1993; Lusted & Knapp, 1996). Generally speaking, a successful EMG pattern recognition technique relies on two principle elements: a pattern classifier with reliable discrimination accuracy and efficient representation of EMG feature characteristics.

Probabilistic neural networks (PNNs) developed in the field of pattern recognition make a decision according to the probability density distribution of patterns in the feature space (Specht, 1990; Tsuji et al., 1999). Since PNNs integrate statistical models into the neural networks’ architecture as prior knowledge, outstanding performance has been reported. Recently, PNNs have become widely accepted as important classifiers and have been proven to be efficient, especially for complicated problems such as pattern recognition of bioelectric signals.

For EMG pattern recognition using PNNs, the feature characteristics usually used include: (1) amplitude, (2) frequency, and (3) spatial information from multiple channels of EMG signals. However, significant temporal characteristics exist in the transient and non-stationary EMG signals, which cannot be considered by the traditional PNNs based on static stochastic models, and, in some cases, temporal characteristics could be the only clues for reliable recognition.

This chapter introduces a recurrent PNN called recurrent log-linearized Gaussian mixture network (R-LLGMN) (Tsuji et al., 2003) into EMG pattern recognition, with emphasis on utilizing temporal characteristics. The structure of R-LLGMN is based on the hidden Markov model (HMM) algorithm, which is a routinely used technique for modeling stochastic time series. Since R-LLGMN inherits the advantages from both HMM and neural computation, it is expected to have higher representation ability and exhibit better classification performance when dealing with time series like EMG signals.

After a review of the literature, the structure and algorithm of R-LLGMN are explained. The proposed EMG pattern recognition method using R-LLGMN is then described, and experiments on filtered EMG and raw EMG signals are presented. Based on the experimental results, the possibility of applying the proposed method to practical human interface control is discussed. The final section offers some concluding remarks.

BACKGROUND

Up to now, many techniques have been developed for EMG pattern recognition using statistical methods and neural networks (NNs). Kang et al. (1995) proposed a maximum likelihood method (MLM) based on Mahalanobis distances between input pattern and the prototypes, and the Bayes decision rule is applied in this method. A traditional linear discriminant analysis (LDA) classifier is used in an EMG classification scheme for multifunction myoelectric control (Englehart et al., 2001).

Due to NNs’ learning capability of finding near-optimum functional relationships between the class memberships and the EMG patterns, several NN-based EMG pattern recognition methods have been presented. For example, Hiraiwa et al. (1989) used a multilayer perceptron (MLP) NN to perform pattern discrimination of five finger motions. Kelly et al. (1990) applied an MLP to classify four arm functions. Hudgins et al. (1993) devised a control system for powered...
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