A NEW APPROACH TO AMPUTEE TRAINING USING COMPUTER GRAPHICS

Edmond Zahedi
Biomedical Engineering Lab., Department of Electrical Engineering
SHARIF University of Technology, Tehran - Iran.
E-mail : zahedi@irearn.bitnet

ABSTRACT

In this paper, a new approach is presented for the training of amputees for an effective fitting of upper-extremity myo-electric prostheses. Electromyogram (EMG) signals from the remaining muscles of the stump are amplified and filtered, digitized with 8 bit resolution and fed into a microcomputer with a sampling rate of 2500 Hz. The extracted feature is the integral absolute value of the biceps and triceps. A fuzzy classifier is used for clustering and classification. The EMG signals are processed and the decision of the classifier animates a graphically simulated 3 degree of freedom prosthesis on the microcomputer monitor. Five healthy persons have been trained with this system. It took less than 10 minutes for the subjects to familiarize with the operation of the system. The error rate was less than 5%. The main advantages of such an approach are thought to be: training of amputees before using a real prosthesis by remembering them the concept of "muscle state", easy evaluation of the misclassification error rate of different algorithms, expert man-power time saving, accurate follow-up of the amputee, more availability of the training set and self-paced learning so less frustration of the amputee.

Keywords: EMG, artificial hand, computer graphics

INTRODUCTION

The acceptance of a myoelectric prosthesis is always conditionned by the ease of operation the handicapped person has when using it. One of the most important challenges in this kind of (smart) artificial organ is to implement a straight-forward and simple man-machine interface. The classical approach in which an operator guides the amputee is generally long and not optimal because each person has it's own stump and learning characteristics. The basic idea in this paper is to use computer graphics in order to make more attractive the learning phase to the amputee, thus improving the matching of the artificial system with his requirements. This paper will try to demonstrate the effectiveness of computer graphics compared to the classical approach consisting of an amputee being trained by an operator for upper-extremity prostheses.

METHODS

EMG signals from the remaining muscles of the stump are amplified and filtered, digitized with an analog to digital board (AX-5411) with 8 bit resolution and fed into a microcomputer (IBM-PC AT) with a sampling rate of 2500 Hz. The extracted feature is the integral absolute value (IAV) of the biceps and triceps. The electrode position is selected at the bulk of the muscles. Many algorithms exist for processing the computed features of the EMG [1]-[4]. In this work we used a fuzzy classifier [5]-[6] because of the fitness of this kind of logic to this specific problem: clusters in the IAV feature space tend to overlap, and a crisp approach would lead to unacceptable results. The subject is then asked to contract his muscles in order to move a cursor on the monitor which coordinates correspond to the IAV of each muscle. He (she) sees the position of this cursor and this visual feedback closes the loop in the training phase (fig. 1). The regions in which he (she) feels that the IAV feature vector is more stable are selected by the operator as candidates for a cluster: the subject is asked to try to keep the IAV feature vector in this region and the corresponding EMG signals are recorded as raw data. The (natural) arm is not constrained.

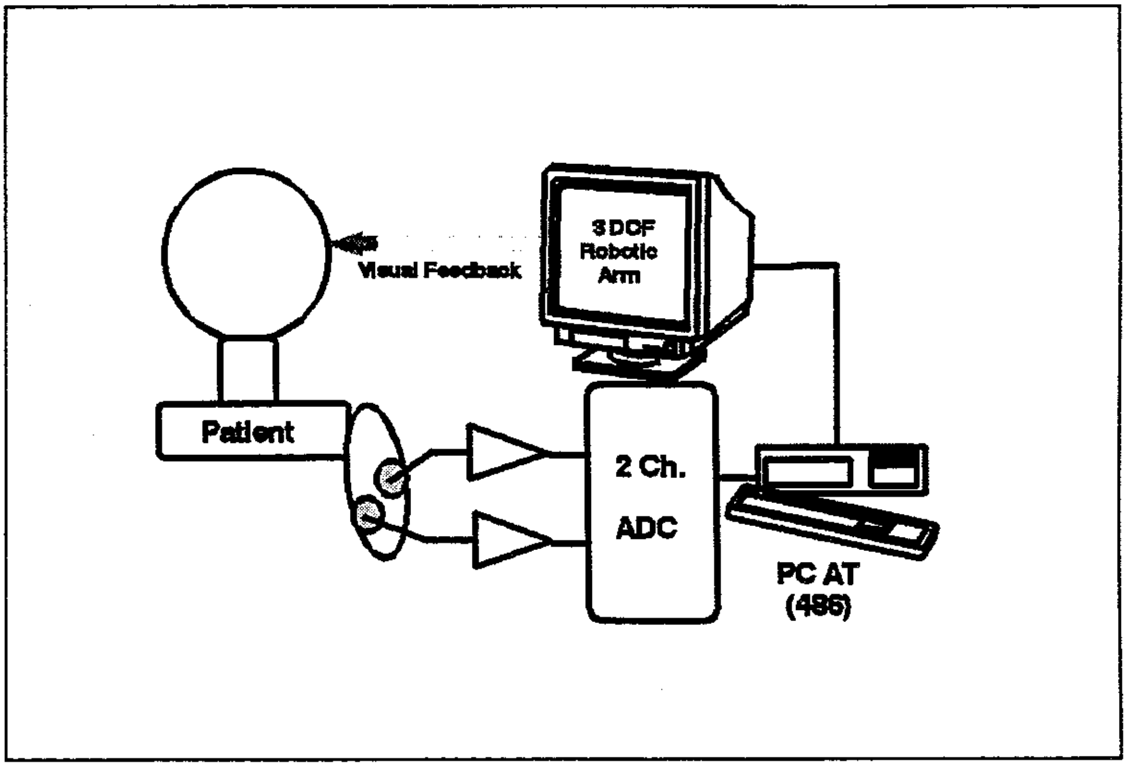

Fig. 1 : The set-up.

The fuzzy classifier needs to be trained using existing raw data. The operator defines the number of motion classes and the needed clusters in the IAV feature space are formed (fig. 2). The end of this training phase is determined by the operator by setting an error value. Then the operator is asked to label each class: each cluster in the IAV feature space is assigned to a specific motion.

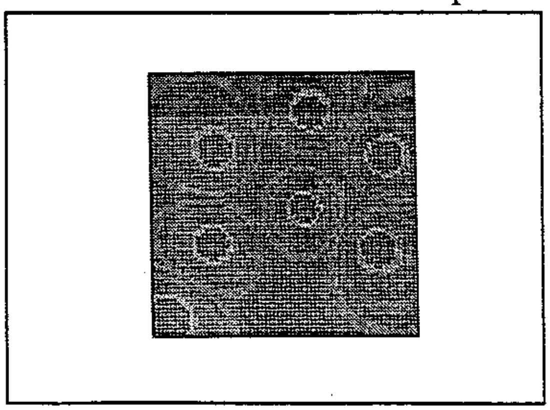

Fig. 2 :
Fuzzy clusters in the EMG-IAV feature space.

The classification then begins on-line, e.g. the EMG signals are processed and the output (or decision) of the classifier animates a graphically simulated 3 degree of freedom linkage stylizing a prosthesis on the microcomputer monitor (fig. 3). This is done by the mean of a fuzzy k-means algorithm [5]-[6]. Each 3 seconds, a command choosen randomly by the computer is given to the subject. Between two commands, a non-motion state is issued in order to let enough time for rest. Special emphasis has been put on the user-interface in order to enhance the man-machine interface. In this way computer graphics are used efficiently for learning purposes, especially with peoples who have little or no computer literacy.

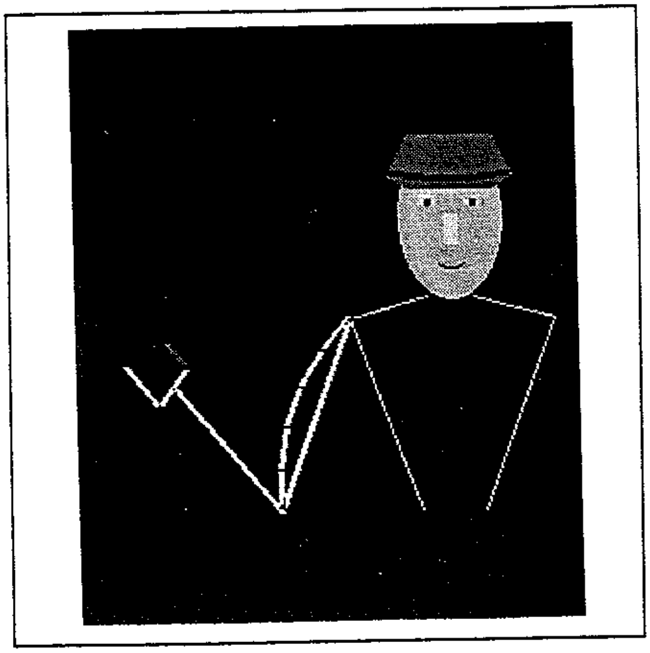

Fig. 3: The stylized robotic arm shown to the amputee.

RESULTS

Five healthy persons have been trained with this system. It took less than 10 minutes for the subject to familiarize with the operation of the system. Each experiment lasted for less than 5 minutes. The error rate, defined as the error cases divided by the total number of commands issued to the subject, was less than 5%. The training is repeated until the learning curve of the user which is a function of the error in executing a random command issued each 3 seconds by the microcomputer reaches a steady state (fig. 4).

CONCLUSIONS

A new training tool has been developed in order to train upper-extremity amputees. The main advantages of such an approach are:

- training of amputees before using a real prosthesis by remembering them the concept of "muscle state",
- easy evaluation of the misclassification error rate of different algorithms in the quasi-same conditions,
- expert man-power time saving, - accurate follow-up of the amputee,
- more availability of the training set (even at home),
- self-paced learning so less frustration of the amputee.

FUTURE DIRECTIONS

As computer graphics have been very efficient in the training of healthy subjects, work is pursued on the application of this novel method to amputees in order to assess the effectiveness of such approach in their case. One other direction is to use a more immersive environment for training adopting such new available tools as virtual reality [7].

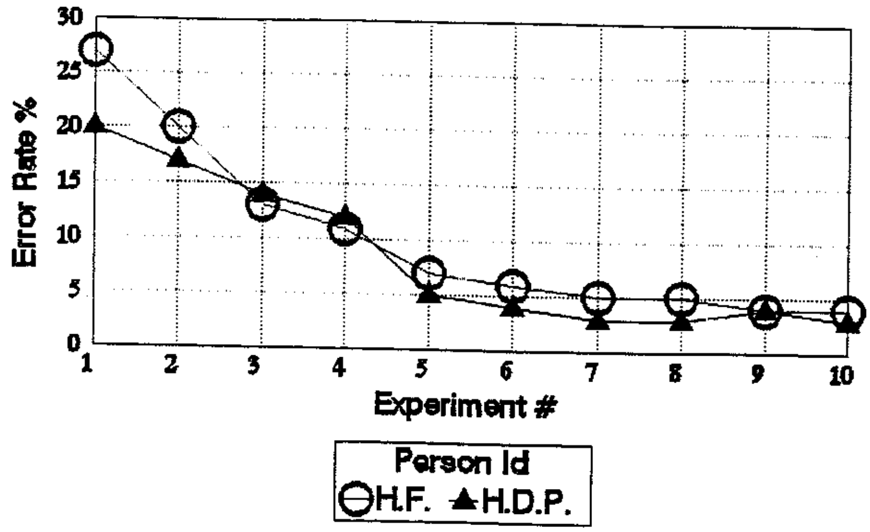

Fig. 4: Learning curve (healthy subjects).

REFERENCES

[1]- G.N. Saridis, T.P. Gootee, "EMG pattern analysis and classification of a prosthetic arm", IEEE Trans. on BME, Vol. 27, pp.403-412, June 1982.

[2]- D. Graupe, "Functional separation of EMG signals via ARMA identification methods for prosthesis control purposes", IEEE Trans. on Sys. Man Cybern., vol. SMC-5, pp. 252-259, March 1975.

[3]- B. Hudgins, P.A. Parker, R.N. Scott, "A new strategy for multifunctiopn myoelectric control", IEEE Tran. on BME, Vol-40, No 1, pp 82-93, Jan. 1993.

[4]- E. Zahedi, T. Khoshaba, R. M. Hashemi, "Electromyogram pattern classification based on heuristic rules." in Proceedings of the 12th Annual Conference, IEEE Engineering in Medicine and Biology, USA, pp 2202-2204, 1990.

[5]- H. Alghassi, "EMG pattern recognition using fuzzy logic", M.S. thesis, Electrical Engineering Dept., SHARIF Univ. of Tech., Tehran, Iran, Sep. 1993.

[6]- M.H. Farahani, E. Zahedi, "Intelligent control of artificial arm in real-time", Proceedings of the 7th Iranian Biomedical Engineering Conference, pp 208-215, Tehran, Iran, Dec. 1994 (in persian).

[7]- E. Zahedi, H. Miyake, "A new concept in the evaluation of cybernetic actuators control", accepted for oral presentation at the Myoelectric Control and Powered Prosthetics Symposium, University of New Brunswick, Fredericton, NB, Canada, August 1995.