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COMPARISON OF DIFFERENT FUZZY MODELS TO EXTRACT POSITION INFORMATION FROM MUSCLE AFFERENT ACTIVITY

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Abstract—The aim of this study was to investigate different fuzzy models for joint position prediction using the ElectroNeuroGram (ENG) signals recorded from muscle afferents using cuff electrodes. The Dynamic Non-Singleton Fuzzy Logic System (DNSFLS) model performed best. The good performance of this fuzzy model suggests it might be possible to use activity from muscle afferents recorded with cuff electrodes for Functional Electrical Stimulation (FES) closed-loop control of joint position.

Keywords -- nerve cuff recordings, muscle afferents, fuzzy logic, Functional Electrical Stimulation.

I. Introduction

In the recent past, FES has been used to restore impaired functions in paraplegic and quadriplegic patients. The complexity of the controlled system calls for the implementation of closed-loop control algorithms. The aim of this paper was to compare different fuzzy models for extracting position information from muscle afferents as a preliminary step toward implementing an FES closed-loop controller of joint position using natural sensory information as a feedback signal.

II. Methods

A. Experimental Set-up- The ankle angle of a normal human subject was recorded during standing and this signal was used as a template to move the ankle of a rabbit preparation. The whole nerve activity of the tibial and peroneal nerves were recorded as described in [1].

B. Fuzzy Models - Three fuzzy models were implemented with characteristics as follows:

1. The Modified FCRM Fuzzy Model is a Takagi-Sugeno (TS) fuzzy system. To obtain the rules directly from the data, a fuzzy clustering algorithm named fuzzy C-regression model (FCRM) is implemented [2].
2. The Adaptive Network-based Fuzzy Inference System (ANFIS) model is a TS fuzzy system implemented as a feed-forward neural network. The principal characteristic of this network is the hybrid learning procedure described in [3].
3. The Dynamic Non-Singleton Fuzzy Logic System (DNSFLS) is a Mamdani fuzzy system, implemented in the framework of recurrent neural networks [4].

III. Results

To compare the performances of the different fuzzy models, the root mean square (RMS) of the prediction error, and the correlation coefficients between the desired and the actual trajectories were introduced as a figure of merit. In Tables 1 and 2 the RMS of the prediction error and the correlation coefficients for the training and test sets are presented, respectively.

Table 1: RMS of the Prediction Error for the Different Fuzzy Models

Fuzzy model	Training Traj RMS	Test Traject RMS	Rule Number
FCRM	0.0216	0.0480	49
ANFIS	0.0047	0.0079	49
DNSFLS	0.0013	0.0057	45

Table 2: Correlation Coefficients between Desired and Actual Trajectories for the Different Fuzzy Models

Fuzzy model	Corr Coef (Training Tr)	Corr Coef (Test Tr)
FCRM	0.5750	0.3210
ANFIS	0.8388	0.5978
DNSFLS	0.9989	0.7731

IV. Discussion and Conclusions

We implemented different fuzzy models to predict the ankle angle using cuff recordings from the tibial and peroneal nerves. The DNSFLS outperforms the other fuzzy systems suggesting its use for closed loop control purpose. Future work will show if the DNSFLS model is robust when additional data is applied and when different initial positions are included.

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References

[1] W. Jensen, R.R.Riso, T.Sinkjaer, "Position Information in whole nerve cuff recordings of muscle spindle afferents in a rabbit model of normal and paraplegic subjects", Proc. IEEE/EMBS Annual Meeting, Hong Kong, 1998.

[2] E. Kim, M.Park, S.Ji, and M.Park, "A new approach to fuzzy modeling", IEEE Trans Fuzzy Sys, vol. 5, pp. 328-337, August 1997.

[3] J.-S. R. Jang, "ANFIS: Adaptive-network-based fuzzy inference system", IEEE Trans Sys Man Cyber, vol. 23, pp. 665-685, May/June 1993.

[4] G.C. Mouzouris, J.M. Mendel, "Dynamic non-singleton fuzzy logic systems for nonlinear modeling", IEEE Trans Fuzzy Sys, vol. 5, pp.199-208, May 1997.

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