Proceedings of The First Joint BMES/EMBS Conference **Serving Humanity, Advancing Technology** Oct. 13-16, '99, Atlanta, GA, USA

Classification of Neural Spike Under Nearly 0 dB Signal-to-Noise Ratio

Kyung Hwan Kim and Sung June Kim
School of Electrical Engineering, Seoul National University, Seoul, Korea

Abstract: We present neural spike sorting when the signal-to-noise ratio (SNR) is close to 0 dB. The use of nonlinear energy operator enables detection of an action potential even when the SNR is so poor that the usual amplitude thresholding method cannot be applied. Thus training sets that effectively represent the probability distribution of the input vectors can be obtained and the learning capability of the neural network classifiers can be better utilized. The trained classifiers exhibit correct classification ratio higher than 90 % when the SNR is as low as 1.2 (0.8 dB) when applied to the extracellular recording obtained from *Aplysia* abdominal ganglion using semiconductor microelectrode array.

Keywords: Extracellualr recording, Neural spike sorting, Signal-to-noise ratio, Nonlinear energy operator, Neural network classifier

Introduction

To analyze the extracellular neurophysiological recording, classification of the recording into spike trains from each cell must precede. Various methods have been applied for neural spike sorting, and by now, it appears that when the signal-to-noise ratio (SNR) is sufficiently high, a lot among them would yield satisfactory results. But one often faces situations where the SNR is very low (close to 0 dB) in real extracellular recording. Correct detection of neural spikes must precede the classification in both the learning and operation stage of the classifier. Under low SNR, detection of action potential by thresholding is difficult no matter how well the threshold level is adjusted. So methods by which we can utilize the information other than the amplitude should be employed. We employed nonlinear energy operator (NEO), and detection of neural spikes under the SNR close to 0 dB was possible. As a result, satisfactory training and operation of artificial neural network classifier was realized.

Methods and Results

Training and operation procedure of overall neural spike sorting system is as follows. Neural spikes are detected by processing the raw extracellular recording with the NEO. For a discrete-time sequence $x(n)$, the NEO is given as $\psi(x(n)) = x^2(n) - x(n+1)x(n-1)$ [1]. Fig. 1 shows input and output of the NEO. Neural spikes in very noisy recording (SNR=1.084) are clearly identified. Each detected spike is aligned according to the peak value. We use two representative artificial neural networks, multilayer percepton (MLP) and radial basis function network (RBFN) as classifier. They take 25 points (2.5 msec segment) of detected spikes as input. The classifiers are trained so that the output node corresponding to the given input spike yields the maximum output value. The number of the output nodes is same as that of the units to be identified. In MLP, the number of hidden nodes is determined considering the generalization and error.

The trained classifiers were tested for three-unit recording obtained from the abdominal ganglion of *Aplysia*, while varying the SNR by scaling the ARMA modeled background noise of the recording. Overall classification performance of our method are shown in Fig. 2 along with the recent result of Chandra and Optican [2]. The structure and learning scheme of their classifier are similar to those of our MLP classifier, except in that their classifier has a hidden layer with Gaussian activation function. The remarkable enhancement in classification performance seems to result mainly from the difference in the ability of representing the large amount of variation in the input pattern. In other words, we can promote the learning capability of the neural networks by providing more abundant and exact information about the distribution of input vectors than previous methods employing simple threshold detection scheme.

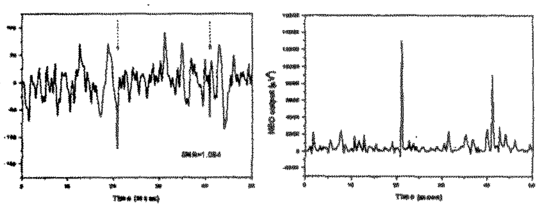

Fig. 1

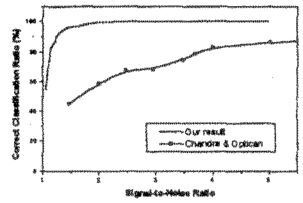

Fig. 2

Conclulsion

We implemented a neural spike sorting system showing satisfactory classification accuracy when the SNR is close to 0 dB. Due to the effective training set obtained from the enhanced detection ability of the NEO, we could fully utilize the learning capability of artificial neural networks.

References

[1] P. Maragos *et al., IEEE Trans. Signal Processing*, vol. 41, pp. 1532-1550, 1993

[2] R. Chandra and L. M. Optican, *IEEE Trans. Biomed. Eng.*, vol. 44, pp. 403-412, 1997