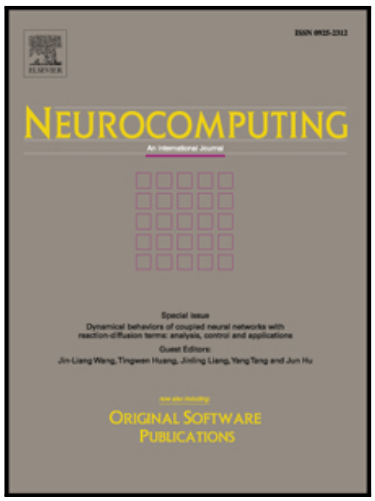

Hierarchical estimation of neural activity through explicit identification of temporally synchronous spikes

R. Veerabhadrappa , A. Bhatti , Michael Berk , S.J. Tye , S. Nahavandi

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Hierarchical estimation of neural activity through explicit identification of temporally synchronous spikes

[1]R. Veerabhadrappa, [1*]A. Bhatti, [3]Michael Berk, [2]S. J. Tye, [1]S. Nahavandi

[1] Centre for Intelligent Systems Research, Deakin University, Vic 3216, Australia

[2] Department of Psychiatry & Psychology, Mayo Clinic, Rochester, MN 55905, USA

[3] IMPACT Strategic Research Centre, Barwon Health, Deakin University, Vic 3216, Australia

Abstract:
Extracellular recording from living neurons employing microelectrode arrays has attracted paramount attention in recent years as a way to investigate the functionality and disorders of the brain. To decipher useful information from the recorded signals, accurate and efficient neural spike activity detection and sorting becomes an essential prerequisite. Traditional approaches rely on thresholding to detect individual spikes and clustering to identify subset groups; however, these methods fail to identify temporally synchronous spikes due to neuronal synchrony. To address this challenge, we introduce a novel spike sorting algorithm incorporating both quantitative and probabilistic techniques to better approximate the ground truth information of the spike activity. A novel pre-clustering method for identifying key features that can form natural clusters and a dimension reduction technique for identifying the spiking activity are introduced. To address the temporal neuronal synchrony phenomenon leading to detection of multineural overlapped spikes, a procedure for template spike shape estimation and iterative recognition is developed employing the cross correlation methodology tailored to individual neuron's spike rate. A performance comparison between the proposed method and existing techniques in terms of the number of spikes identified and efficiency of sorting the spikes is presented. The outcome shows the effectiveness of the proposed method in identifying temporally synchronous spikes.

1. Introduction

Neurons communicate with each other through a series of electrochemical signals which can be characterized by electrical pulses. Each electrical pulse is associated with a pattern, which is composed of an action potential followed by a refractory period or resting period as shown in Figure.1. The spiking interval of each electrical pulse lasts approximately 3ms [1] and no action potential can be generated by the same neuron during the refractory period [1, 2]. When the electrical signal is sufficient to generate an action potential, this initiates the release of neurotransmitters that modulate electrical conductance of adjacent neurons and hence the communication is established. The generation of an action potential is therefore critical for neuronal communication, and is a measurable phenomenon commonly known as neural spike activity [1, 3].

Extracellular recordings is a technique generally employed to record the spiking activity of neurons which are processed and studied to understand the communication system of neurons and other electrophysiological aspects. In the early invivo aproach a probe is placed in the vicinity of the neuronal spiking activity, and variations in electrical voltage owing to the generation of action potentials by the neuron cells are recorded [4]. This technique is very slow as its focus is restricted to an individual neuron per recording. Further, recording techniques employing probe with four electrodes was introduced in [5, 6] which recorded the activity of mulitple neuron at any single time.

Technical advancements in neural spike analysis have led to the introduction of invitro techniques such as Multi-electrode array system (MEA) [7]. The MEA system consists of a number of electrodes arranged in a pattern with certain spacings [8] and is capable of recording the activity of collection of cells[9]. The MEA systems have been used to study the activity of retinal ganglion cells [10], to analyse the activity of cultured cardiac myocytes as a part of drug testing and medical diagnosis [11], and to understand the life support system within rodents [12]. Understanding each neuron's contribution from a population is vital to analyse the physiolgy of the cells under observation. This

* A. Bhatti - asim.bhatti@deakin.edu.au