Título: PATTERN RECOGNITION OF NEURAL DATA: METHODS AND ALGORITHMS FOR SPIKE SORTING AND THEIR OPTIMAL PERFORMANCE IN PREFRONTAL CORTEX RECORDINGS

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Resumen: Pattern recognition of neuronal discharges is the electrophysiological basis of the functional characterization of brain processes, so the implementation of a Spike Sorting algorithm is an essential step for the analysis of neural codes and neural interactions in a network or brain circuit. Extracted information from the neural action potential can be used to characterize neural activity events and correlate them during behavioral and cognitive processes, including different types of associative learning tasks. In particular, feature extraction is a critical step in the spike sorting procedure, which is prior to the clustering step and subsequent to the spike detection-identification step in a Spike Sorting algorithm.
In the present doctoral thesis, the implementation of an automatic and unsupervised computational algorithm, called 'Unsupervised Automatic Algorithm', is proposed for the detection, identification and classification of the neural action potentials distributed across the electrophysiological recordings; and for clustering of these potentials in function of the shape, phase and distribution features, which are extracted from the first-order derivative of the potentials under study. For this, an efficient and unsupervised clustering method was developed, which integrate the K-means method with two clustering measures (validity and error indices) to

verify both the cohesion-dispersion among neural spike during classification and the misclassification of clustering, respectively. In additions, this algorithm was implemented in a customized spike sorting software called VISSOR (Viability of Integrated Spike Sorting of Real Recordings). On the other hand, a supervised grouping method of neural activity profiles was performed to allow the recognition of specific patterns of neural discharges.

Validity and effectiveness of these methods and algorithms were tested in this doctoral thesis by the classification of the detected action potentials from extracellular recordings of the rostro-medial prefrontal cortex of rabbits during the classical eyelid conditioning. After comparing the spike-sorting methods/algorithms proposed in this work with other methods also based on feature extraction of the action potentials, it was observed that this one had a better performance during the classification. That is, the methods/algorithms proposed here allowed obtaining: (1) the optimal number of clusters of neuronal spikes (according to the criterion of the maximum value of the cohesion-dispersion index) and (2) the optimal clustering of these spike-events (according to the criterion of the minimum value of the error index). The analytical implication of these results was that the feature extraction based on the shape, phase and distribution features of the action potential, together with the application of an alternative method of unsupervised classification with validity and error indices; guaranteed an efficient classification of neural events, especially for those detected from extracellular or multi-unitary recordings.

Rabbits were conditioned with a delay paradigm consisting of a tone as conditioned stimulus. The conditioned stimulus started 50, 250, 500, 1000, or 2000 ms before and co-terminated with an air puff directed at the cornea as unconditioned stimulus. The results obtained indicated that the firing rate of each recorded neuron presented a single peak of activity with a frequency dependent on the inter-stimulus interval (i.e., ≈ 12 Hz for 250 ms, ≈ 6 Hz for 500 ms, and ≈ 3 Hz for 1000 ms). Interestingly, the recorded neurons from the rostro-medial prefrontal cortex presented their dominant firing peaks at three precise times evenly distributed with respect to conditioned stimulus start, and also depending on the duration of the inter-stimulus interval (only for intervals of 250, 500, and 1000 ms). No significant neural responses were recorded at very short (50 ms) or long (2000 ms) conditioned stimulus-unconditioned stimulus time intervals. Furthermore, the eyelid movements were recorded with the magnetic search coil technique and the electromyographic (EMG) activity of the orbicularis oculi muscle. Reflex and conditioned eyelid responses presented a dominant oscillatory frequency of ≈ 12 Hz. The experimental implication of these results is that the recorded neurons from the rostro-medial prefrontal cortex seem not to encode the oscillatory properties characterizing conditioned eyelid responses in rabbits. As a general experimental conclusion, it could be said that rostro-medial prefrontal cortex neurons are probably involved in the determination of CS-US intervals of an intermediate range (250-1000 ms).