An Alternate Burst Analysis for Detecting Intraburst Firings Based on Interburst Period

David C. Tam
Dept. of Biological Sciences
University of North Texas
Denton, TX 76203
(940) 565-3261
(940) 565-4136 (FAX)
dtam@unt.edu

Abstract

We will introduce a novel burst detection algorithm for single-unit spike train analysis. This method differs from other burst detection techniques by using the interburst period as a criterion for identifying the duration of the bursts. A burst, in this case, is defined as the period in which the interburst periods (interspike intervals) are greater than the sum of adjacent consecutive interspike intervals (collectively grouped as a burst). This analysis will detect dynamically varying burst patterns based solely on the firing pattern of the spike train itself without any externally imposed burst parameters.

Preference:
Poster presentation

An Alternate Burst Analysis for Detecting Intraburst Firings Based on Interburst Period

David C. Tam
Dept. of Biological Sciences
University of North Texas
Denton, TX 76203
(940) 565-3261
(940) 565-4136 (FAX)
dtam@unt.edu

Abstract

We will introduce a novel burst detection algorithm for single-unit spike train analysis. This method differs from other burst detection techniques by using the interburst period as a criterion for identifying the duration of the bursts. A burst, in this case, is defined as the period in which the interburst periods (interspike intervals) are greater than the sum of adjacent consecutive interspike intervals (collectively grouped as a burst). This analysis will detect dynamically varying burst patterns based solely on the firing pattern of the spike train itself without any externally imposed burst parameters.

1. Introduction

We will introduce a new single-unit spike train analysis technique to detect burst firing in neurons. Burst-firing is a phenomenon often encountered in neural firings. It is a phenomenon that is often defined qualitatively rather than quantitatively, because there are many different definitions of "burst" depending on the burst-detection method used. Thus, a burst extracted by one method may not be the same as the burst detected by another method, such as the "surprise measure" for identifying the spike intervals that exceed the chance occurrence of spikes and/or other *ad hoc* methods for defining bursts.

Although a lot of traditional spike train analyses exist for identifying spike patterns, such as the auto-correlation technique (Perkel, *et al.*, 1967a) and cross-correlation technique (Perkel, *et al.*, 1967b) establish the univariant statistics ISIs and CIs, respectively, the current analysis extends the traditional cross-correlation analysis and the doublet (double spikes) integration analysis introduced by Tam (1998).

A burst detection algorithm was introduced last year at CNS*00 (Tam, 2001). The current alternate burst-detection algorithm is entirely *different* from the previous method by Tam (2001). We will use the interburst and intraburst information to define the burst rather than using the probability of consecutive firings as the criteria in previous methods.

2. An Alternate Definition of Burst

This paper will provide an alternate self-adapting statistical measure to detect burst firing. We use an alternate definition to define a "burst" based on the *sum of firing intervals within the burst*. Before we define a "burst" quantitatively, it is easier to define the *duration* of a "burst" by the sum of the interspike intervals (ISIs) within that burst (see Fig. 1). [An ISI is defined as the time interval between consecutive spikes.] This is the conventional definition of a "burst-duration" even though it seems to be a circular definition.

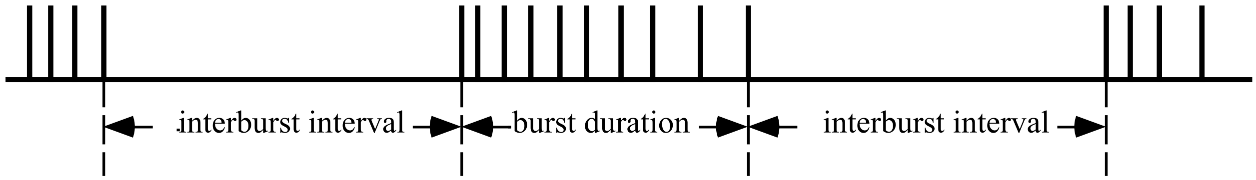

Fig. 1. Definitions of burst duration and interburst interval.

Given the above burst-duration definition, we can now define a burst based on the interburst interval (see Fig. 1). An interburst interval is basically an interspike interval (ISI) in the conventional sense that is relatively long compared to the burst-duration. This is the qualitative definition that most neuroscientists seem to adopt conventionally.

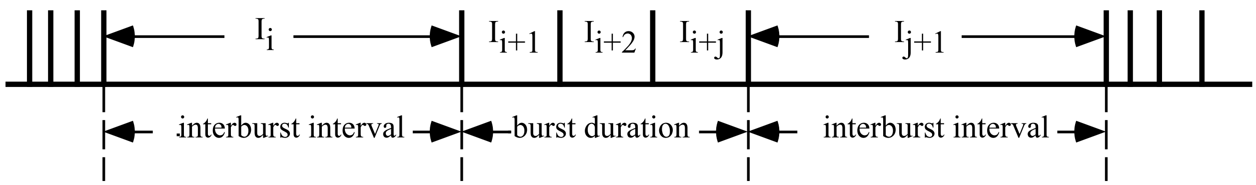

Fig. 2. Definitions of burst and interspike interval (ISI).

3. The Alternate Theoretical Definition of Burst

We will now quantify this qualitative definition quantitatively by the following:

Let I_i represents the *i*-th interspike interval in a spike train (see Fig. 2). A burst is defined by the burst-duration, $B_{i,k}$, as follows:

$$B_{i,k} = \sum_{k=i+1}^{j} I_k , \qquad \text{if } \sum_{k=i+1}^{j} I_k < I_i \text{ and } \sum_{k=i+1}^{j} I_k < I_{j+1} \tag{1}$$

In other words, if the *burst-duration* for any consecutive sum of *j* ISIs is *less than* the *preceding ISI* or the *succeeding ISI*, then a burst is defined within that burst-duration. Otherwise, the consecutive sum of *j* ISIs does not define a burst, if the sum is greater than either preceding or succeeding ISIs. This provides a self-adapting algorithm independent of number of spikes within the burst or other probability measures.

4. Advantages of This Alternate Burst Definition

This alternate definition of burst becomes a *self-adaptive* measure in which the burst (and burst-duration) are defined by the delimiting ISIs (i.e., the interburst intervals before and after the burst).

It does not require any *a priori* or *ad hoc* burst-detection parameters, such as the number of spikes within a burst, the burst duration in msec or other "surprise measure" of unexpected deviation from chance occurrence of spikes within the spike train.

It does not require any specific firing pattern to determine the burst characteristics other than the criteria used to define burst-duration based on the interburst intervals before and after the hypothetical burst. If the criteria are not satisfied, then the cluster of *j* spikes is not considered as a burst.

This burst definition is also time-scale invariant. That is, a burst is defined by the relative time intervals within the intraburst and interburst intervals locally. No specific *ad hoc* msec time-scale parameter is imposed on defining whether it is a burst or not.

Furthermore, the total number of spikes within a burst is also a self-adaptive measure based on the local relative timing information rather than an artificial number of spikes (parameter) imposed by the observer used in the burst-detection algorithm.

5. Disadvantages of This Alternate Burst Definition

As with other burst-detection algorithms, there are disadvantages for each method. This alternate definition of burst does not take into account of the local firing pattern within a burst. In other words, the intraburst spike patterns are degenerate using this algorithm. It is because only the *sum* of the ISI within the burst is used as the criterion rather than the intraburst spike patterns.

Nonetheless, the specific intraburst spike patterns are often ignored in other burst-detection algorithms. Most burst-detection methods detect the duration and presence of a burst, but not the intraburst spike patterns, because the focus of interest is burst detection rather than burst classification.

[It is beyond the scope of this paper to classify different burst patterns, since we are introducing a novel method for burst-detection. We will address burst classification in our subsequent papers.]

6. Results

To test the validity of our burst definition, we simulation a set of spike trains using different criteria for generating the burst firing patterns. We applied this alternate burst-detection algorithm to detect the presence of bursts (or non-bursts), the onset time and the duration of the bursts.

We also change the time-scale of the spike trains using the same sequential firing pattern to test if our burst-detection algorithm can detect bursts that span different time-scales.

The results show that this burst-detection algorithm can detect the presence of bursts, the onset time, and the duration of bursts in a self-adaptive manner without any externally imposed burst-detection parameters.

The results also show that the algorithm can detect bursts that span different time scales independent of the intrinsic spike firing ISIs within the burst (intraburst intervals).

7. Conclusion

The proposed burst-detection method and burst definition provide a robust way to detect the presence of bursts, onset time and their duration. This definition is consistent with the qualitative, intuitive definition of bursts used by most neuroscientists. This burst definition allows neuroscientists to quantify the presence of bursts that is consistent with the intuitive burst definition.

References

D.H. Perkel, G.L. Gerstein, G.P. Moore, Neuronal spike trains and stochastic point process, I. The single spike train. Biophys. J., 7 (1967) 391-418.

D.H. Perkel, G.L. Gerstein, G.P. Moore, Neuronal Spike Trains and Stochastic Point Process. II. Simultaneous Spike Trains, Biophys. J., 7 (1967) 419-440.

D. C. Tam, A cross-interval spike train analysis: the correlation between spike generation and temporal integration of doublets, Biological Cybernetics 78 (1998) 95-106.

D. C. Tam, A Spike Train Analysis for Correlating Burst Firings in Neurons, Neurocomputing (2001) (in press)