Analyzing Spike Train Similarity Measures: the Effects of Bursts and Silences

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Introduction

- Spike train similarity measures address the question: How similar are two spike trains?
  - Why use them?
    - Quantifying reliability of single neurons
    - Identifying cell assemblies
  - But what does it mean for two trains to be similar?

Previous work has shown the differences between some measures on the basis of firing rate and synchrony (figures reproduced from Antonio 2010).

We utilize a different set of criteria for distinguishing between measures (bursts and silences), and propose a new technique for measuring spike train similarity.

Methods

The following spike train similarity measures were analyzed:
1. van Rossum metric - convolve trains with exponential kernel, compute L2 distance.
2. Victor-Purpura Metric - cost based metric, costs assigned to adding/deleting spikes, moving spikes.
3. ISI-Distance - trains are mapped to functions that depend on the distance with increasing silent period.
4. Spike Correlation distance - convolve trains with Gaussian kernel, minimum cost.
5. Event synchronization - counts normalized number of synchronous spikes.

Burst Sensitive Component

Procedure:
1. Convolve trains with Gaussian kernel
2. Choose threshold T
3. Discard everything below T
4. Compute:
   \[ d(f_1, f_2) = 1 - \frac{<f_1, f_2>}{||f_1|| ||f_2||} \]

Silence Sensitive Component

Procedure:
1. Map each train to a function that grows linearly between spikes but is reset to zero at each spike
2. Compute:
   \[ d(f_1, f_2) = 1 - \frac{<f_1, f_2>}{||f_1|| ||f_2||} \]

Combination

Combine into a single measure by taking the weighted average:
\[ W_B d(f_1, f_2) + W_S d(f_1, f_2) \]

Example

2 pairs of trains
1st pair contains bursts and gaps

Testing Sensitivity to Bursts and Silences

Measures responded to bursts vs. single spikes in 3 distinct ways

BSI = d(original, bursts missing) - d(original, spikes missing) (normalized)

New measure is uniquely responsive to shared silence

Other similarity measures

- van Rossum
- Victor-Purpura
- ISI-Distance
- Spike Correlation
- Event Synchronization
- Synapse-like v. R.

New measure (different weights)

### Burst Sensitive Component

\[ W_B = 0 \quad W_S = 1 \]

### Silence Sensitive Component

\[ W_B = 1 \quad W_S = 0 \]

### Combination

\[ W_B = 0.5 \quad W_S = 0.5 \]

Conclusions

- We focus on bursts and silences because of their potential physiological importance, and the fact that their effect on spike train similarity measures has not been explored.
- Simple, empirical tests using surrogate data reveal important and intrinsic differences in the way existing spike train similarity measures respond to specific spike train features (bursts and silences).
- We propose a new spike train similarity measure that is sensitive to both bursts and silent periods.
- The parameters of our new measure are physiologically motivated and can be chosen based on the data.

References


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