A van Rossum metric with a synapse-like filter

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How is information coded?

Spike trains are unreliable: in the primary sensory areas for example, spike patterns and precise spike times will vary between responses to the same stimuli. Nonetheless, information about sensory inputs is communicated in the form of spike trains. A challenge in understanding spike trains is to assess the significance of individual spikes in encoding information.

Metrics

One approach to this is to define a spike train metric, allowing a distance to be calculated between pairs of spike trains [5, 2, 4]. A good metric will measure a short distance between responses to the same stimuli and a longer distance between responses to different stimuli: this indicates that the distance measured between two spike trains is related to the information they encode.

Evaluating metrics

A metric can be evaluated by performing distance-based clustering and calculating how accurately it clusters responses by stimulus. Using this comparison to optimize a parameter in a family of metrics then gives a measurement of how information is coded in the spike trains.

- Ten spike train responses to each of 20 songs.
- Cluster responses using a metric.
- Assess accuracy of clustering.
- Interpret metric features.

A new metric

A new van Rossum-like metric is defined by filtering of the spike train with a new map:

$$\text{spike train} \to f(t)$$

where $f(t)$ is the solution of

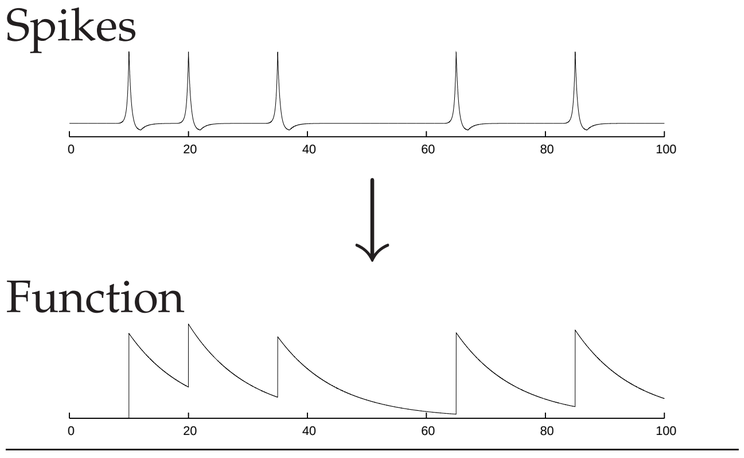
$$\tau \frac{d}{dt} f = -f$$

with discontinuities

$$f \to (1-\mu)f + 1$$

at the spike times. The usual L^2 metric on the space of functions then induces a metric on the space of spike trains:

$$d = \sqrt{\int dt [\delta f(t)]^2}$$

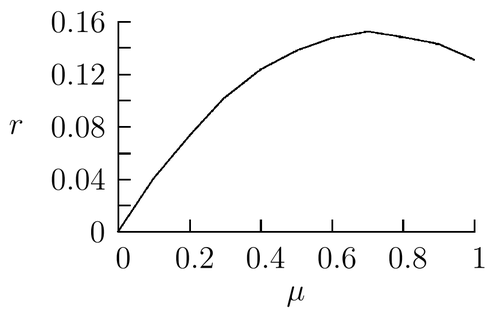


Motivation

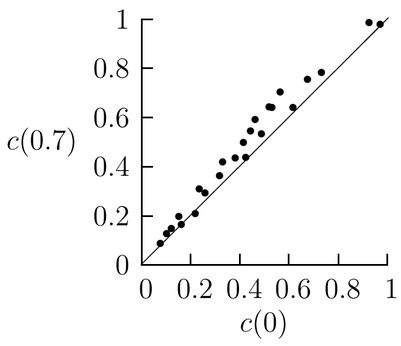
The filter mimicks the short term dynamics of synaptic conductance, modelling rapid binding and stochastic unbinding of neurotranmitter to gates in the synaptic cleft [1]

- τ is the time-scale for unbinding.
- μ quantifies the effect of the depletion of available binding sites.

Results



A plot of the relative clustering performance, r, of the metric against μ with $\tau = 10$ms.



$c(0.7)$, the clustering performance at $\mu = 0.7$, is plotted against the performance of van Rossum metric, $c(0)$, for each of the 24 sites.

Conclusions

The van Rossum metric corresponds to $\mu = 0$; for the data examined here there is a modest but definate improvement if a non-zero value of μ is used.

- Isolated spikes are weighted more heavily.
- Synaptic conductances track information content.

References

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[2] Hunter JD, Milton JG, Thomas PJ, Cowan JD. *Journal of Neurophysiology*, 80:1427–1438, 1998.

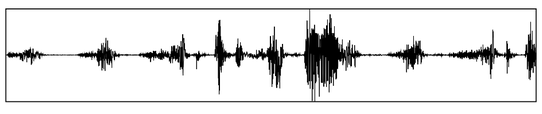
[3] Narayan R, Graña G, Sen K. *Journal of Neurophysiology*, 96:252–258, 2006.

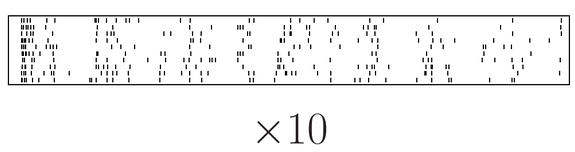
[4] van Rossum M. *Neural Computation*, 13:751–763, 2001.

[5] Victor JD, Purpura KP. *Journal of Neurophysiology*, 76(2):1310–1326, 1996.

Data

The metrics have been applied electrophysiological data recorded from the primary auditary area of zebra finch during playback of conspecific songs [3].





The recordings were taken from field L of anesthetized adult male zebra finch and data was collected from sites which showed enhanced activity during song playback. 24 sites are considered here; of these, six are classified as single-unit sites and the rest as consisting of two to five units. The average spike rate during song playback is 15.1 Hz with a range of across sites of 10.5-33 Hz.

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