Comparing Ca^{2+} deconvolution methods

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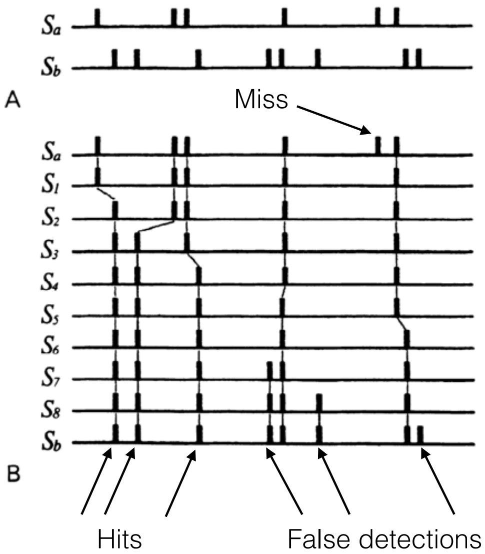
Abstract

Some notes on our efforts to compare calcium deconvolution methods. After describing a different spike distance metric (Victor & Purpura 1996), we outline the different deconvolution methods attempted and compare their results on ground truth and example 'real' data.

1 Spike train metrics

It became clear that Pearson correlation coefficient between real and estimated spike trains (raw, downsampled, or smoothed) results in biased results. Namely, overestimation of spikes is rewarded with higher scores than underestimation of spikes.

We therefore additionally measured the spike distance metric of Victor & Purpura, which is described in Fig. 1.



$$\text{sensitivity} = \frac{\text{detected spikes}}{\text{total spikes}} = 1 \; \frac{\text{misses}}{\text{total spikes}}$$

$$\text{precision} = \frac{\text{detected spikes}}{\text{total detections}} = 1 \; \frac{\text{falsed etections}}{\text{total detections}}$$

$$ER = 1 - F_1 \text{score} = 1 - 2\,\frac{\text{sensitivity} \times \text{precision}}{\text{sensitivity} + \text{precision}}.$$

Figure 1: Spike metrics. Left: Victor and Purpura (1996) proposed a spike metric to compare spike trains. This metric is generated by determining the number of elementary operations (shift, addition, or deletion of individual spikes) required to match two spike trains, up to some temporal precision (here 0.5s). Right: In Deneaux et al 2016 the Error Rate (ER) is similarly computed as a ratio of sensitivity vs precision in spike detection. Detections are counted to within 0.5s.

2 List of deconvolution methods

2.1 Suite2P

`Suite2P` (https://github.com/cortex-lab/Suite2P) is actively developed by Marius Pachitariu and members of the cortexlab (Kenneth Harris and Matteo Carandini) at UCL. Suite2P's USP is it's application to large scale 2-photon imaging analysis, with an emphasis on end-to-end processing (images to neural event time series) and speed. A preprint describing the toolbox is available here:

http://biorxiv.org/content/early/2016/06/30/061507,

and our own notes on the spike detection algorithm are here:

https://drive.google.com/open?id=1NeQhmoRpS-x8R0e84w3TqkUR1PNMXiem6ZIjJta-U7A.

2.2 MLSpike

`MLSpike` (https://github.com/mlspike) was developed by Thomas Deneux at INT, CRNS Marseille, France. A model-based probabilistic approach, `MLSpike` was developed to recover spike trains in calcium imaging data by taking baseline fluctuations and cellular properties into account. A comprehensive explanation of the algorithm and its benefits can be found in the paper:

Deneux, Thomas, Attila Kaszas, Gergely Szalay, Gergely Katona, Tamás Lakner, Amiram Grinvald, Balázs Rózsa, and Ivo Vanzetta. "Accurate spike estimation from noisy calcium signals for ultrafast three-dimensional imaging of large neuronal populations in vivo." Nature Communications 7 (2016).

Link: https://www.nature.com/articles/ncomms12190

2.3 LZero

The method we refer to as `LZero` was developed by Sean Jewell and Daniela Witten from U.Washington, Seatle, USA. The goal for this implementation was to cast spike detection as a change-point detection problem, which could be solved with an existing l_0 optimization algorithm. In their paper Jewell and Witten show that the l_0 solution is better than previously implemented l_2 solutions, with results much closer to the real spike train (l_2 solutions tend to overestimate the true firing rate). Details can be found in the paper:

Jewell, Sean, and Daniela Witten. "Exact Spike Train Inference Via ℓ_0 Optimization." arXiv preprint arXiv:1703.08644 (2017).

Link: https://arxiv.org/abs/1703.08644

2.4 Yaksi

`Yaksi` refers to the 'vanilla' deconvolution of Yaksi and Friedrich (2006). This is to be used as a baseline for comparison with more sophisticated methods. ***NOTE 8.6.17*** my implementation results in signals that are more temporally smooth (as opposed to more temporally sharp) than the calcium signal, indicating the filtering has not been performed properly.

The method is detailed in the paper:
Yaksi, Emre, and Rainer W. Friedrich. "Reconstruction of firing rate changes across neuronal populations by temporally deconvolved Ca2+ imaging." Nature Methods 3, no. 5 (2006): 377-383.

2.5 Peron events

`Peron events` refer to the extracted events detailed in the original *Peron et al. 2015* paper. It is a version of the 'peeling' algorithm tuned to generate a low number of false positive detections on ground truth data.

Peron, Simon P., Jeremy Freeman, Vijay Iyer, Caiying Guo, and Karel Svoboda. "A cellular resolution map of barrel cortex activity during tactile behavior." Neuron 86, no. 3 (2015): 783-799.