NEURAL DATA ANALYSIS

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COMPUTATIONAL VISION AND NEUROSCIENCE GROUP

QUESTIONS SO FAR?

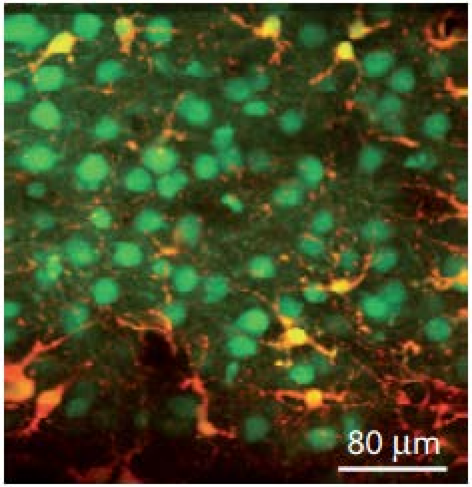
Preprocessing for spikes from electrophysiological recordings

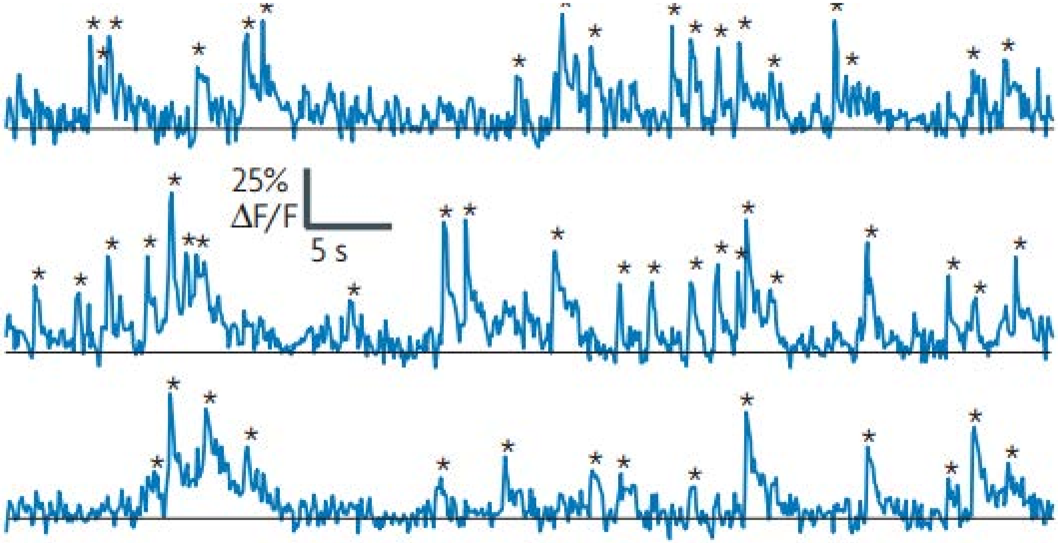
Other recording techniques?

INFERRING SPIKES FROM CALCIUM TRACES

CALCIUM IMAGING

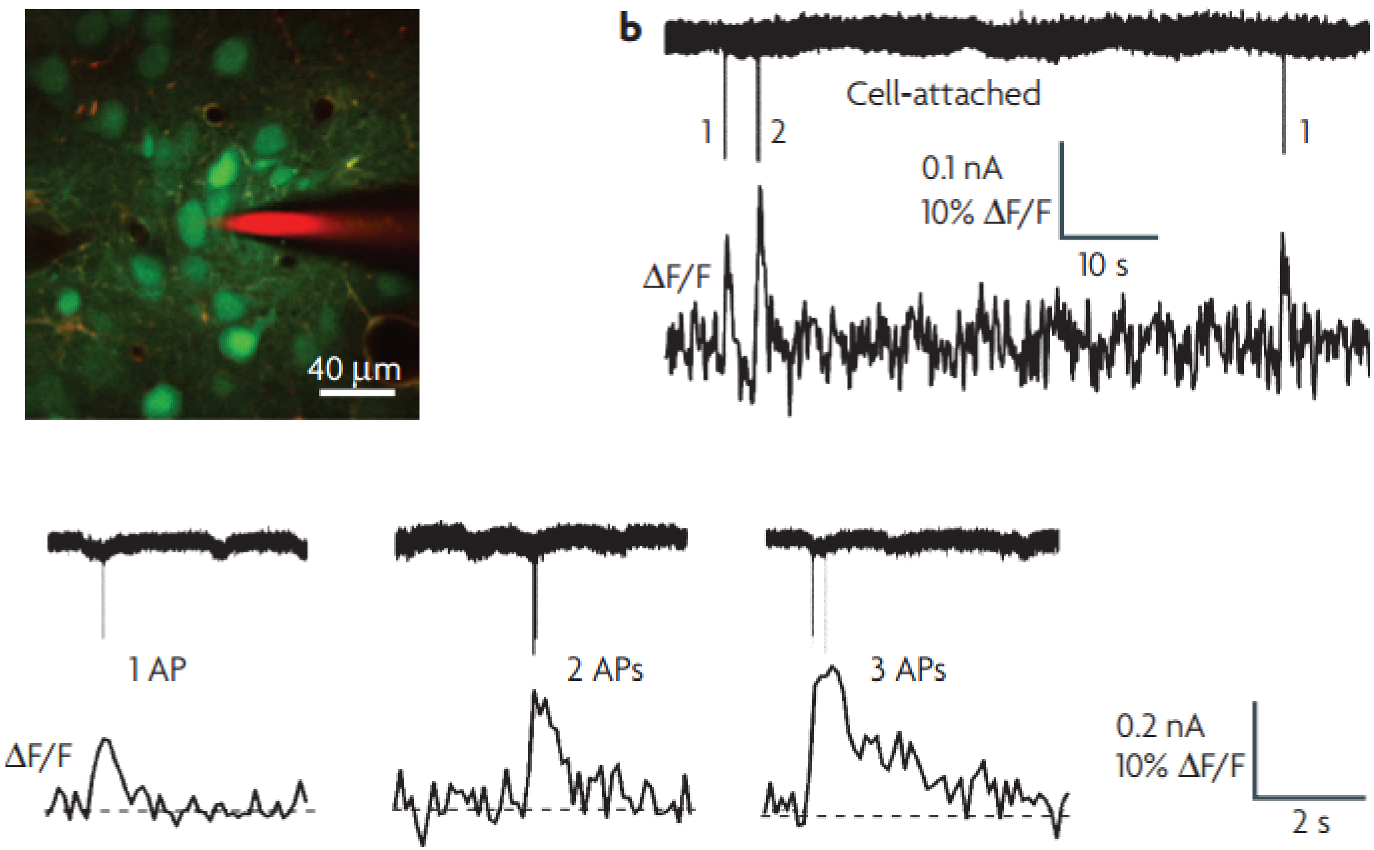
- Calcium indicator: Dye (e.g. OGB1)
- Binds to intracellular calcium and changes fluoresence
- Fluoresence measured by two-photon imaging





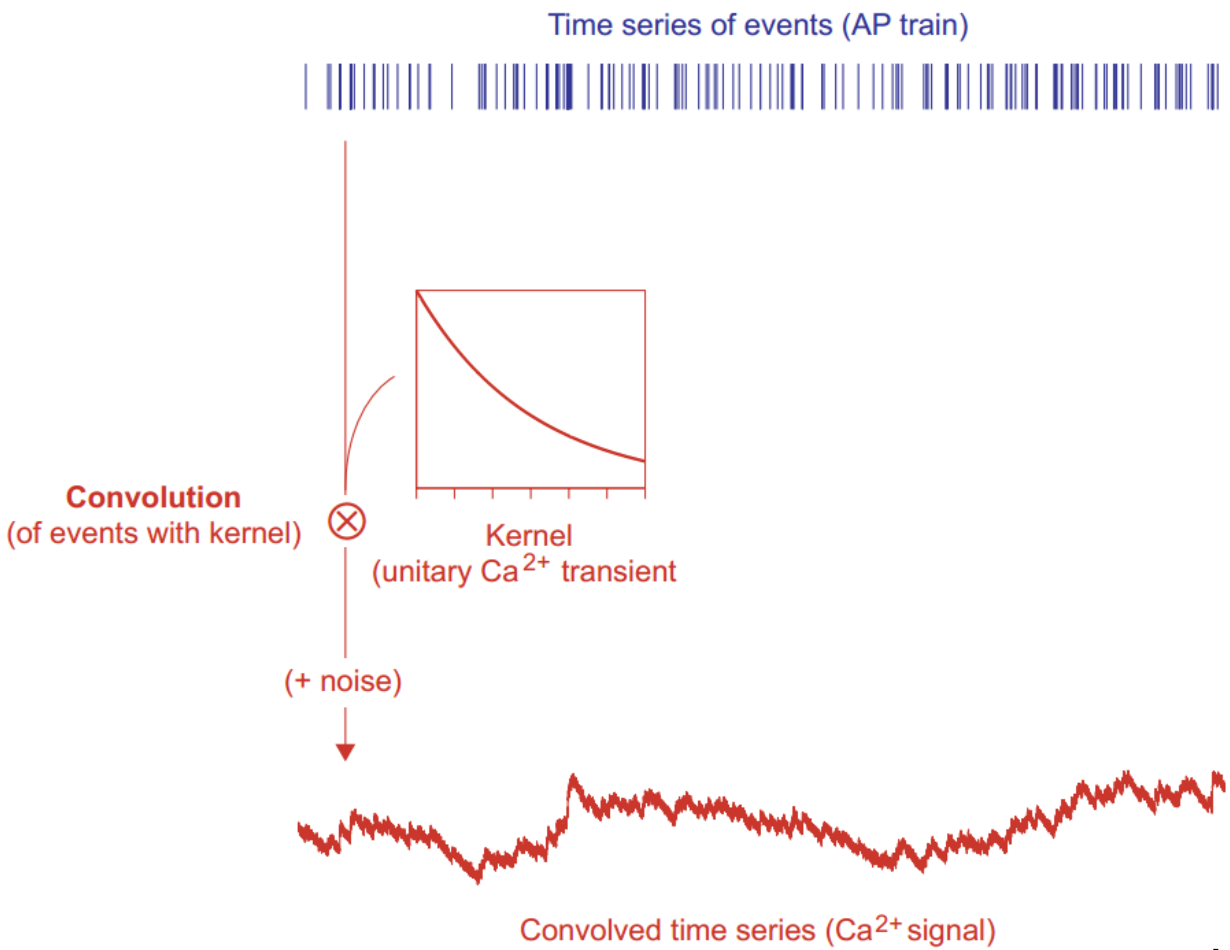
Kerr & Denk, 2008

CALCIUM AND SPIKES



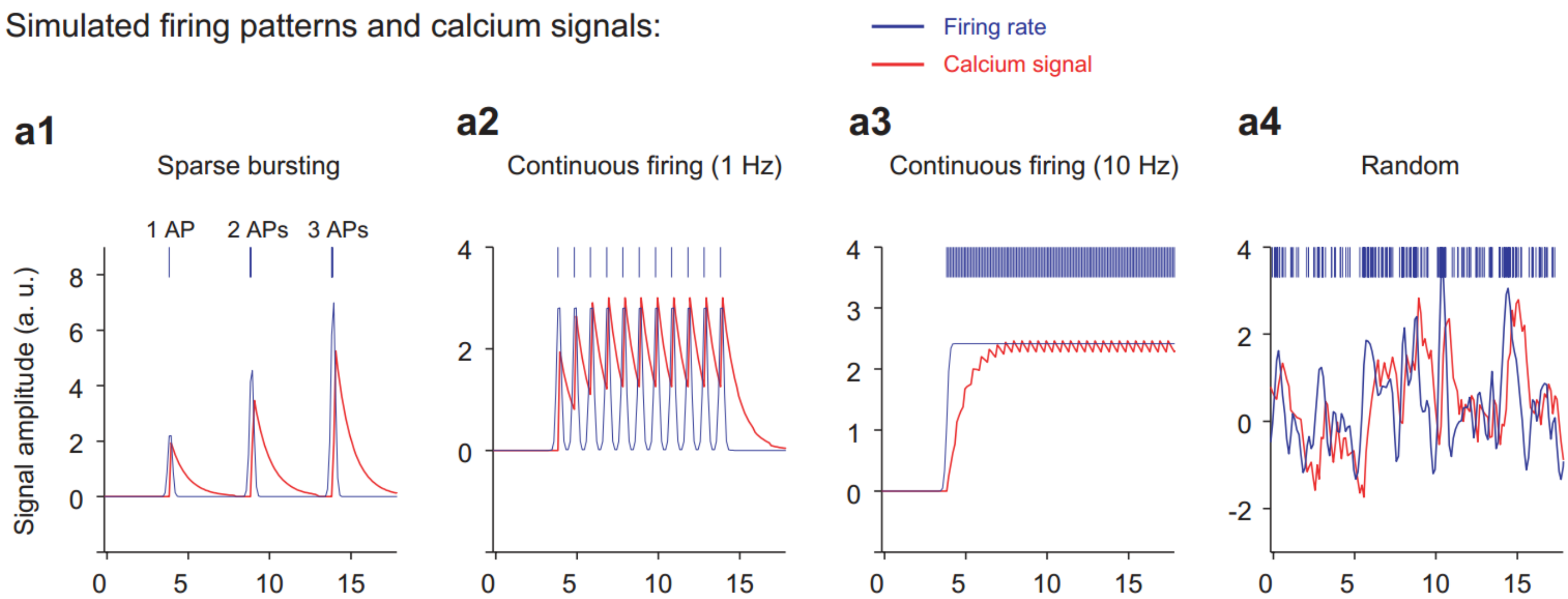
Kerr & Denk 2008

A SIMPLIFIED CALCIUM IMAGING MODEL

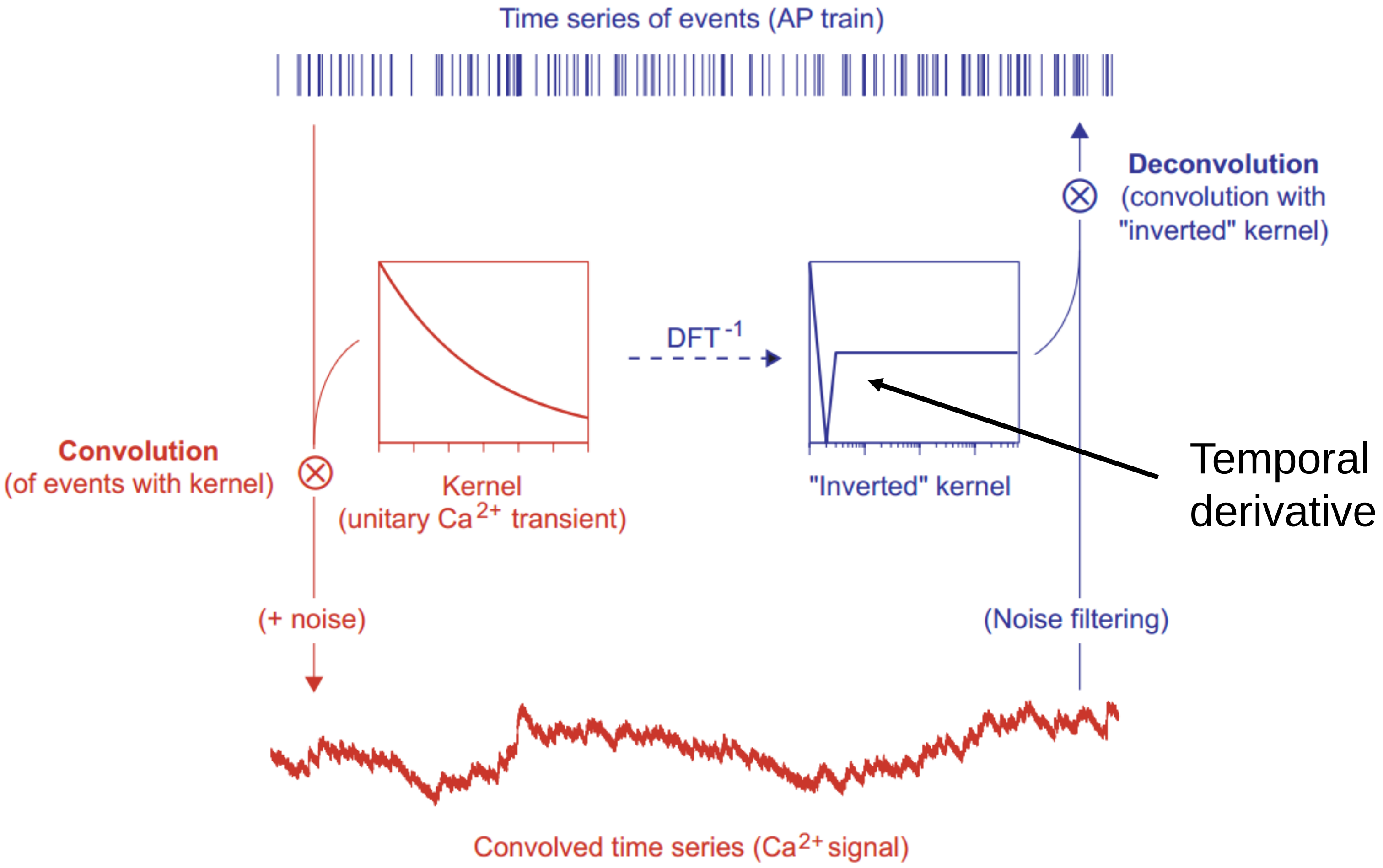


Yaksi & Friedrich 2006

SIMULATED PATTERNS



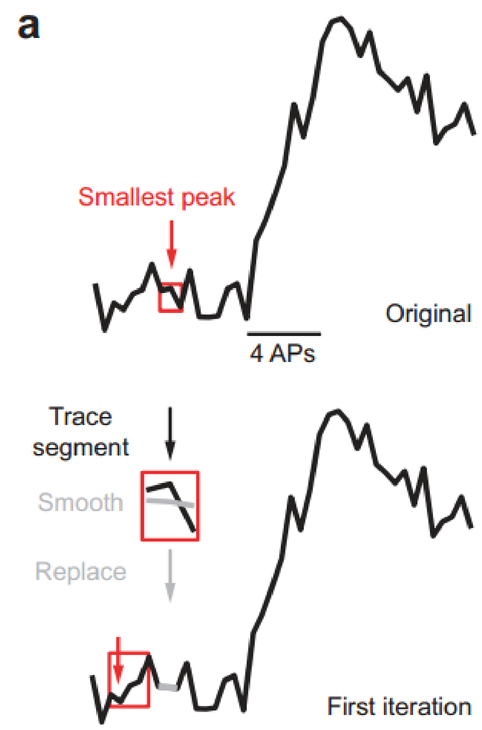
INVERTING THE FORWARD MODEL



ALGORITHM

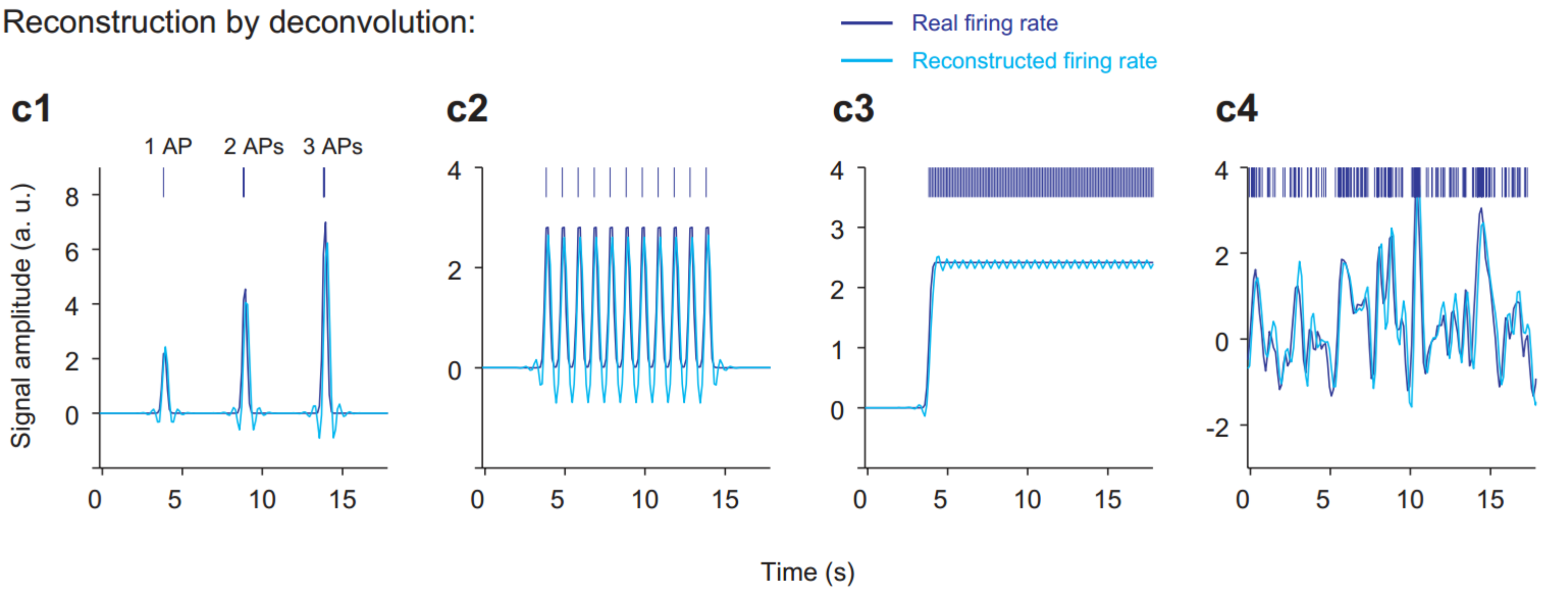
1. **Low pass filter trace (Butterworth/Gaussian)**
2. **Iterative local averaging procedure (for details see paper) to remove noise below a threshold without affecting AP transients**
3. **Deconvolution with exponential ker**

- Finding the time constant?
- Reconstruction of low pass-filterec
- Negative rates?

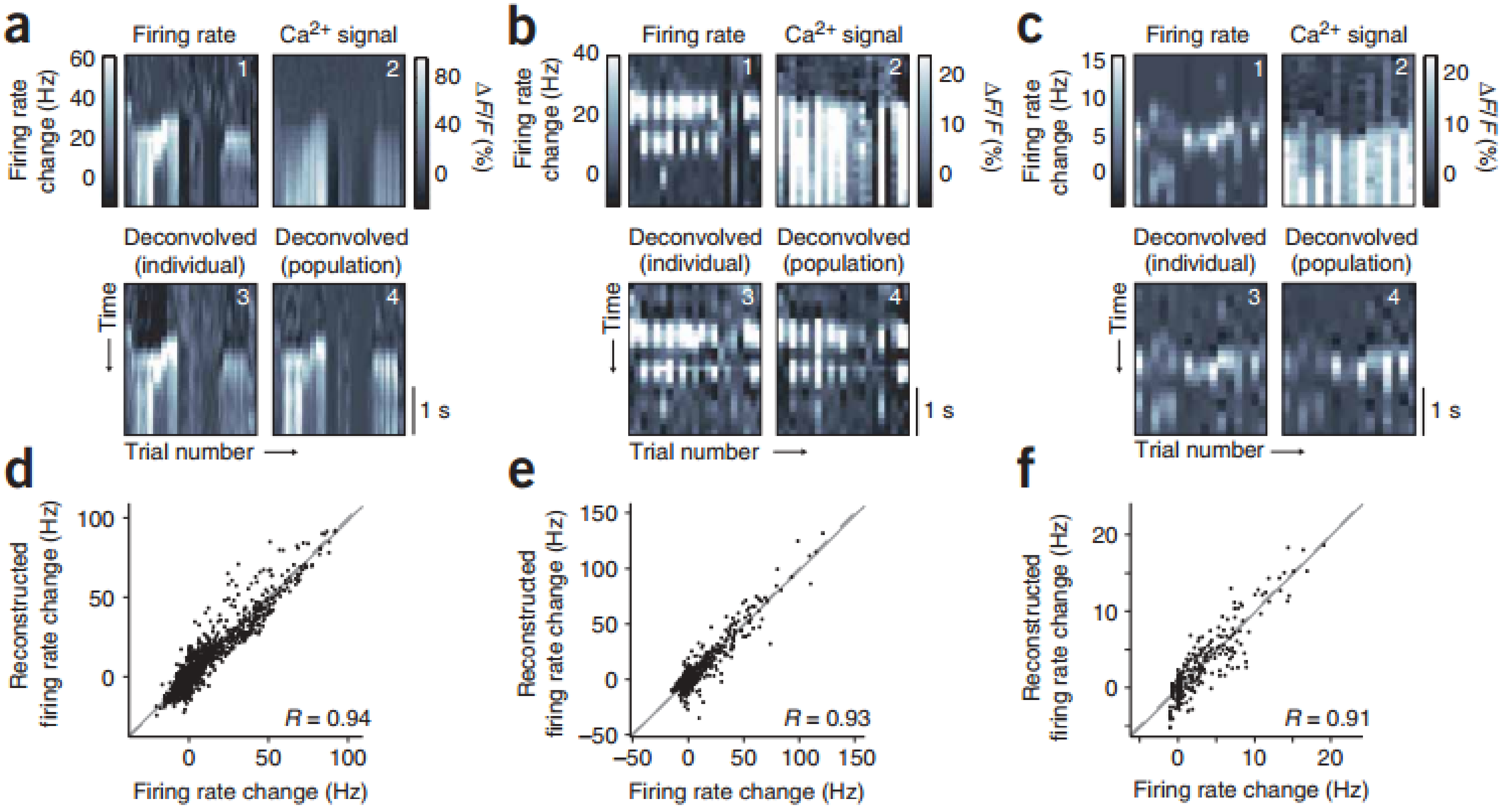


RESULTS

Reconstruction by deconvolution:

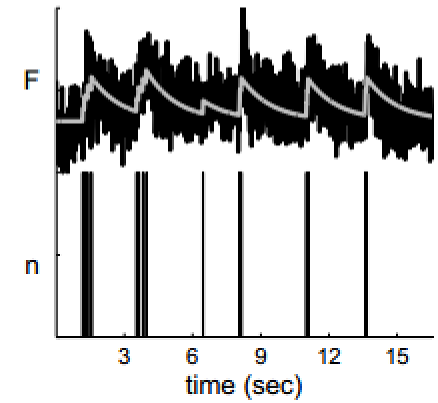


RESULTS



a
Firing rate
Ca2+ signal
Firing rate change (Hz)
60
40
20
0
80
40
0
ΔF/F (%)
1
2
Deconvolved (individual)
Deconvolved (population)
3
4
Time
1 s
Trial number
b
Firing rate
Ca2+ signal
Firing rate change (Hz)
40
20
0
20
10
0
ΔF/F (%)
Deconvolved (individual)
Deconvolved (population)
Time
1 s
Trial number
c
Firing rate
Ca2+ signal
Firing rate change (Hz)
15
10
5
0
20
10
0
ΔF/F (%)
Deconvolved (individual)
Deconvolved (population)
Time
1 s
Trial number
d
Reconstructed firing rate change (Hz)
100
50
0
R = 0.94
0
50
100
Firing rate change (Hz)
e
Reconstructed firing rate change (Hz)
150
100
50
0
–50
R = 0.93
–50
0
50
100
150
Firing rate change (Hz)
f
Reconstructed firing rate change (Hz)
20
10
0
R = 0.91
0
10
20
Firing rate change (Hz)

A MORE COMPLEX MODEL



$$F_t = \alpha[Ca^{2+}]_t + \beta + \epsilon_t$$

$$[Ca^{2+}]_{t+1} = \frac{1-\Delta}{\tau}[Ca^{2+}]_t + n_t \qquad n_t \in N_0$$

$$n_t \sim Poisson(\lambda\Delta)$$

Spike train

Bin width

Fluorescence

Intracellular calcium

Expected rate

$$\hat{n} = \arg\max P[n|F]$$

$$\hat{n} = \arg\max \sum_{t=1}^{T} -\frac{1}{2\sigma}(F_t - \alpha C_t - \beta)^2 + n_t \ln \lambda\Delta - \ln n_t!$$

MAP Estimate

Because of Poisson prior!

Vogelstein et al. 2009/2010

APPROXIMATE SOLUTION

$$\hat{n} = \arg\max P[n|F]$$

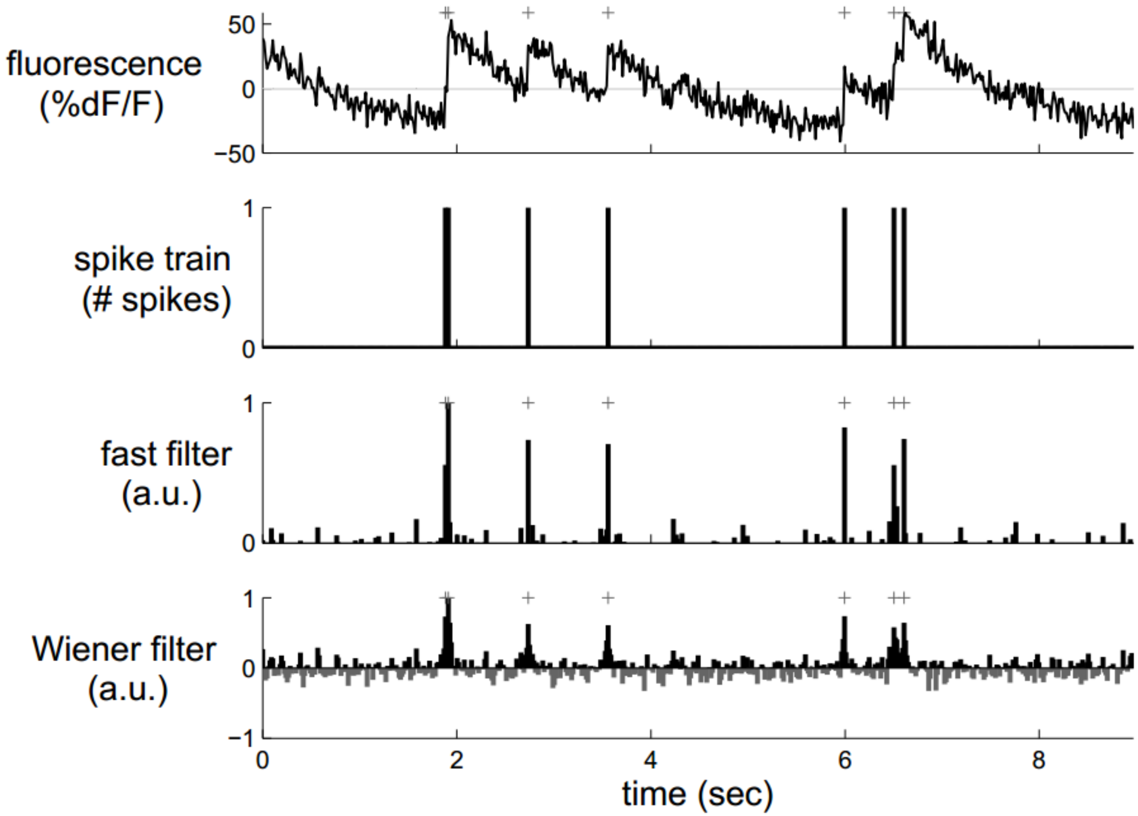
$$\hat{n} = \arg\max \sum_{t=1}^{T} -\frac{1}{2\sigma}(F_t - \alpha C_t - \beta)^2 + n_t \lambda \Delta$$

With exponential prior

$n_t \geq 0$

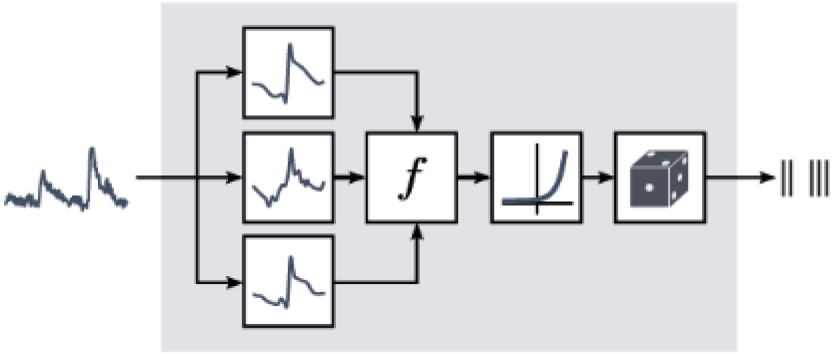
- Convex in spike train
- Interior-point methods because of threshold
- Iterate
  1. Solve for spike train, fix parameters
  2. Solve for parameters, fix spike train

RESULT



fluorescence
(%dF/F)
50
0
−50
spike train
(# spikes)
1
0
fast filter
(a.u.)
1
0
Wiener filter
(a.u.)
1
0
−1
0
2
4
6
8
time (sec)

SUPERVISED LEARNING

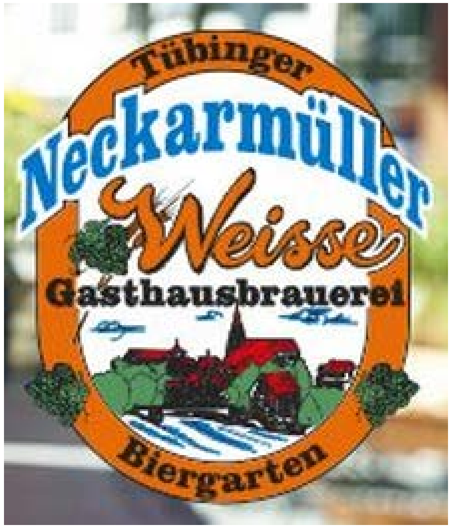


- Learn function from calcium snippets to spike rates
- Flexible model
- See next week: Theis, Berens et al. 2015

OTHER IDEAS

- **GLMs with calcium as input**
- **STA/STC**
- **Classifier that classifies snippets of calcium trace as spike or not spike**
- **…**

COMPETITION



1. **You get a set of 10 cells for which**
   - Calcium trace
   - Spike rate

   has been simultaneously recorded*.

2. **You implement an algorithm to infer rates from calcium signals and learn it‘s parameters on the ten cells you have.**

3. **You submit your m file and we evaluate it on another set of 45 cells.**

4. **The winning team gets a 10 Euro voucher**

* Data courtesy of
M. Froudarakis (BCM)

DETAILS

1. **Data format**
   - Galvo trace
   - Spike trace
   - Fps (frame per second): Temporal resolution of both traces
2. **Don‘t use preimplemented algorithms**
3. **Evaluation**
   - `corr(spiketrace, ispiketrace)`
   - mean across testset
   - Baseline with the most simple algorithm: ~0.32 (0.00-0.54)
   - Due date: 14 of July!