Connectomics through nonlinear dynamics?

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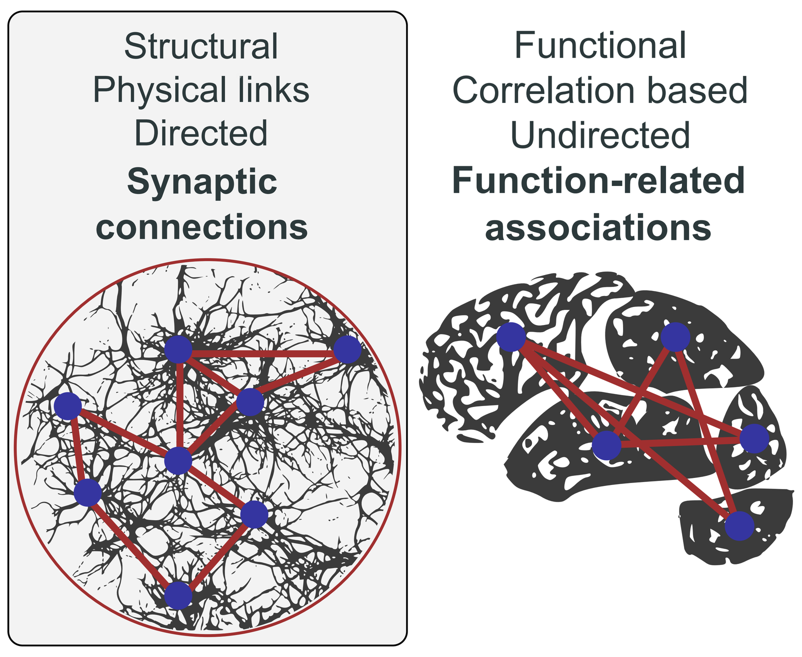
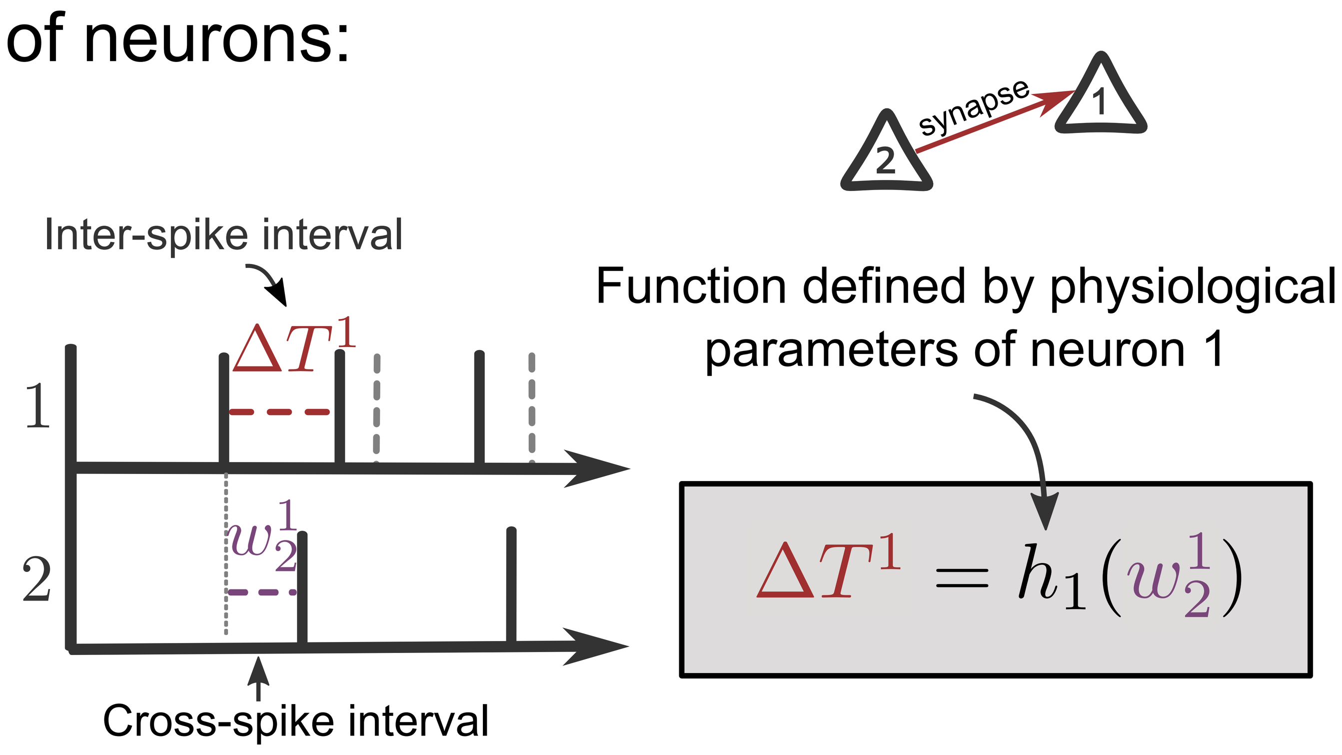
Revealing synaptic connectivity from spike train data

Types of connectivity:



Synaptic inputs change intrinsic behaviour of neurons:

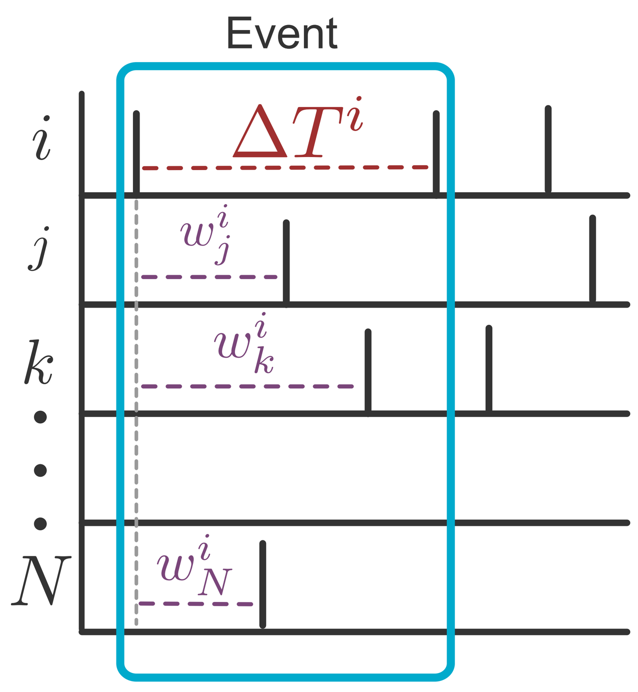


$$\Delta T^1 = h_1(w_2^1)$$

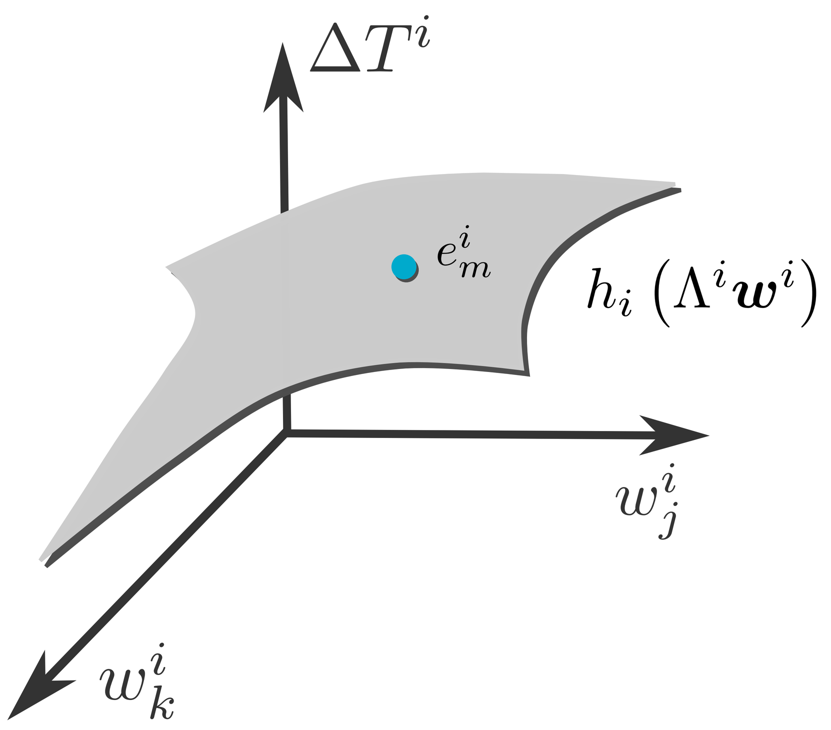
Take-home messages:

- We developed a **model-independent** approach for **revealing synaptic connections** from spike train data **only**.
- **Event space** representations do **not require** prior knowledge of **physiological parameters**.
- **Transmission delays** may be **estimated** from the same spike train data.

Constructing events from spike trains:



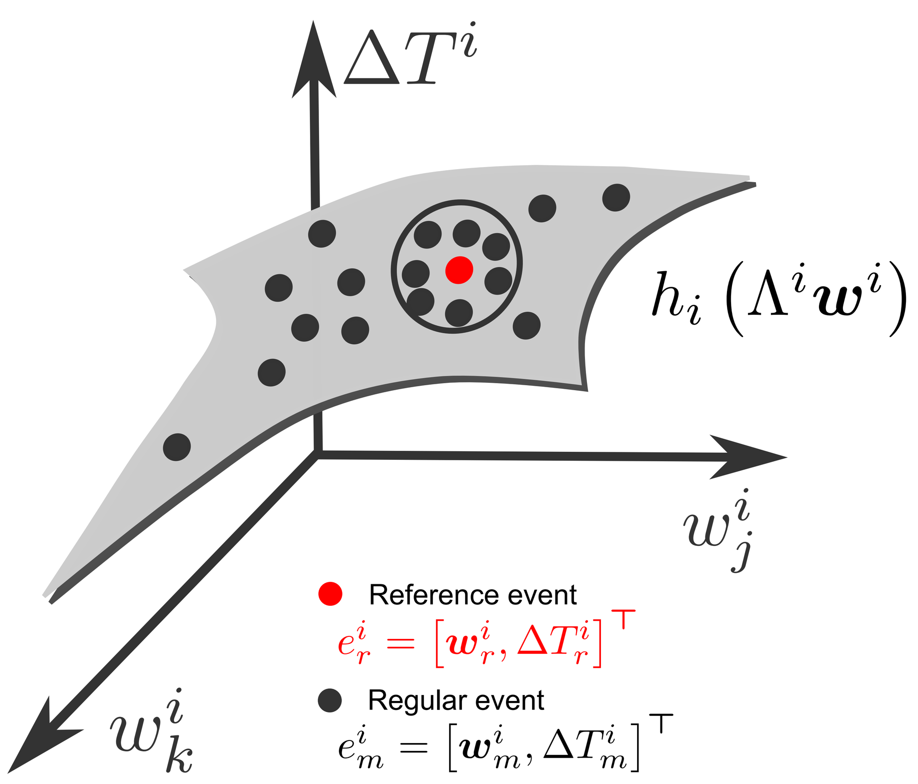
Event space representation:



Local samplings reveal synaptic connections:

$$\Delta T_m^i = \Delta T_r^i + \nabla h_i \Lambda^i \left[\boldsymbol{w}_m^i - \boldsymbol{w}_r^i\right]$$

connectivity mapping



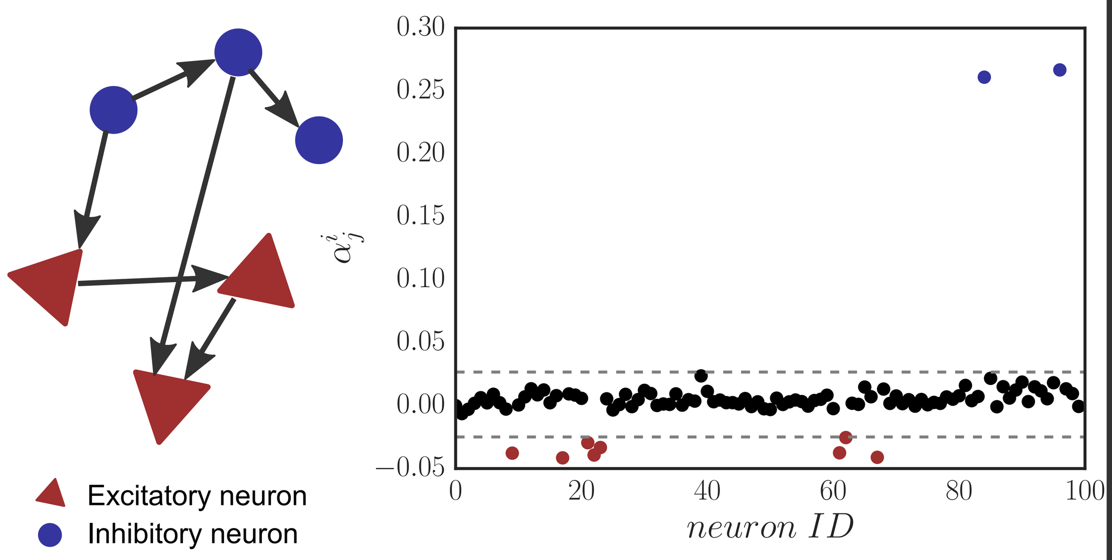
Dynamics of N-coupled neurons:

$$\Delta T^i = h_i\left(\Lambda^i \boldsymbol{w}^i\right)$$

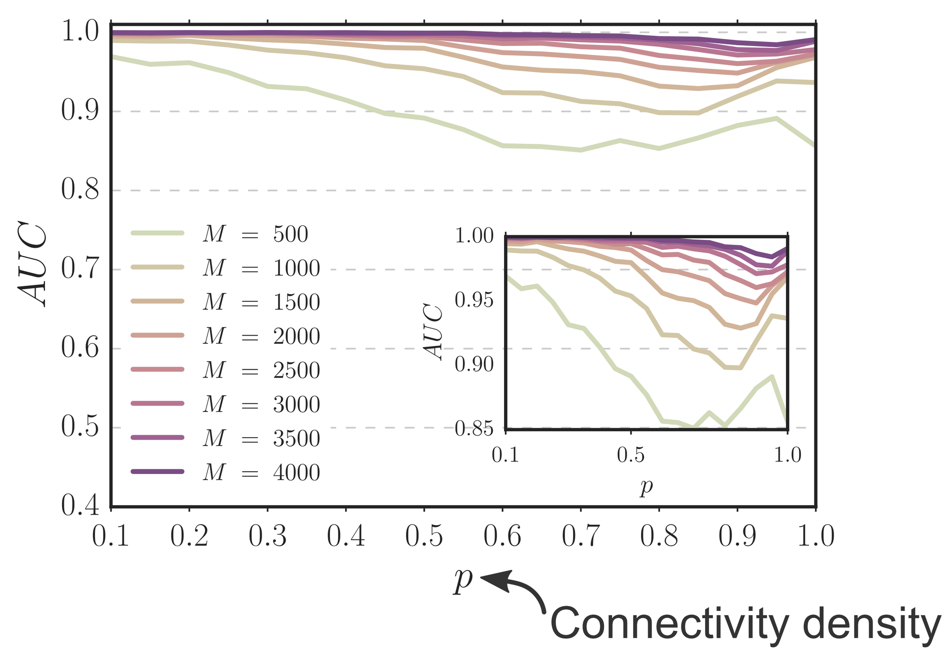
$$\boldsymbol{w}^i = \left[w_1^i, w_2^i, \ldots, w_N^i\right]^\top \in \mathbb{R}^N$$

$$\Lambda_{jj}^i = \begin{cases} 0, & \text{if } \frac{\partial h_i}{\partial w_j} \equiv 0 \\ 1, & \text{if } \frac{\partial h_i}{\partial w_j} \not\equiv 0 \end{cases}$$

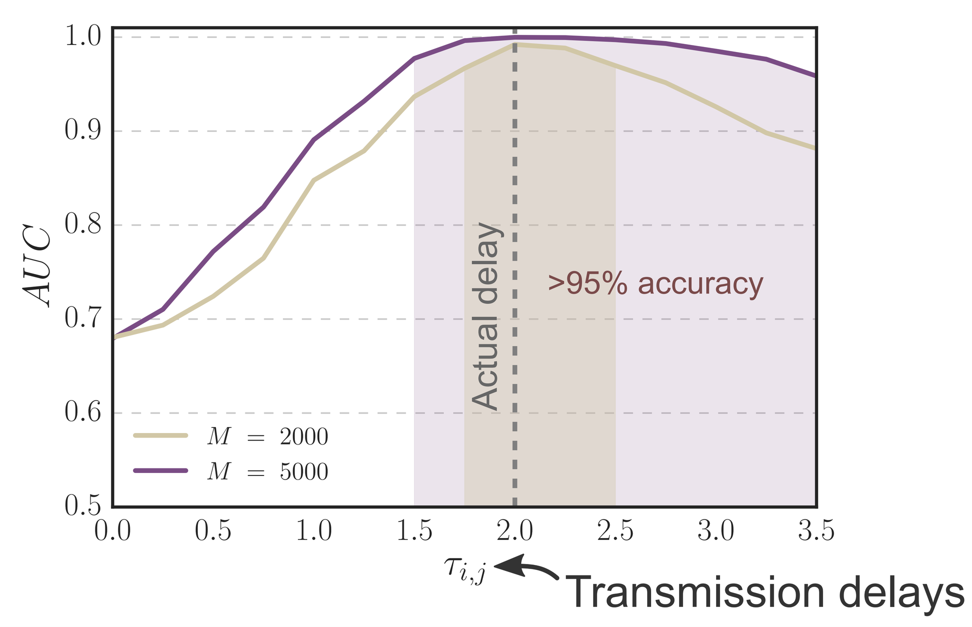
Inferring networks from spike trains:



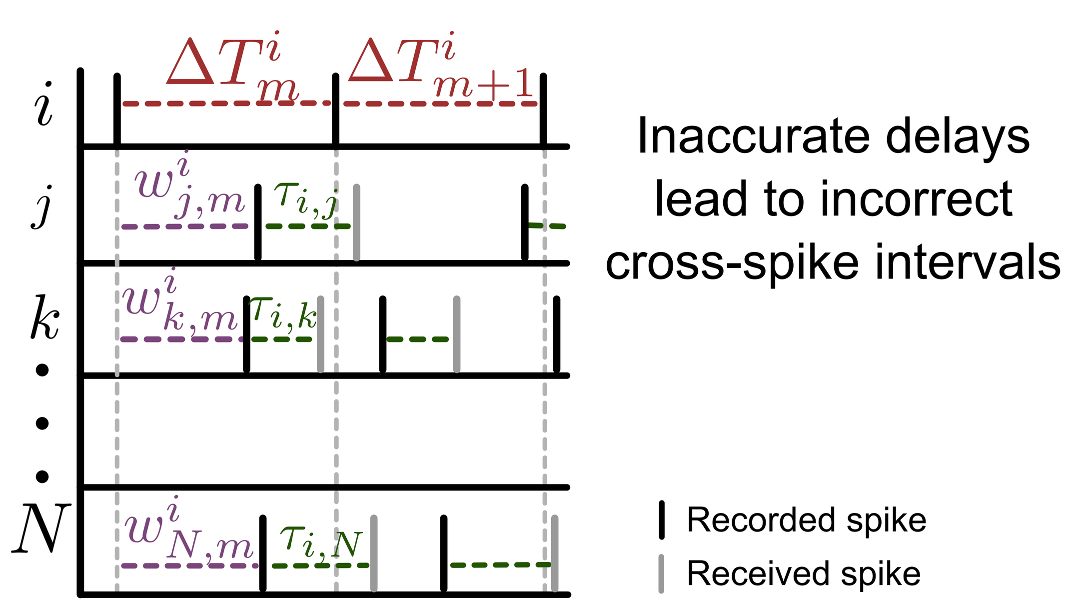
Accurate predictions also for dense networks



Correct predictions for erroneous delays



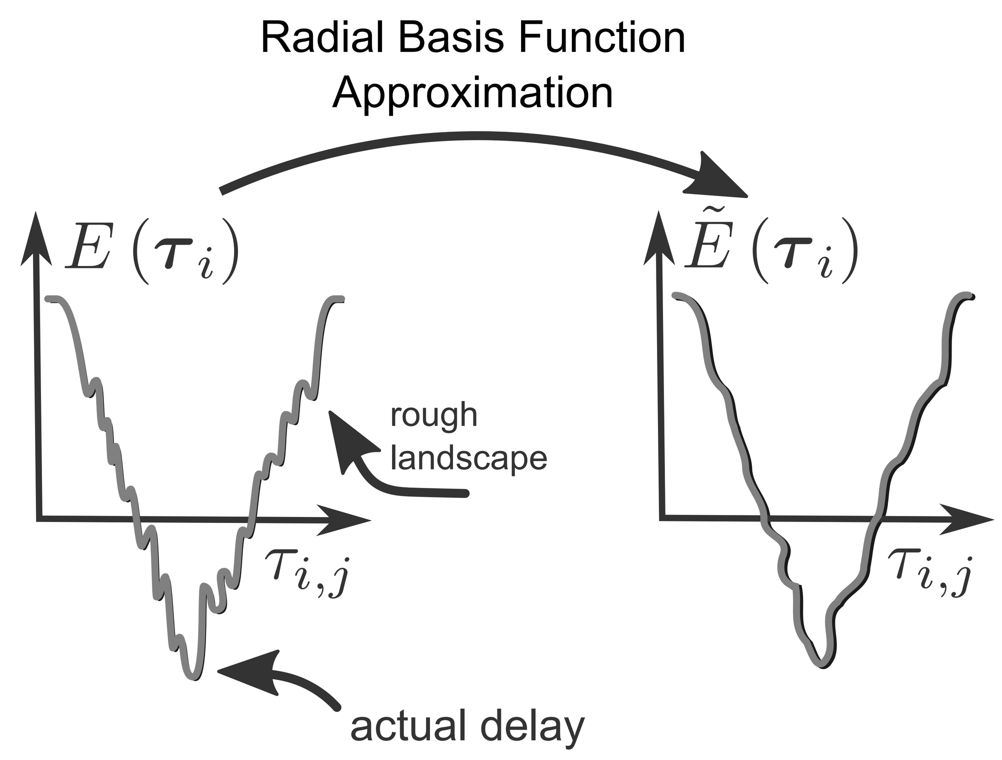
Inferring transmission delays:

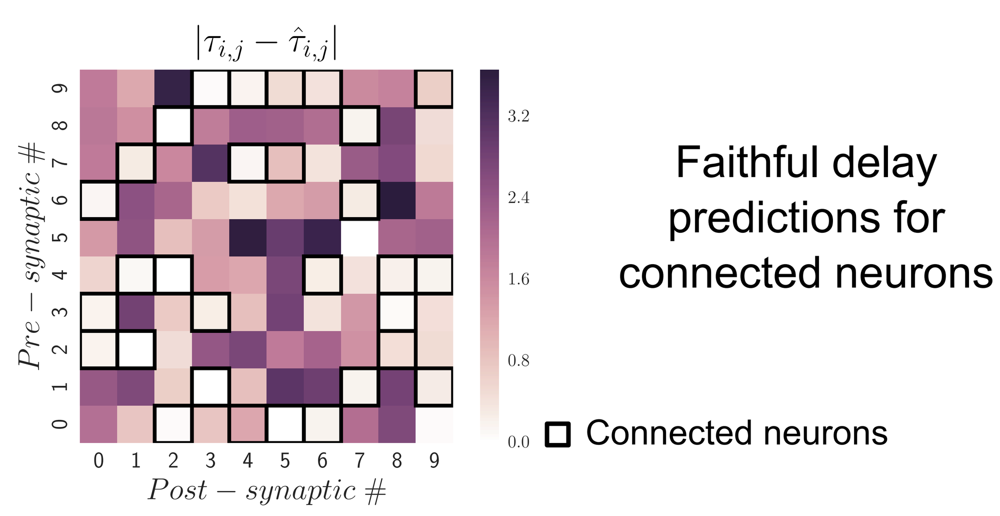


Linear approximation error:

$$E(\boldsymbol{\tau}_i) = \frac{\sum_m \|\Delta T_m^i - \nabla h_i \Lambda^i \boldsymbol{w}_m^i\|_2}{\max_{\boldsymbol{\tau}_i} \sum_m \|\Delta T_m^i - \nabla h_i \Lambda^i \boldsymbol{w}_m^i\|_2}$$

Actual delay vector minimises the approximation error





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