

One-hot generalized linear model for switching brain state discovery



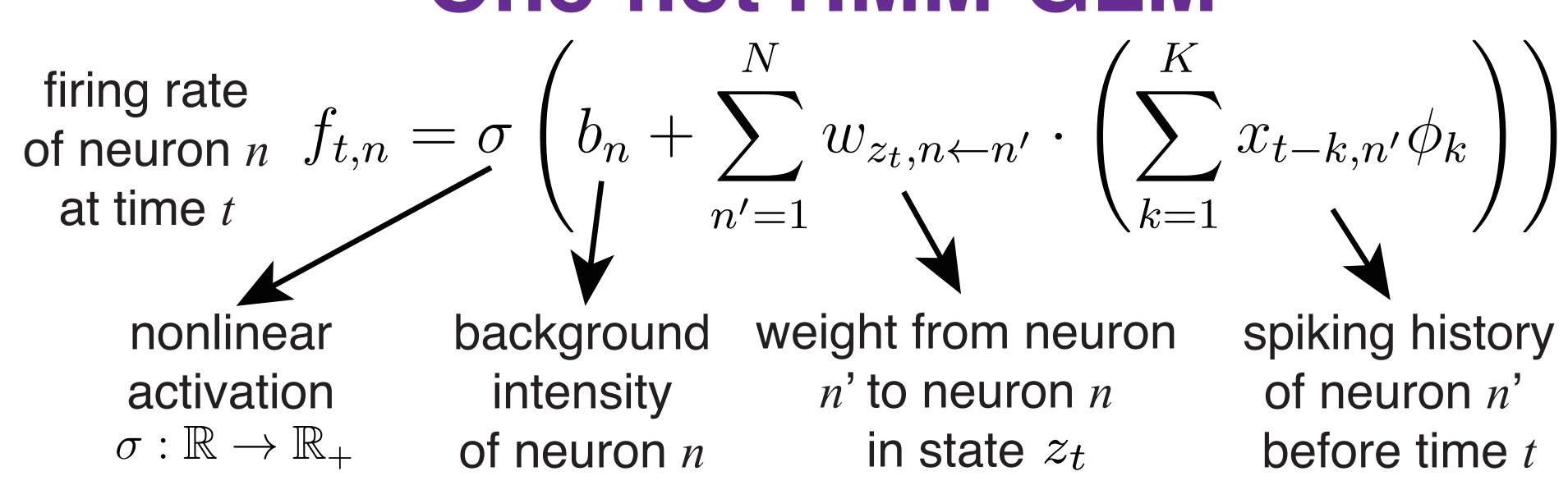
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Introduction

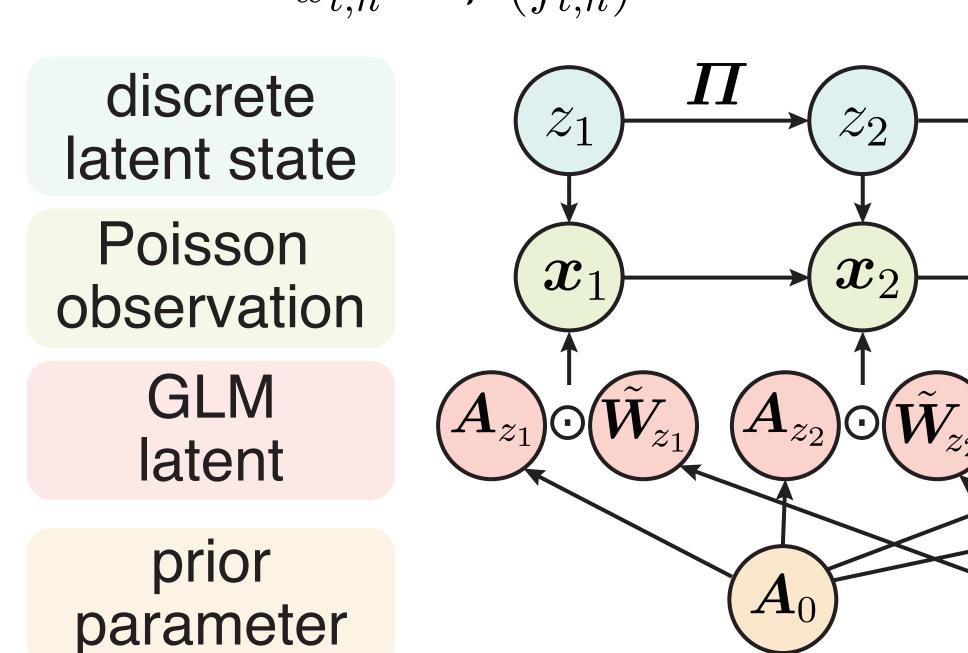
- Exposing meaningful and interpretable neural interactions is critical to understanding neural circuits.
- Classical GLM is only able to find a static functional connectivity graph.
- In a long experiment, subject animals may experience different stages.
- Our new one-hot HMM-GLM can model the dynamically changing functional connectivity confined by an underlying anatomical connectome, which is more biologically plausible over the naive HMM-GLM.

One-hot HMM-GLM



Poisson spikes $x_{t,n} \sim \mathcal{P}(f_{t,n})$

Hidden Markov process of S states $z_{t+1}|z_t \sim \text{Cat}(\pi_{z_t,1}, \pi_{z_t,2}, \dots, \pi_{z_t,S})$



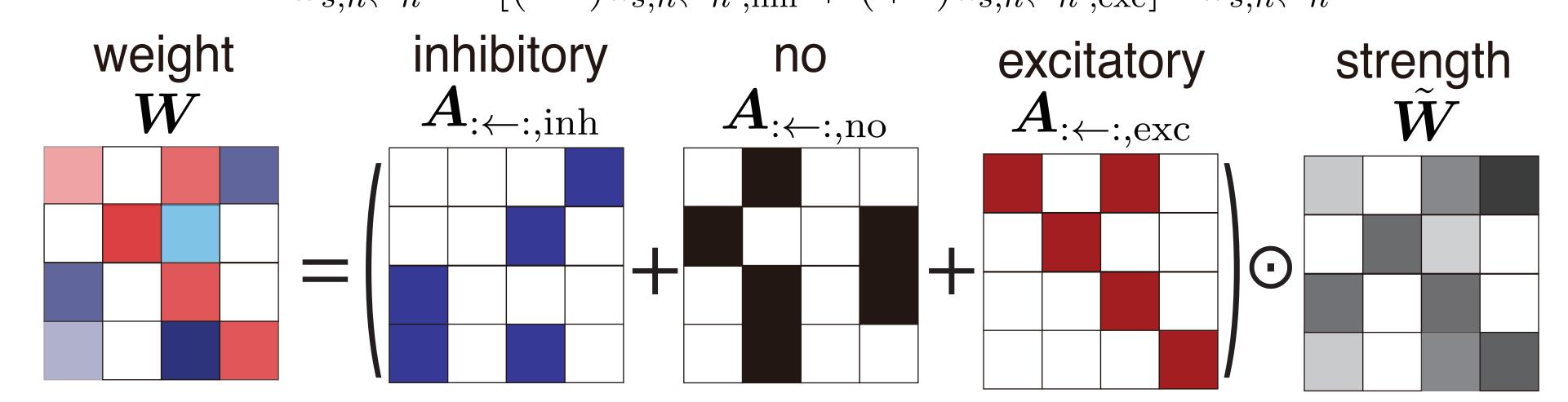
hidden Markov process

Poisson spikes GLM

one-hot decomposition

shared connection prior

One-hot decomposition $a_{s,n\leftarrow n'}\sim \text{Gumbel-Softmax}(a_{0,n\leftarrow n'},\tau)$ $w_{s,n\leftarrow n'} = [(-1)a_{s,n\leftarrow n',\text{inh}} + (+1)a_{s,n\leftarrow n',\text{exc}}] \cdot \tilde{w}_{s,n\leftarrow n'}$



References: [1] Pillow et al., Nature, 2008. [2] Escola et al., Neural computation, 2011. [3] Jang et al., arXiv, 2016. [4] Peyrache et al, 2018. [5] Rodgers et al, Neuron, 2021.

Inference

Baum-Welch (EM) algorithms. E-step: evaluate $Q(\theta, \theta^{\text{old}}) = \mathbb{E}_{p(\boldsymbol{z}|\boldsymbol{X};\theta^{\text{old}})} \ln p(\boldsymbol{X}, \boldsymbol{z}; \theta)$ by the forward-backward algorithm. M-step: maximize it w.r.t θ .

Experiments Synthetic method con prior acc \ $44.81(\pm 0.61)$ GLM $15.45(\pm 2.49)$ $42.84(\pm 1.47)$ $34.04(\pm 0.12)$ HMM Corr $nan(\pm nan)$ $nan(\pm nan)$ $80.60(\pm 0.59)$ Prefrontal cortex during a contingency task trial start (stimulus onset) incorrect trial end ★ correct trial end reward_ state 2 state 3 state 4

- HG: fast switches, limited interpretability.
- GHG: S = 4 states are assumed, but it only infers 2 effective states.
- OHG: 4 stable explainable states. Red: back to the root. Green: go to the turning point. Orange: reach a target. Incorrect trial: blue state. Correct trial: reward, red state.

