Heterogeneous Population Encoding for Multi-joint Regression from surface EMG signals

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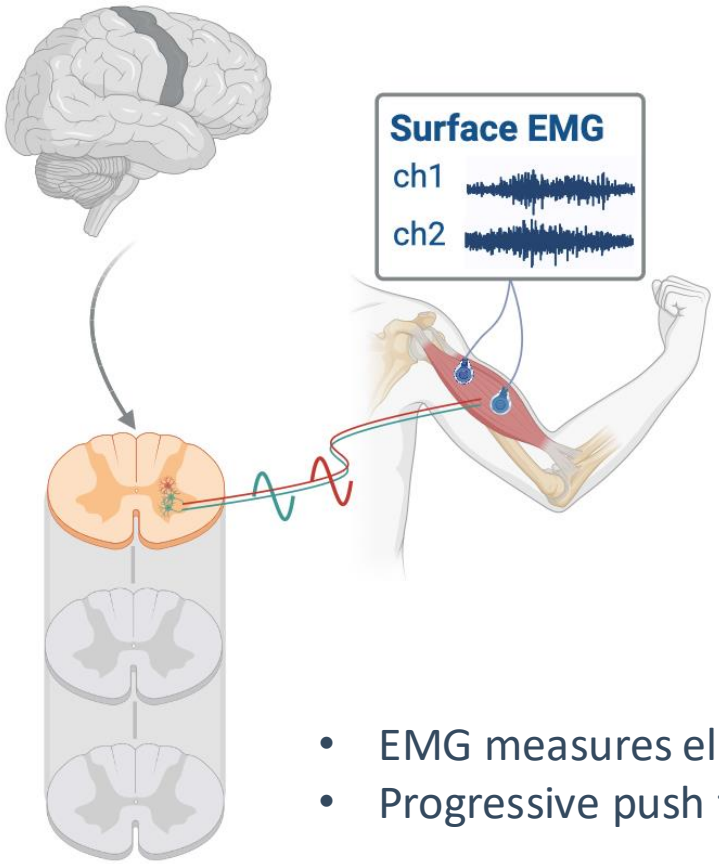
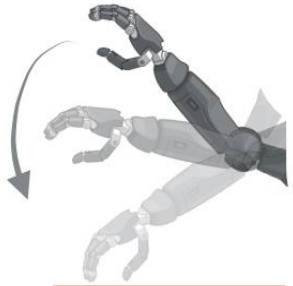
Neuro Inspired Computational Elements 2025

An Application Lens



Process



Prosthetic

regression task

Virtual Reality

Rehabilitation

- EMG measures electrical activity of contracting muscles
- Progressive push towards proportional control of simultaneous DoFs (5+)

- Requirements
  1. Reasonable accuracy
  2. Latency < 200 ms
  3. Battery-operated

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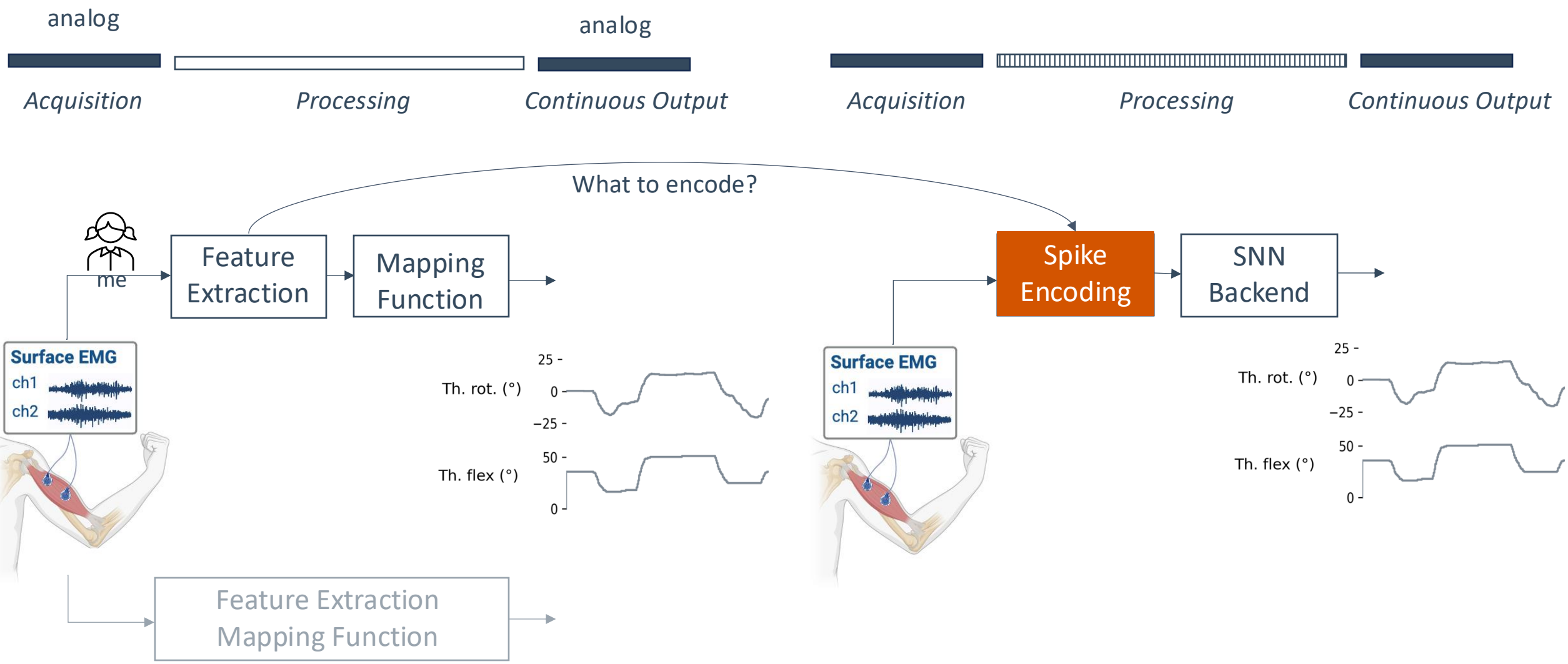
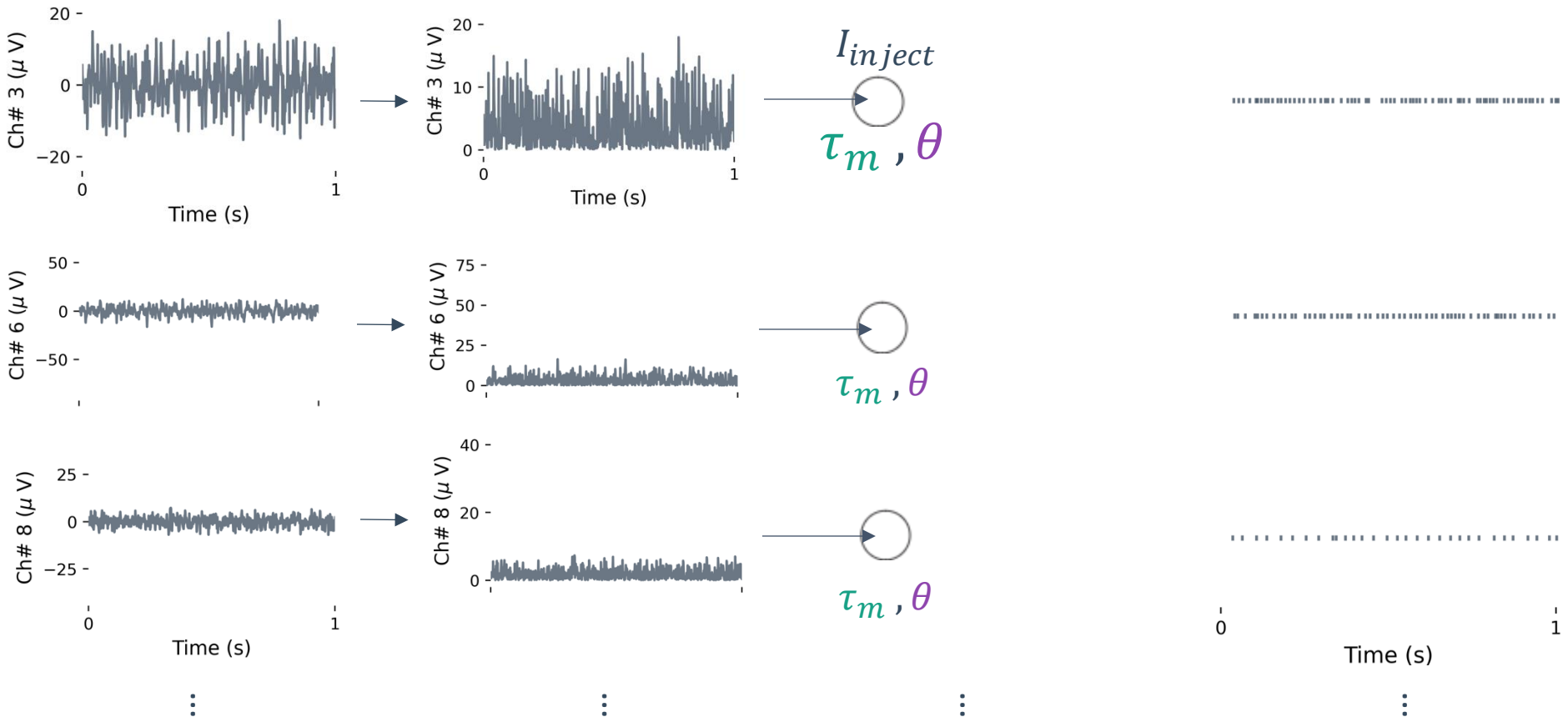
EMG = Electromyography
DoF = Degree-of-freedom

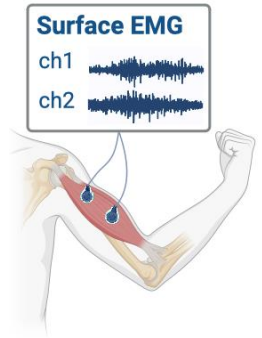
Processing EMG: A Bird's-Eye View



Extracting EMG Features in Spikes

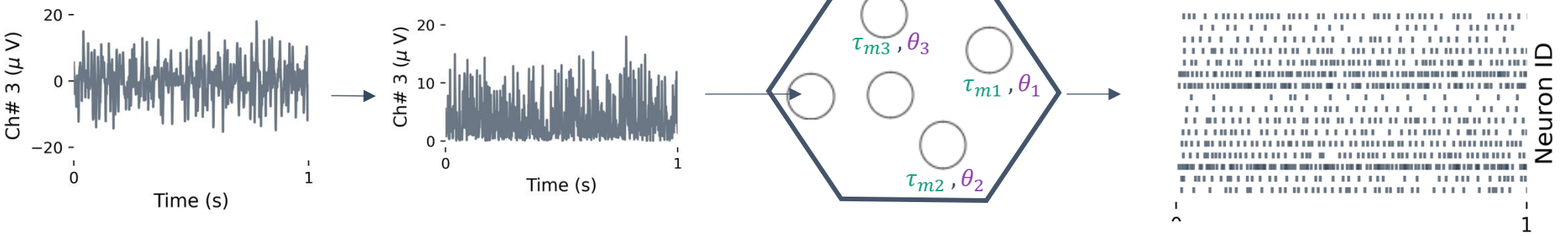


- 'Good' features are related to signal's amplitude (RMS, MAV, power,…)
- Available approaches rely on a single neuron

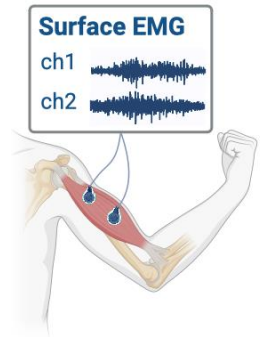


RMS = Root-mean squared
MAV = Mean absolute value

Extracting EMG Features in Spikes



one EMG channel → Heterogeneous population → many spike representations



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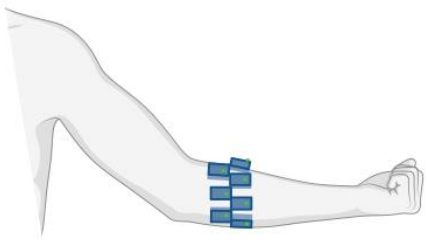
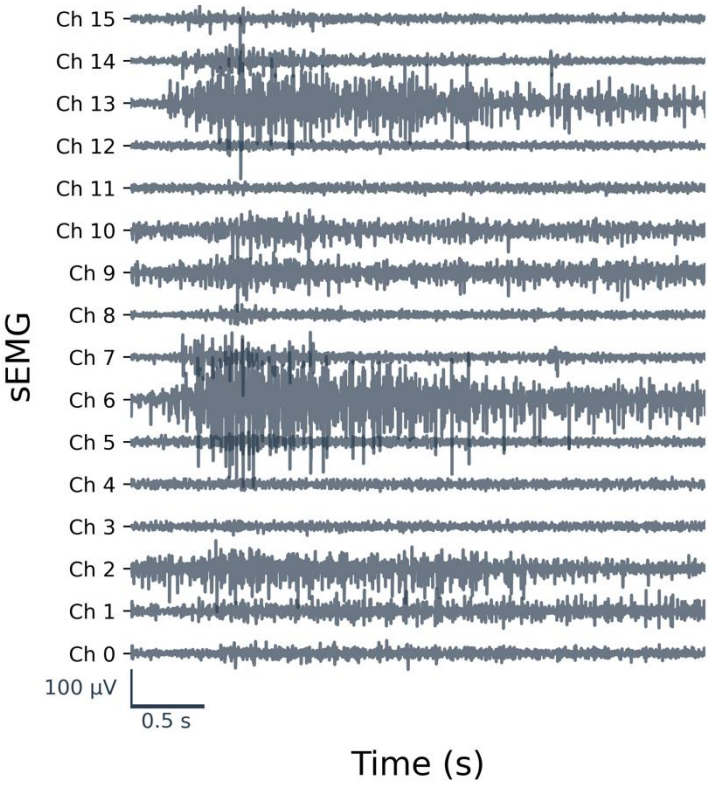
Evaluation



NinaPro DB8

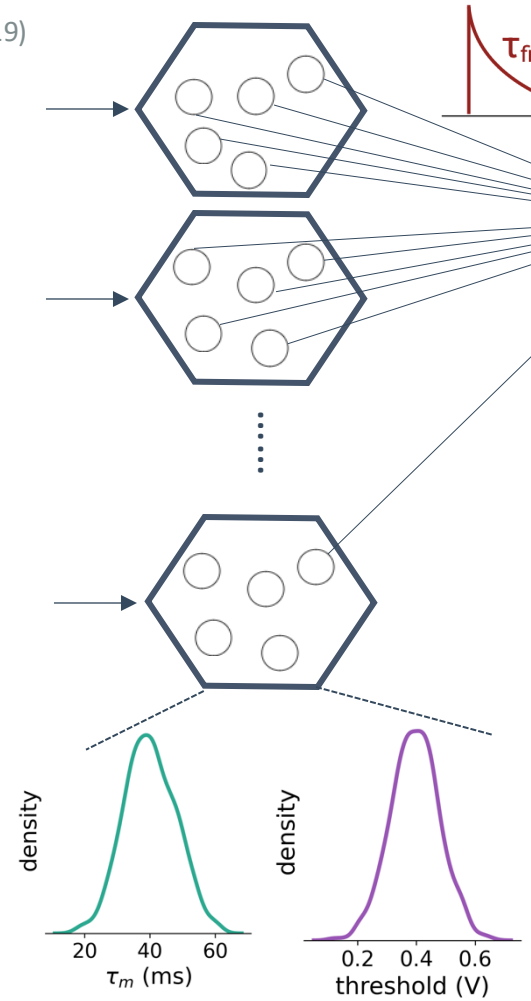
Krasoulis, Vijayakumar, and Nazarpour (2019)



Spike Encoding

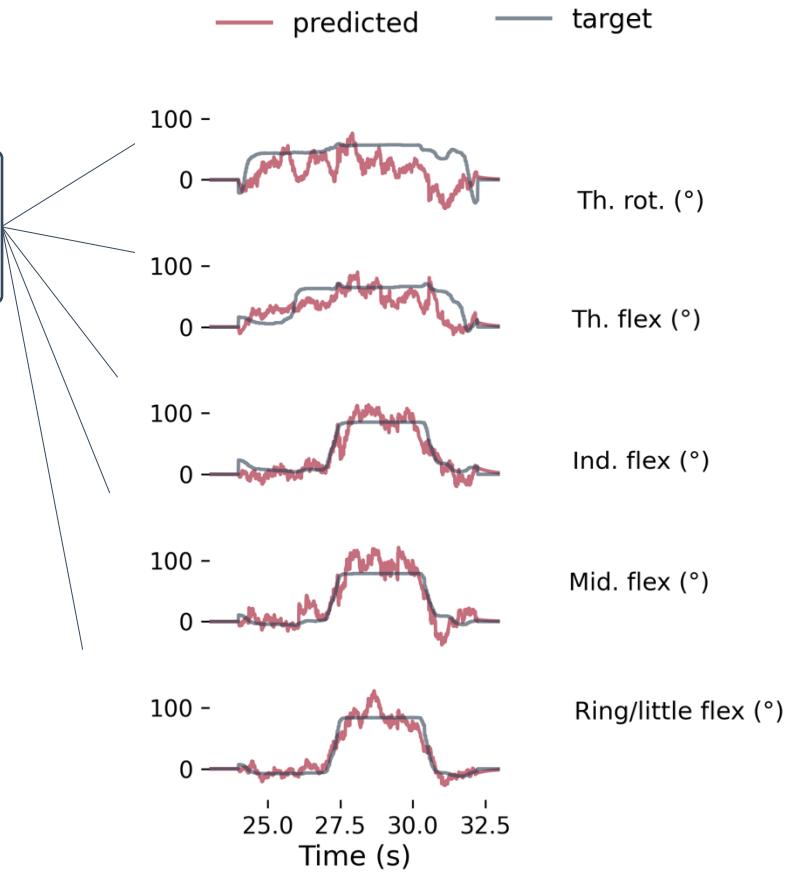
Classic Backend

N LIF neurons



Multi-output linear regression

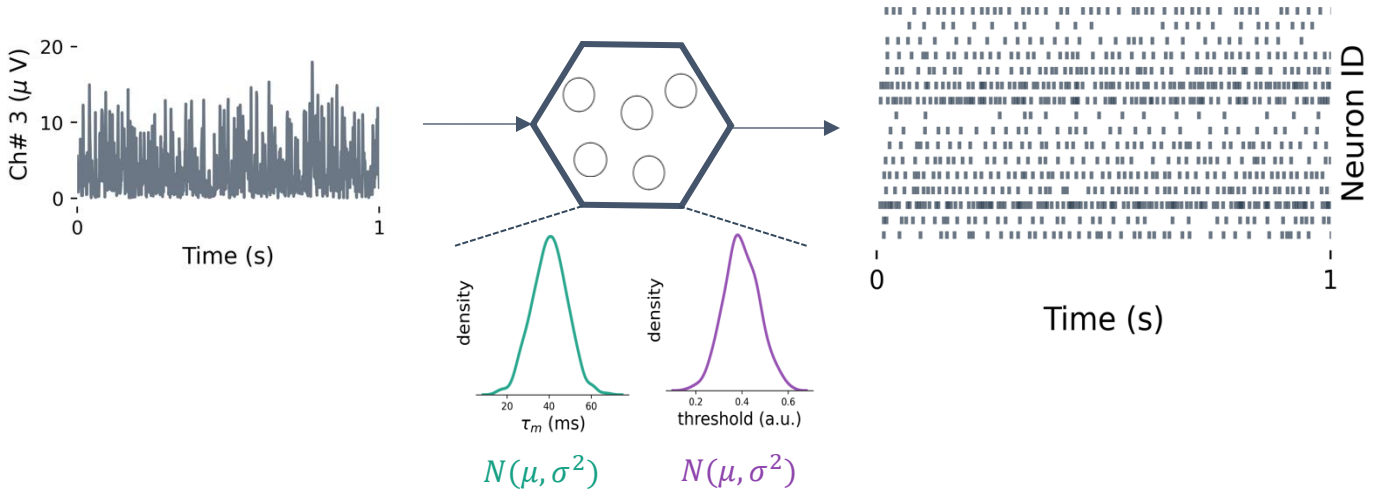
Fit to minimize MAE

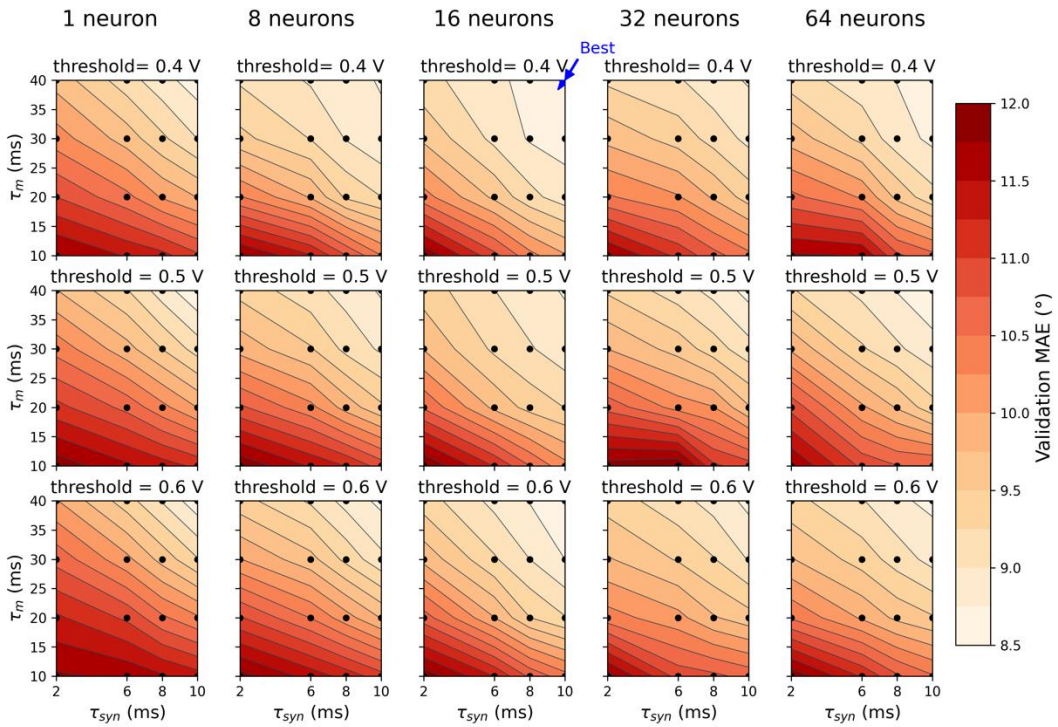


LIF = Leaky integrate-and-fire

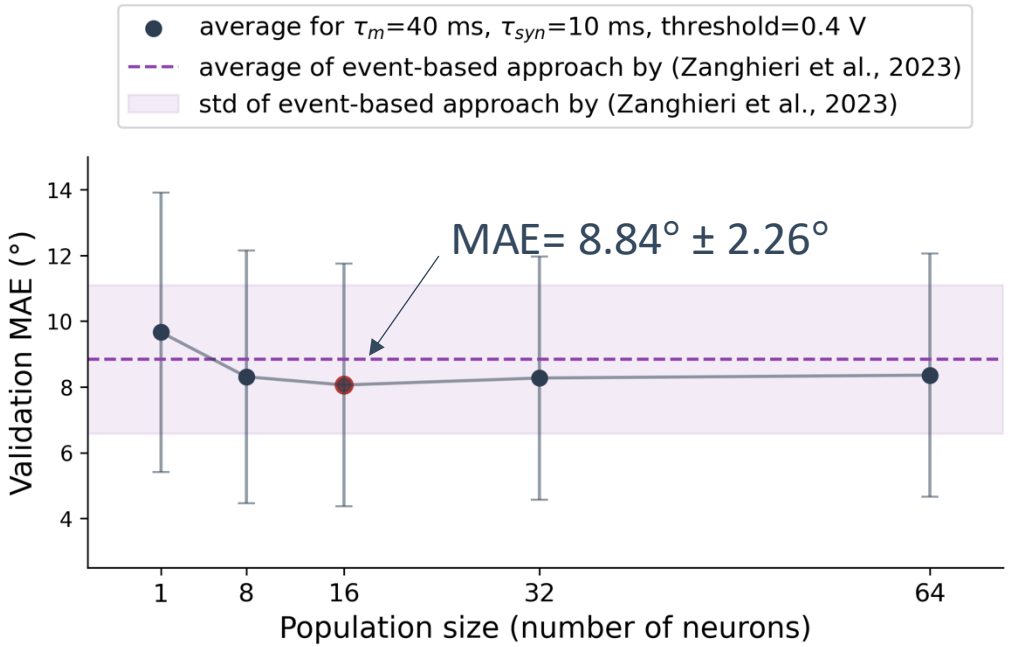
MAE = Mean absolute error

Results





- Find ‘good’ operating regime based on few subjects
- Increasing population size saturates performance
- Having heterogeneous neurons allow generalization on unseen subjects



MAE = Mean absolute error

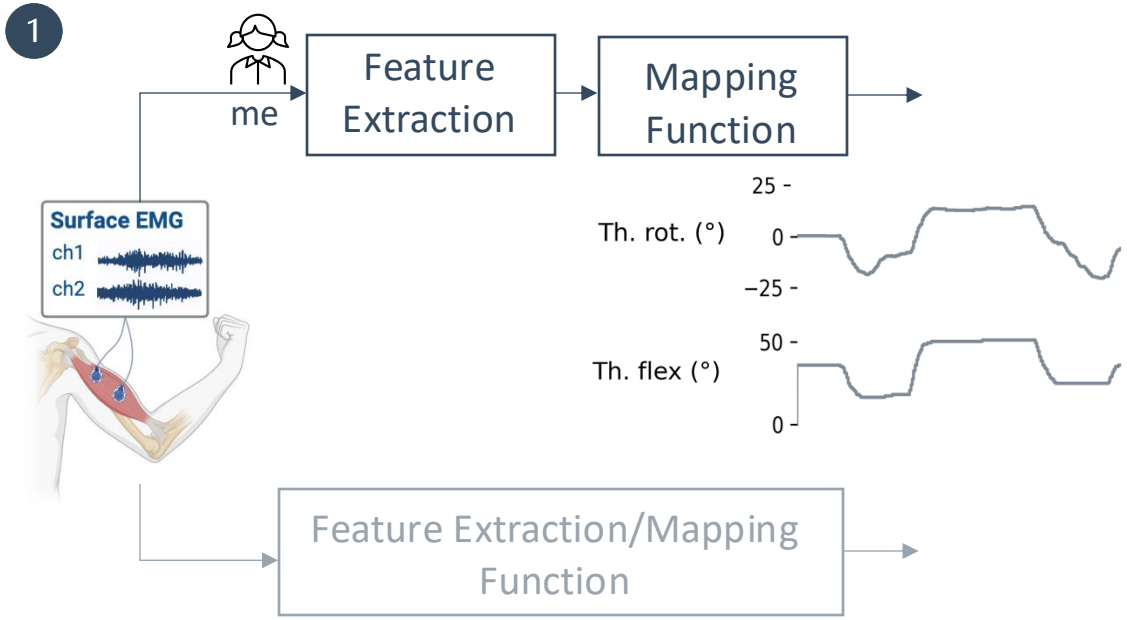
Conclusion

- Avoid optimization of neurons parameters per subject and channel
- Incorporate heterogeneity within the encoding population …
- Evaluate end-to-end decoding performance on a benchmark EMG dataset
- Heterogeneity seems to work fine but to a certain degree…

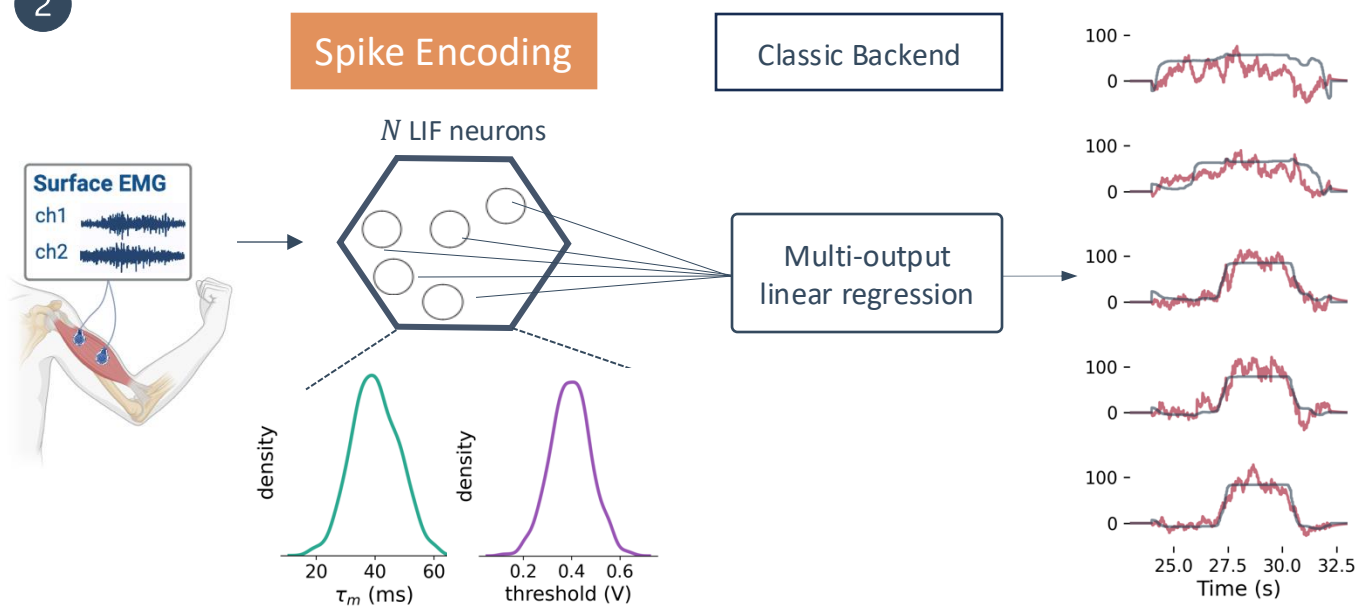
But, what is a “sufficient” degree of correlation within population?

THANK YOU!

1



2



*Using **heterogeneity in encoding** sEMG channels to enable **cross-subject generalization**, eliminating the need for precise tuning.*

3