Spike Sorting based on Dominant-Sets clustering

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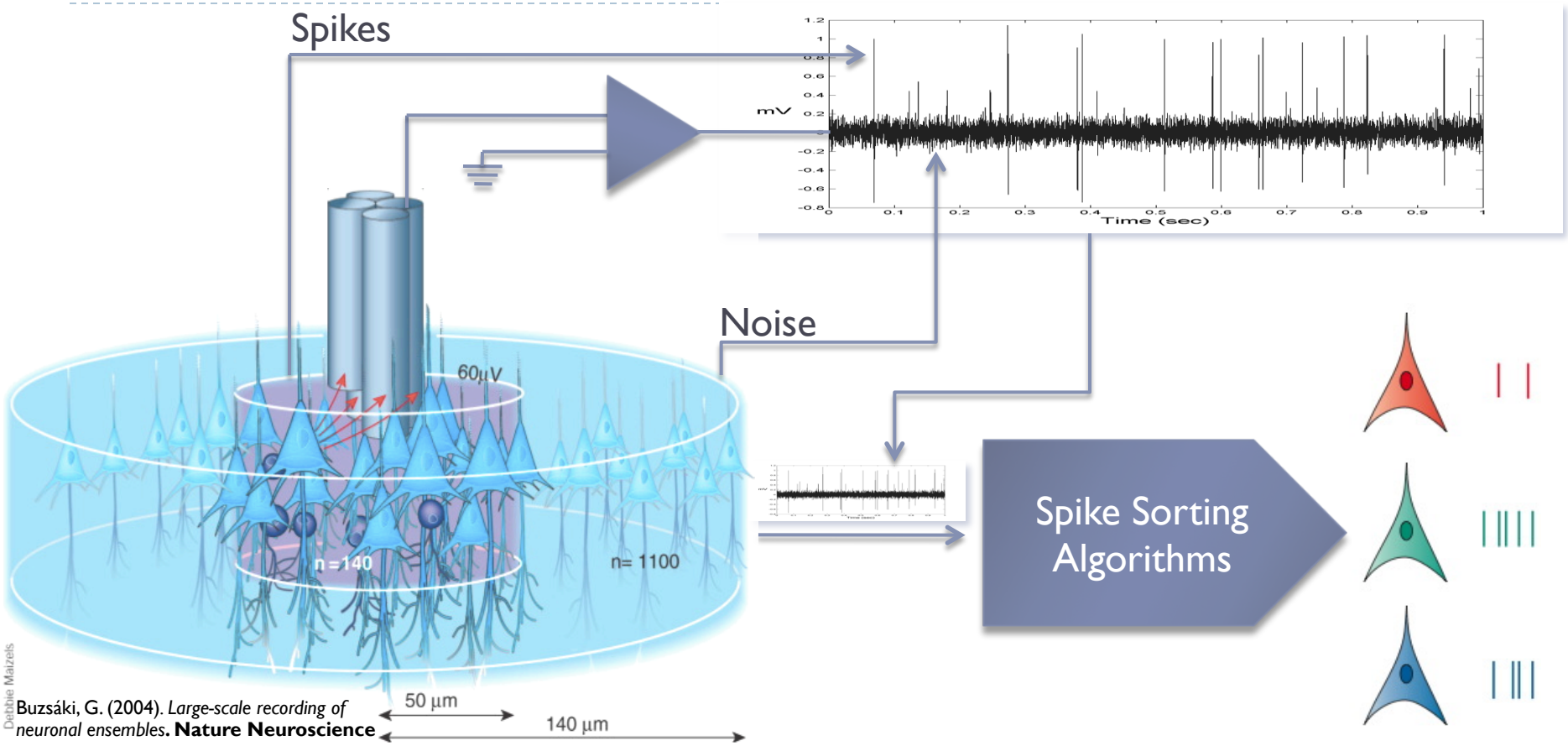
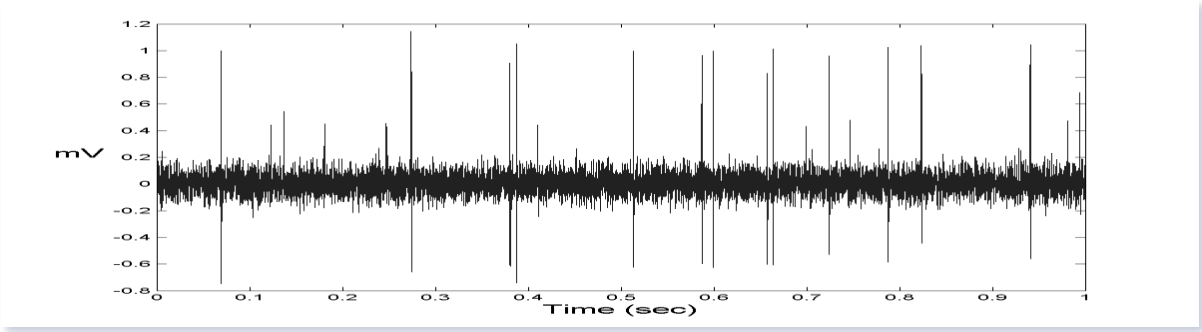
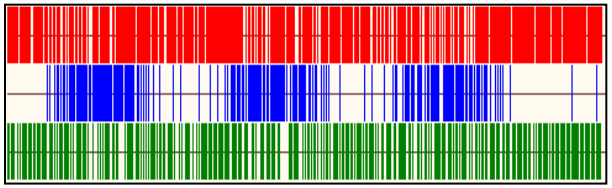
What is spike sorting?

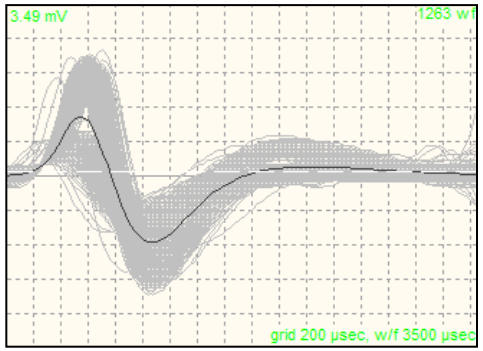


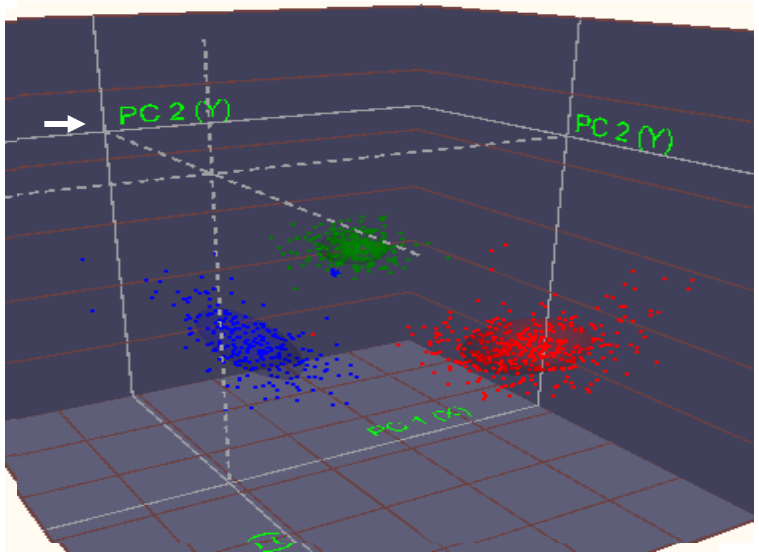
Buzsáki, G. (2004). *Large-scale recording of neuronal ensembles*. **Nature Neuroscience**

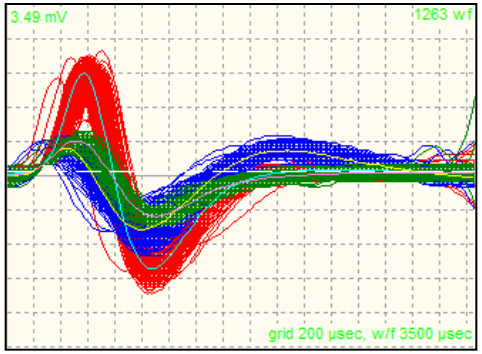
Spike sorting in a nutshell



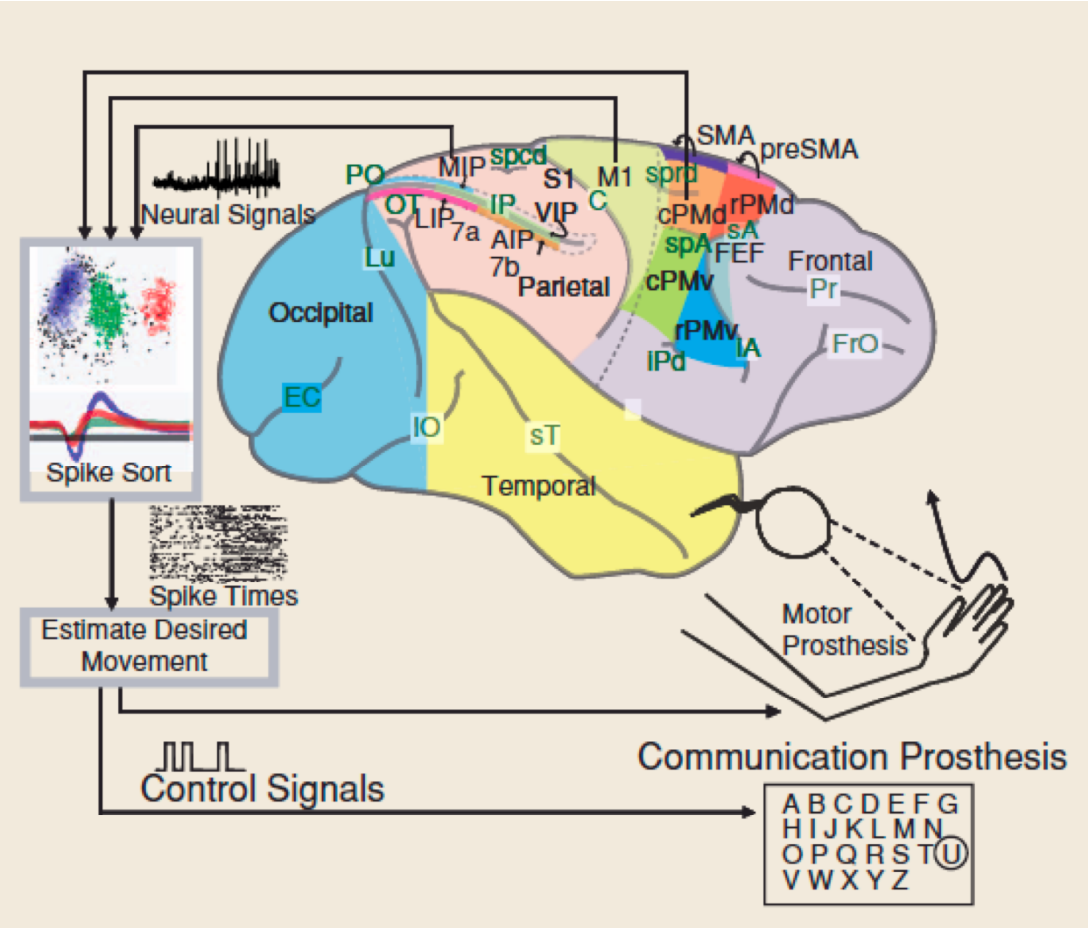






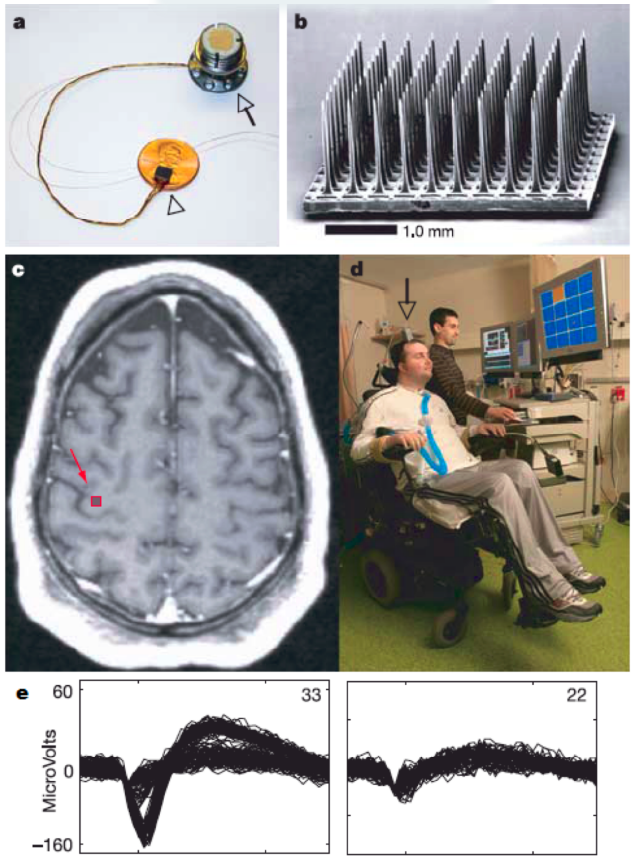


Spike sorting applications



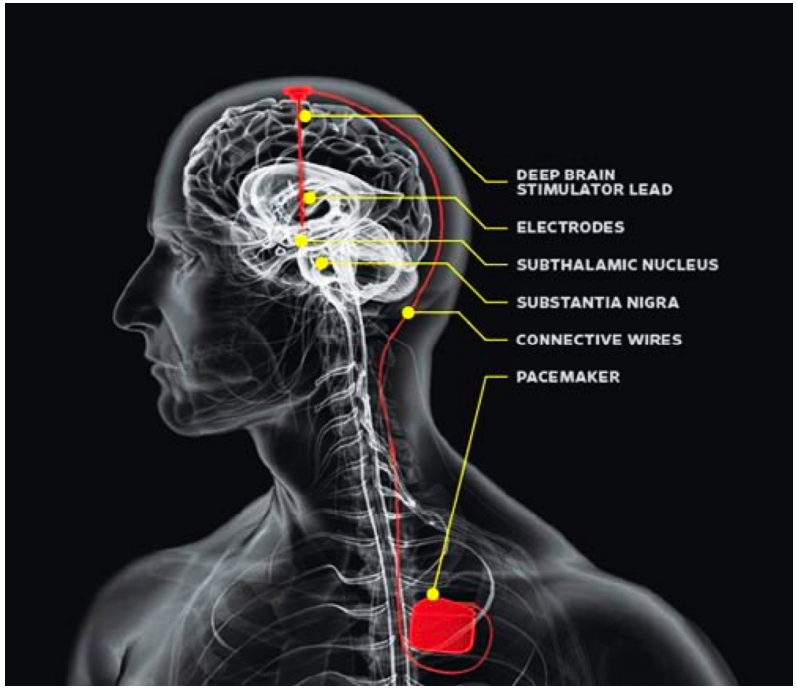
Linderman et al. (2008). *Signal processing challenges for neural prostheses.* ***IEEE Signal Processing Magazine***

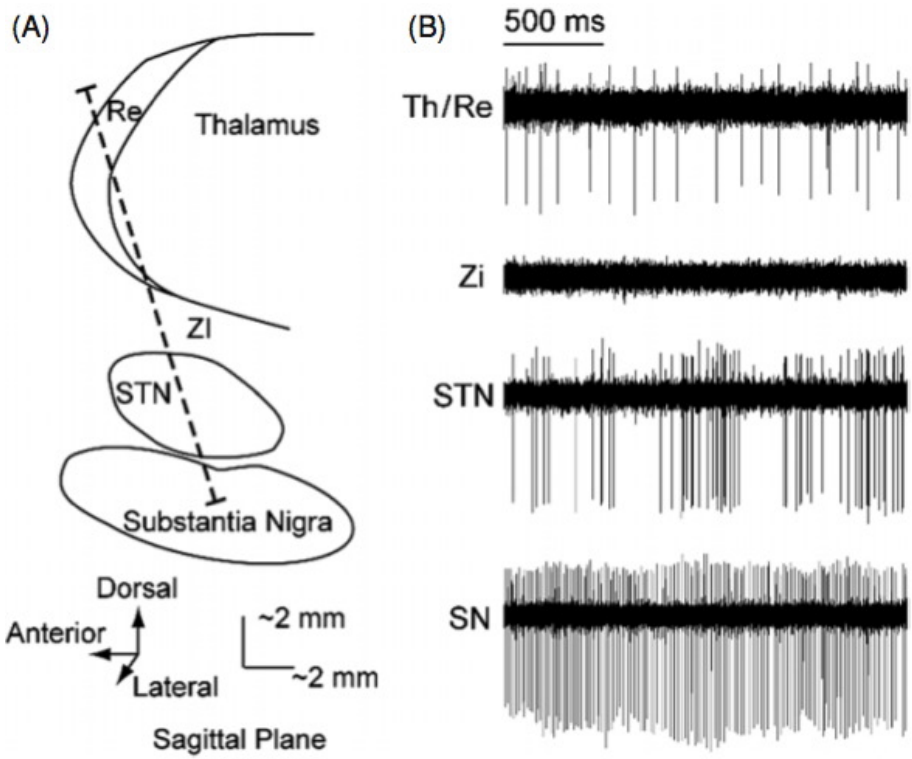
BrainGate



Hochberg et al. (2006). *Neuronal ensemble control of prosthetic devices by a human with tetraplegia.* ***Nature***

Spike sorting applications



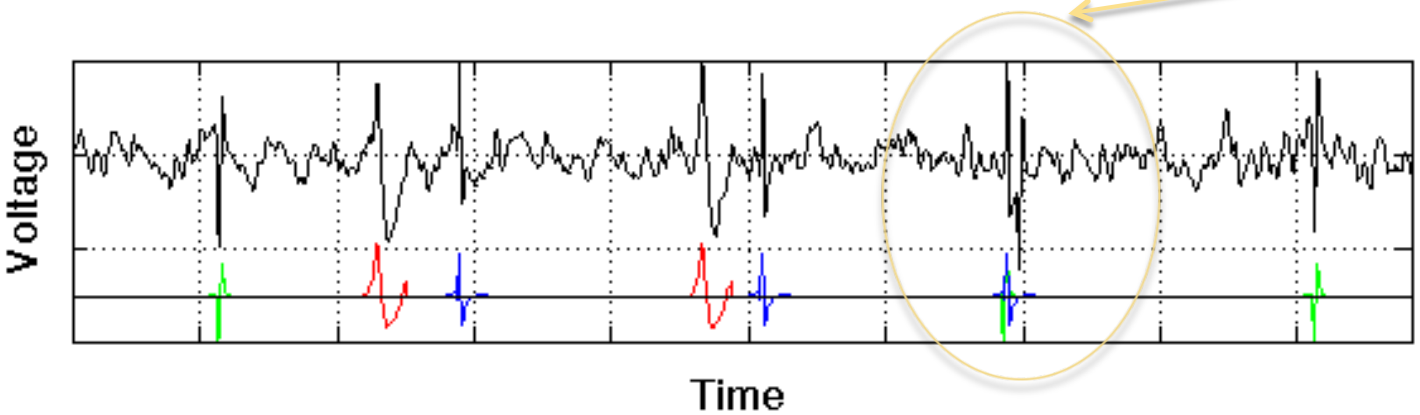


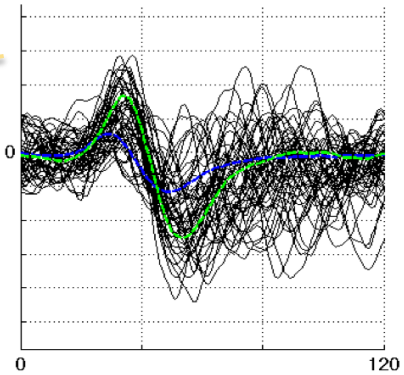
- Functional STN Targeting during DBS surgery

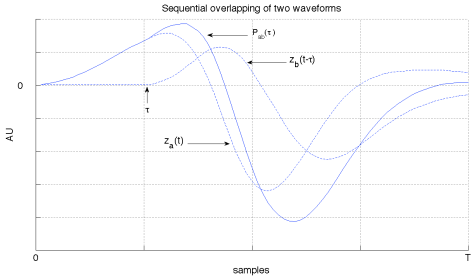
Wong et al. (2009). *Functional localization and visualization of the STN from microelectrode recordings acquired during DBS surgery with unsupervised machine learning*. **J Neural Eng**

Open problems in spike sorting #1

- Resolution of **overlapping** spikes







Adamos DA, Laskaris NA , Kosmidis EK and Theophilidis G.

***NASS**: An empirical approach to **S**pike **S**orting with overlap resolution based on a hybrid **N**oise-**A**ssisted methodology*

(2010) **Journal of Neuroscience Methods** Article in Press doi:10.1016/j.jneumeth.2010.04.018

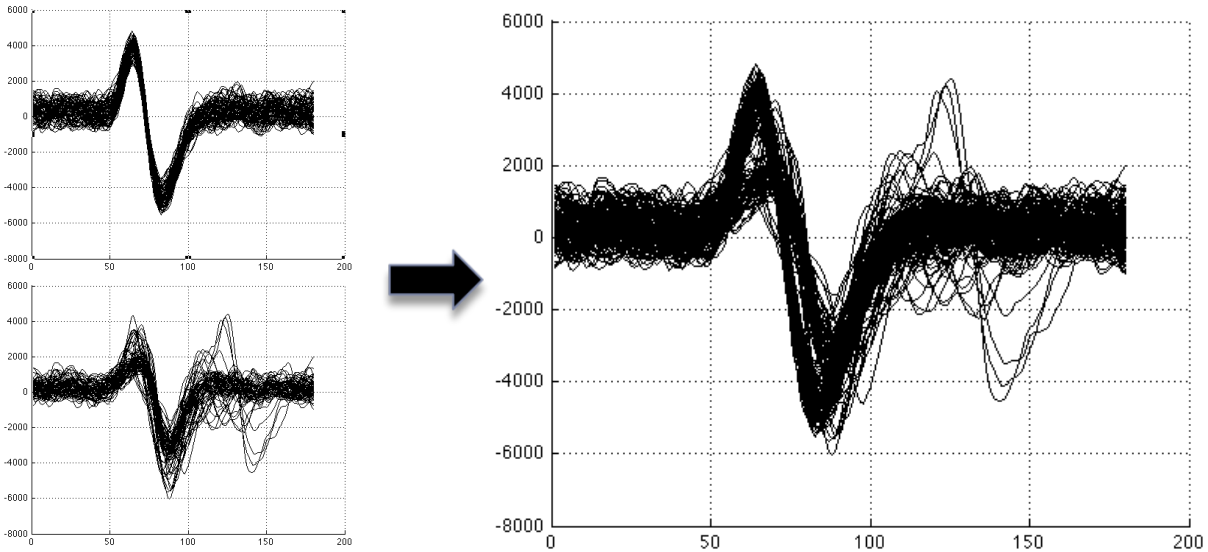
Open problems in spike sorting #2

- Goal of this study: Correct estimation of **active** neurons

  Challenges: **Noise** & **Sparsely firing neurons**

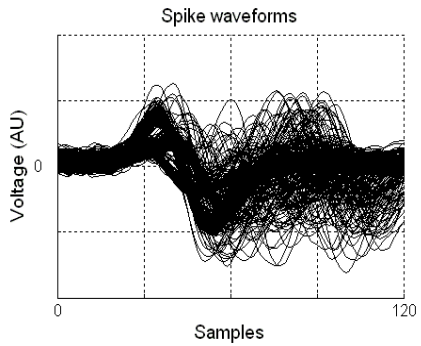
  Common clustering errors: *Under-clustering* & *over-clustering*

<u>*Under-clustering* example</u>

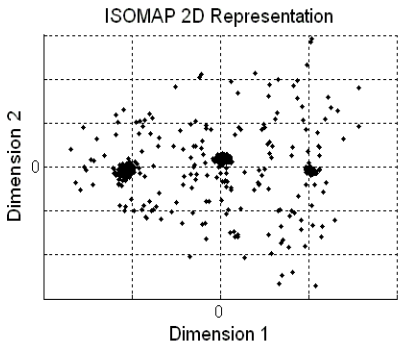


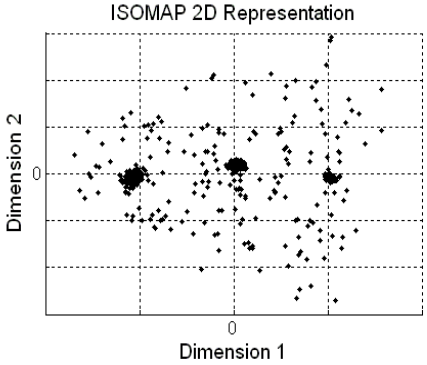
Methods

- Combination of two methods from the graph-theoretic domain

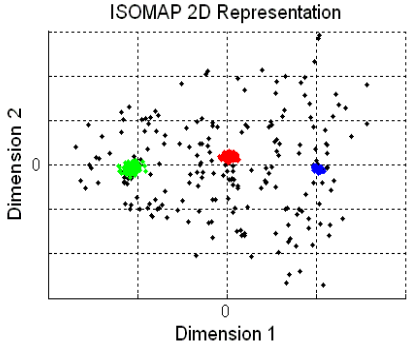


#1 ISOMAP
Graph-theoretic
feature extraction



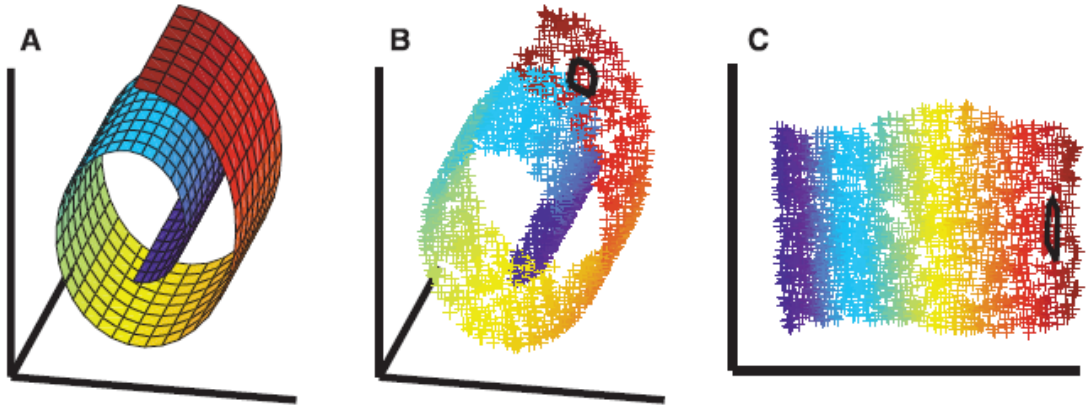


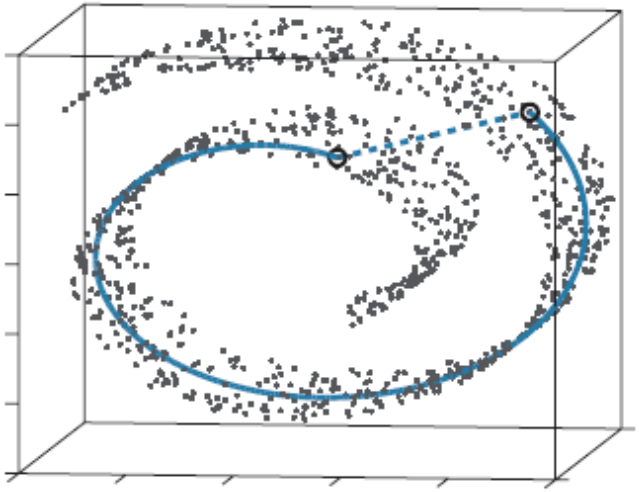
#2 Dominant-sets
Graph-theoretic
clustering



Methods #1: Non-linear low-dimensional representation

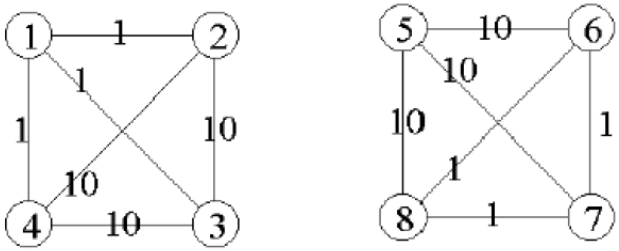
- Manifold learning: Isometric Feature Mapping (ISOMAP)

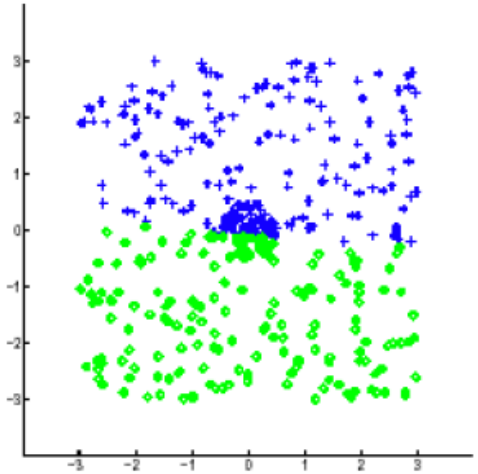




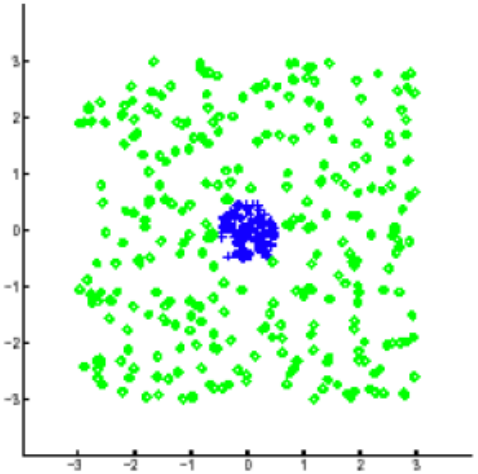
Methods #2: Graph-Theoretic Clustering

- **Dominant-Sets** clustering
  - **Internal criterion**: all objects *inside* a cluster should be highly similar to each other
  - **External criterion**: all objects *outside* a cluster should be highly dissimilar to the ones inside
  - **Similarity** is represented by weights:





K-means

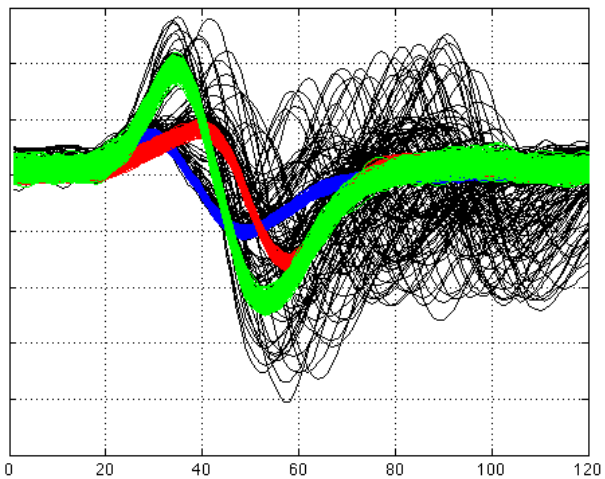


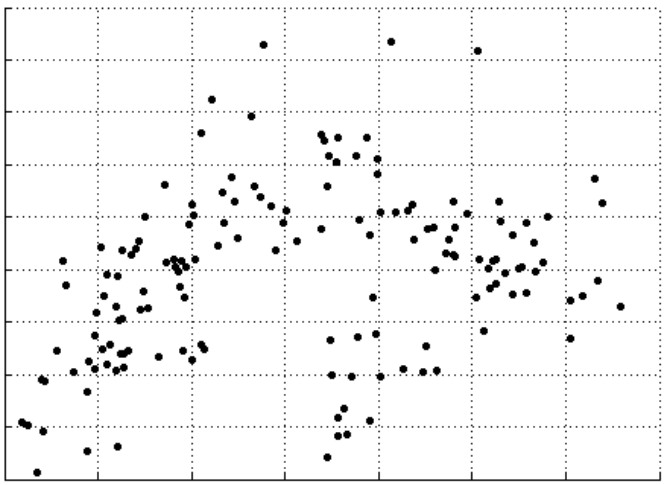
Dominant-Sets

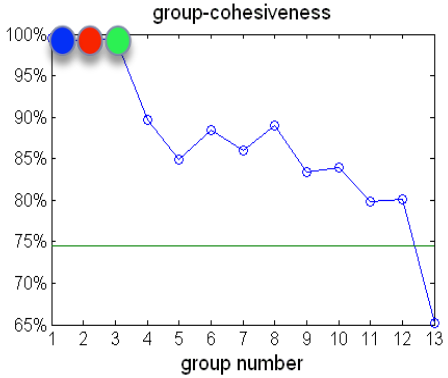
Pavan M and Pelillo M (2007) Dominant Sets and Pairwise Cluster-ing. IEEE Trans. Pattern Anal. Mach. Intell. 29(1): 167-172

Algorithm

- Replicator Dynamics approach

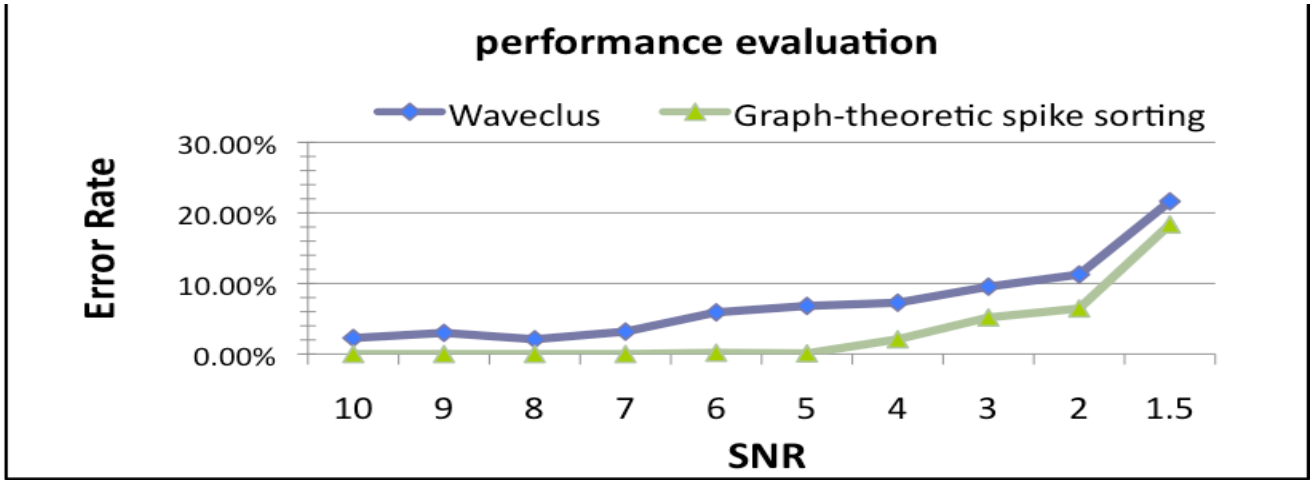






Comparative evaluation

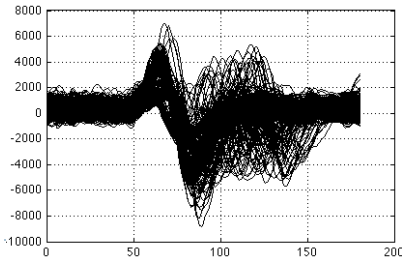
- 3 neurons (3 x 300 spikes)
- 150 random double-overlaps (3 x 50 spikes)
- 50 random triple-overlaps
- Variable SNR

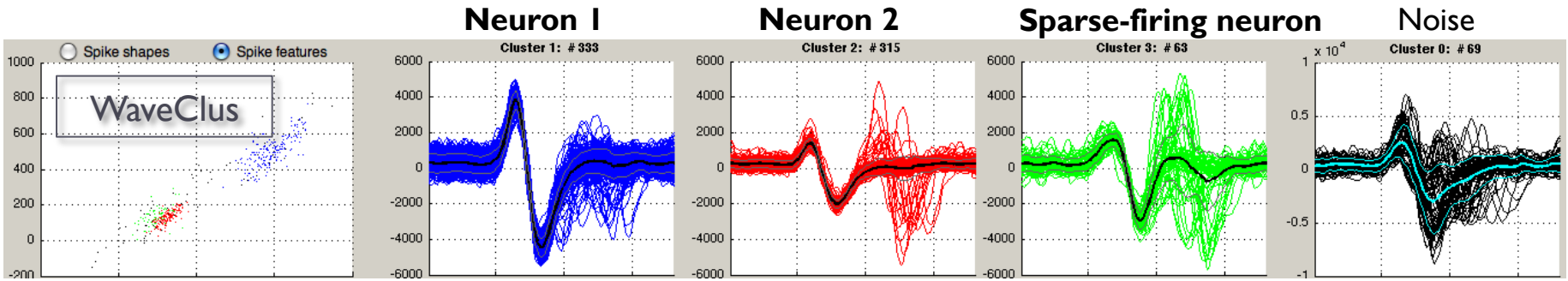


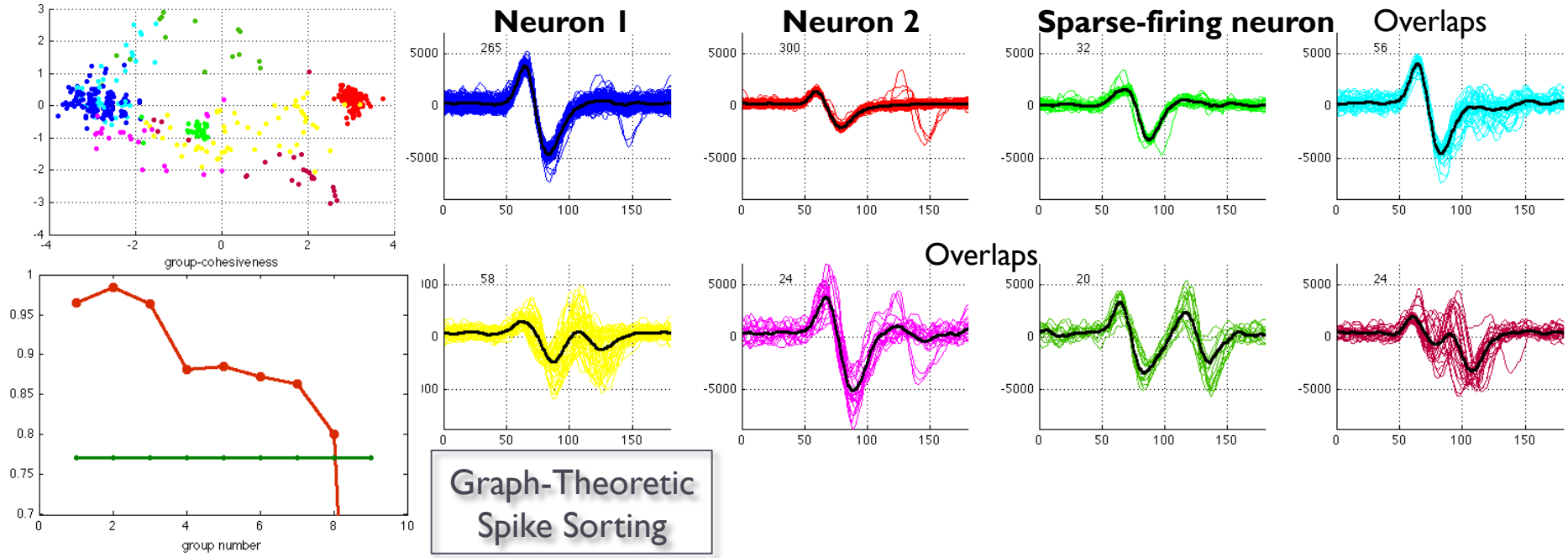
Low SNR example

2 firing neurons (2 x 300 spikes) **+**

+ 1 sparse-firing neuron (30 spikes) **+ overlaps** (150 spikes)







Conclusions

- Problem:
  - Estimating the number of active neurons
- Methods
  - Methods from the graph-theoretic domain
  - Replicator dynamics approach
- Results
  - Semi-supervised spike-sorting approach with relative ranking of groups
  - High ranking: active neurons
  - Medium ranking: overlapping and noisy spikes that need further processing
  - Low ranking: noise

Thank you