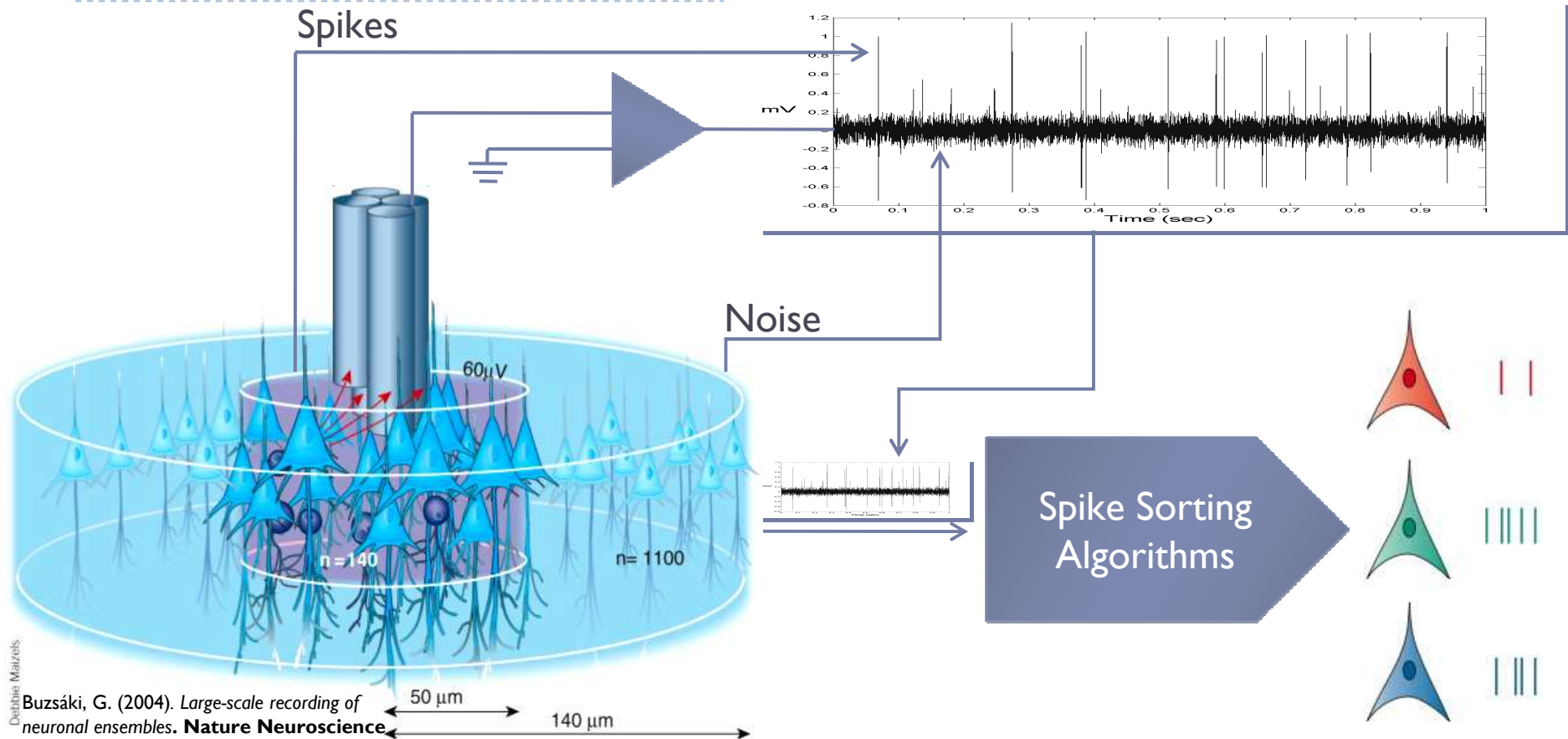# Spike Sorting based on Dominant-Sets clustering

Dimitrios A. Adamos
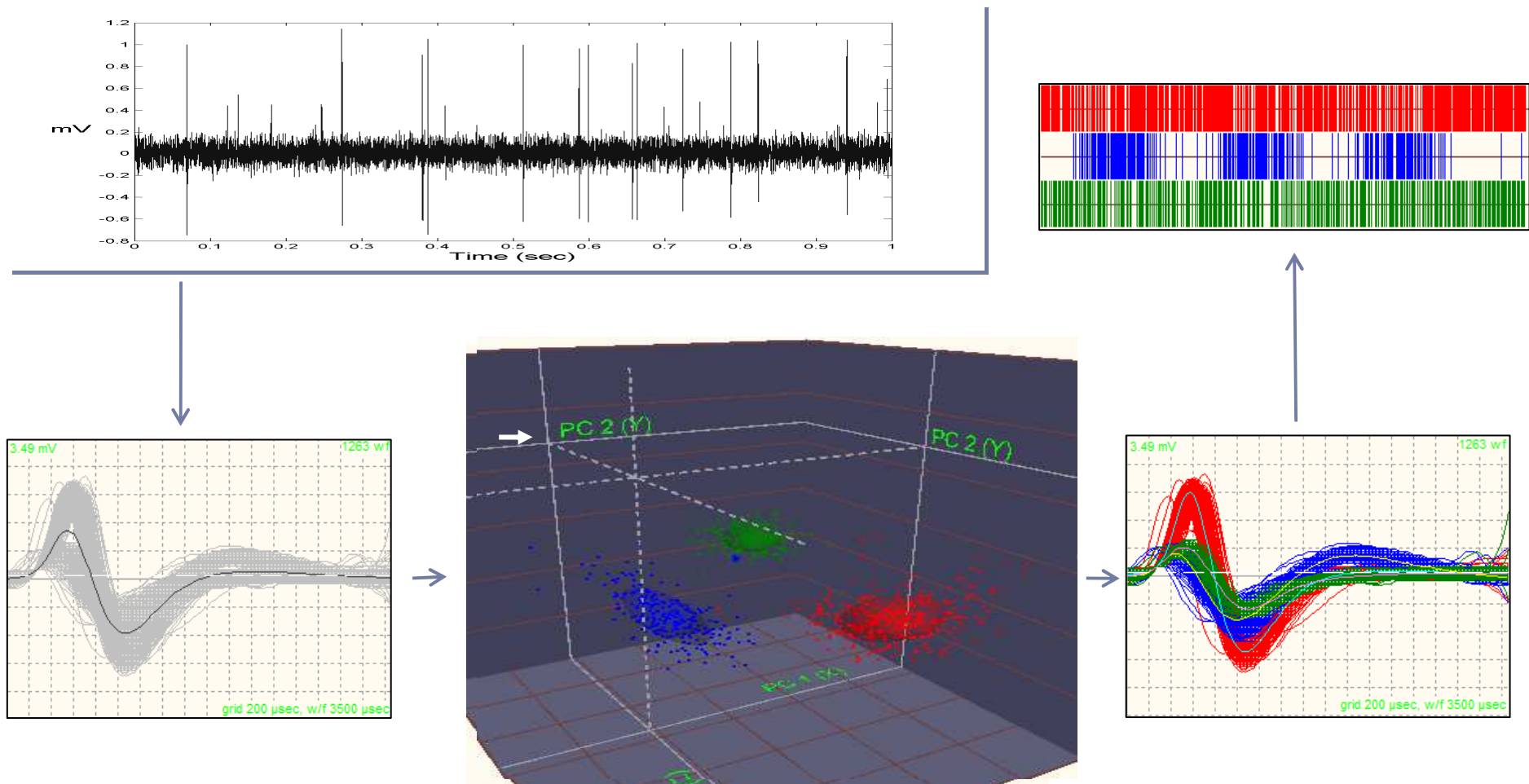
PhD Candidate School of Biology, Aristotle University
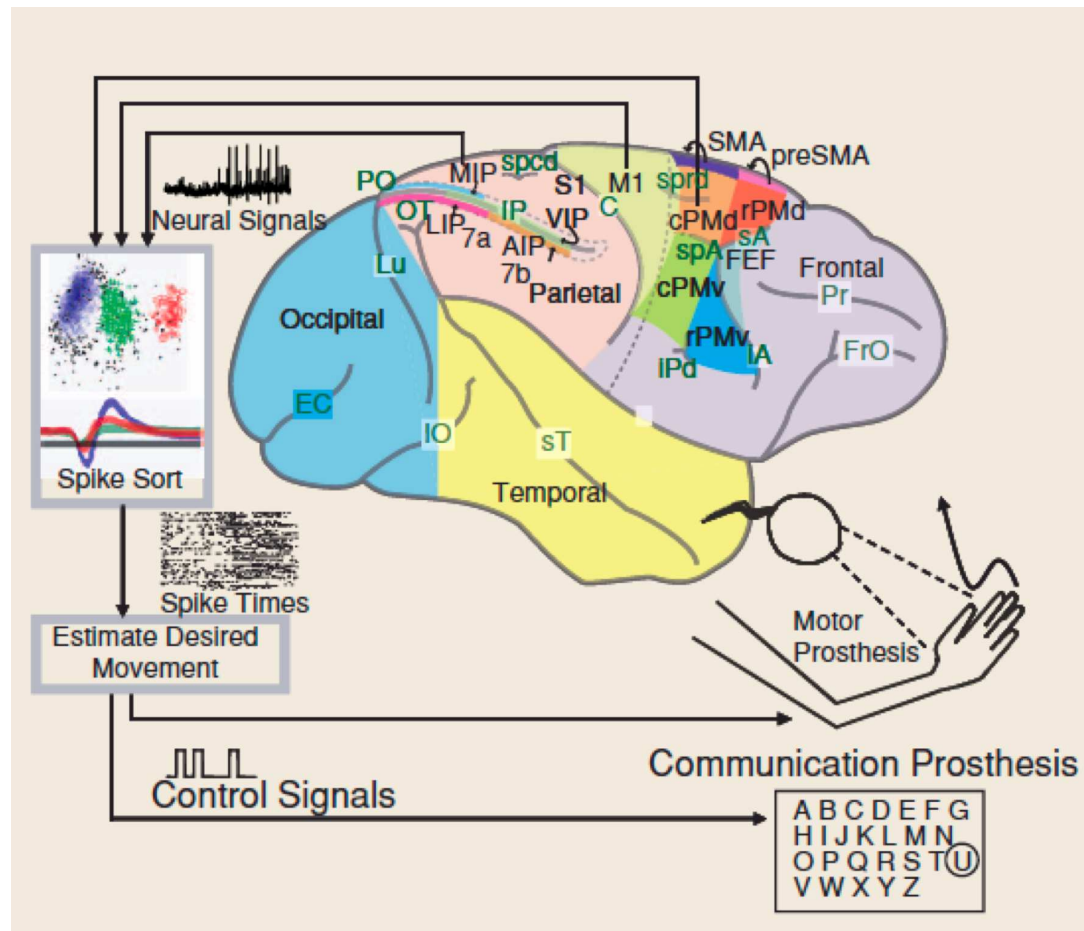
What is spike sorting?

Spikes

Noise

60μV

n = 140

n = 1100

50 μm

140 μm

Debbie Maizels

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

mV

Time (sec)

Spike Sorting Algorithms

Spike sorting in a nutshell

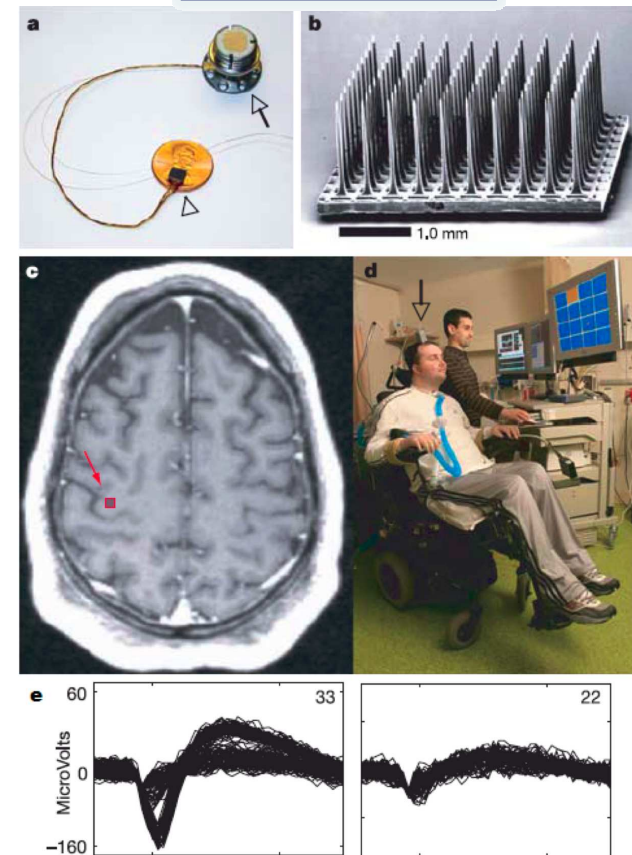# Spike sorting applications

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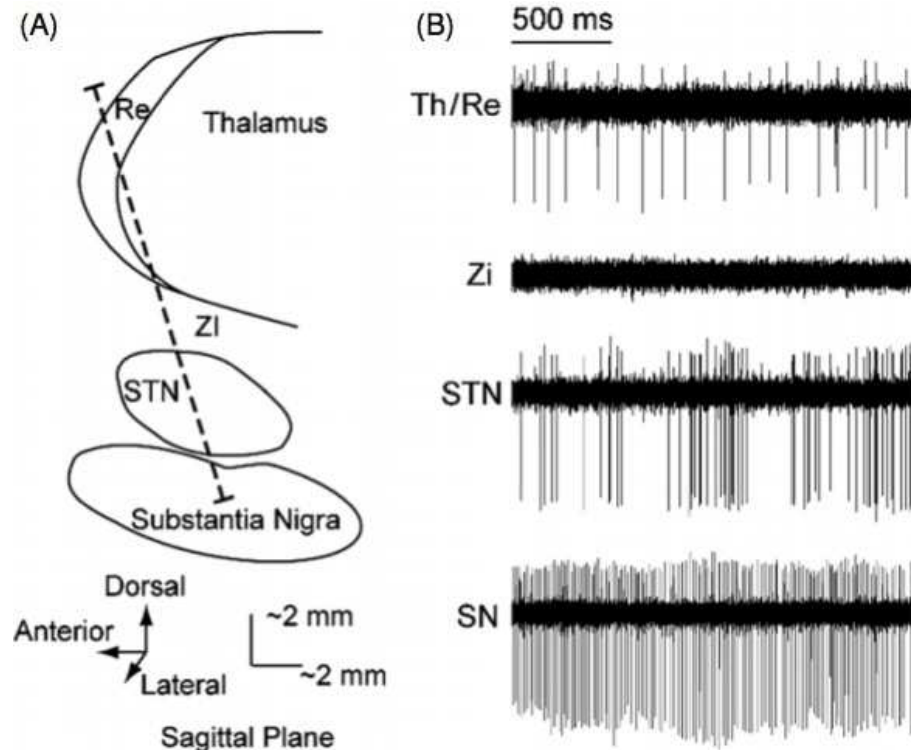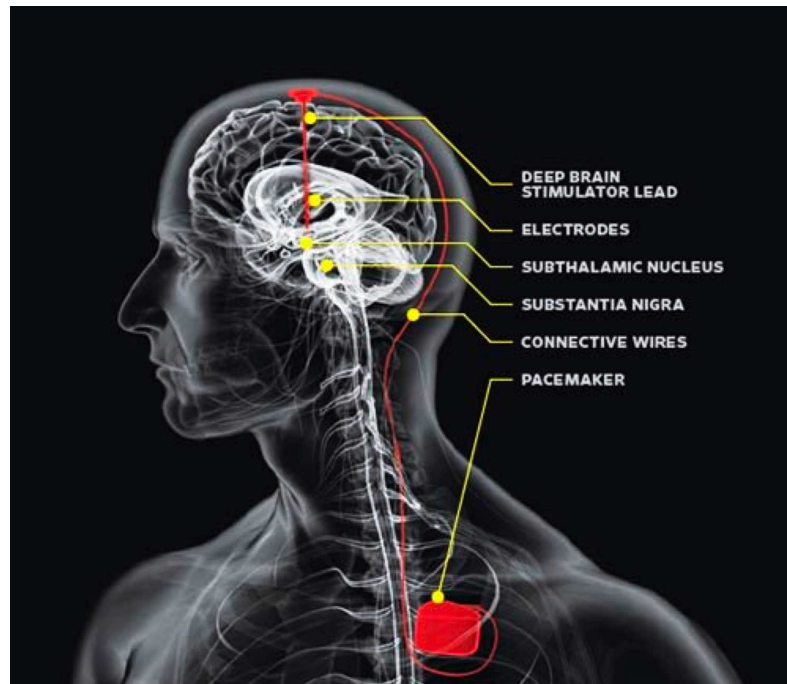
BrainGate

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

Spike sorting applications

DEEP BRAIN STIMULATOR LEAD
ELECTRODES
SUBTHALAMIC NUCLEUS
SUBSTANTIA NIGRA
CONNECTIVE WIRES
PACEMAKER

(A)

T/Re
Thalamus
ZI
STN
Substantia Nigra

Dorsal
Anterior
Lateral
~2 mm
~2 mm
Sagittal Plane

(B) 500 ms

Th/Re
Zi
STN
SN
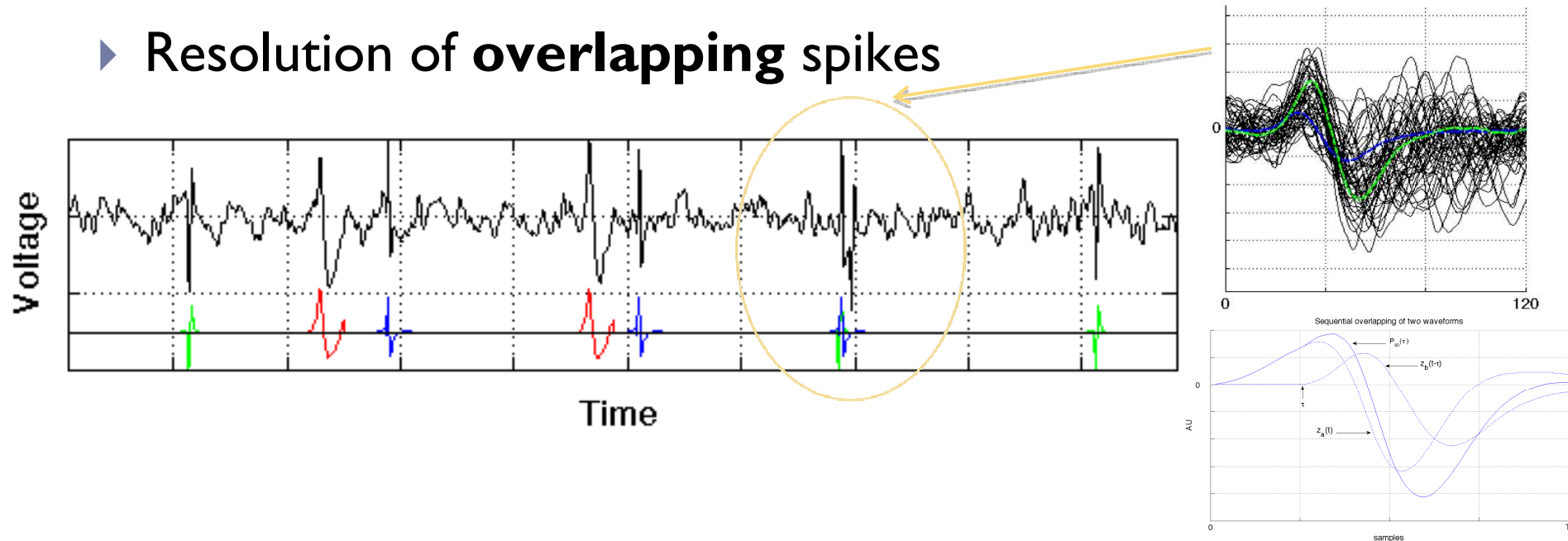
▸ **Functional STN Targeting during DBS surgery**

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*
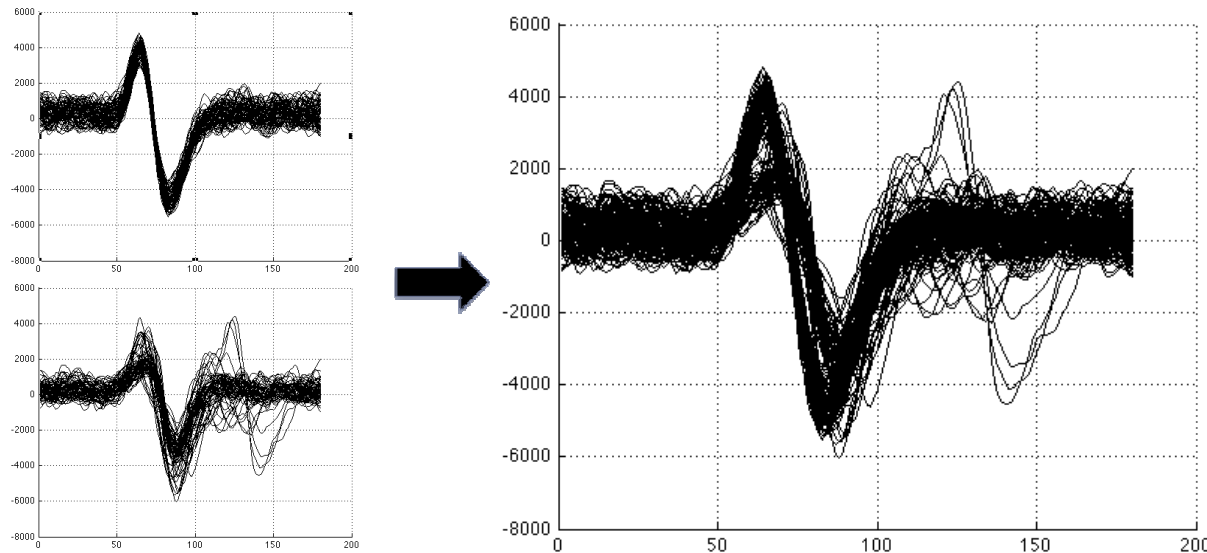
(2010) **Journal of Neuroscience Methods** Article in Press

Open problems in spike sorting #2

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

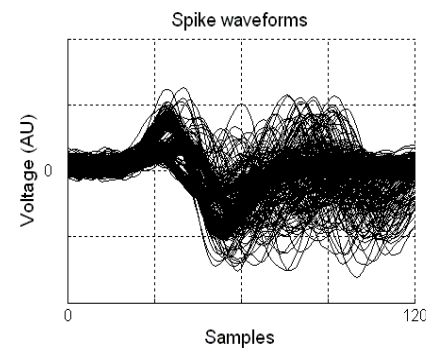Challenges: **Noise** & **Sparsely firing neurons**

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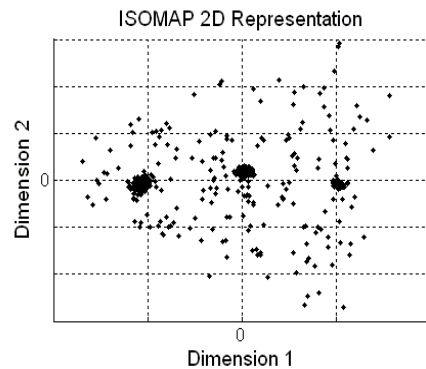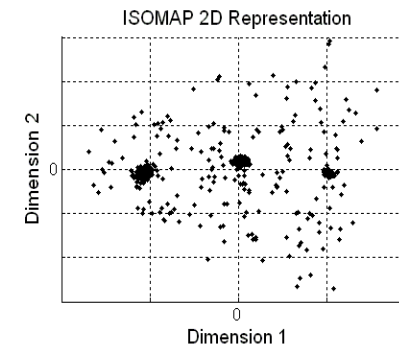
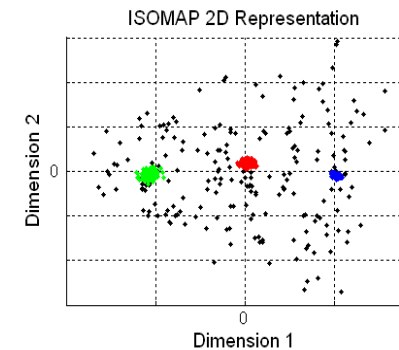*Under-clustering* example

Methods

- Combination of two methods from the graph-theoretic domain

#1 ISOMAP
Graph-theoretic
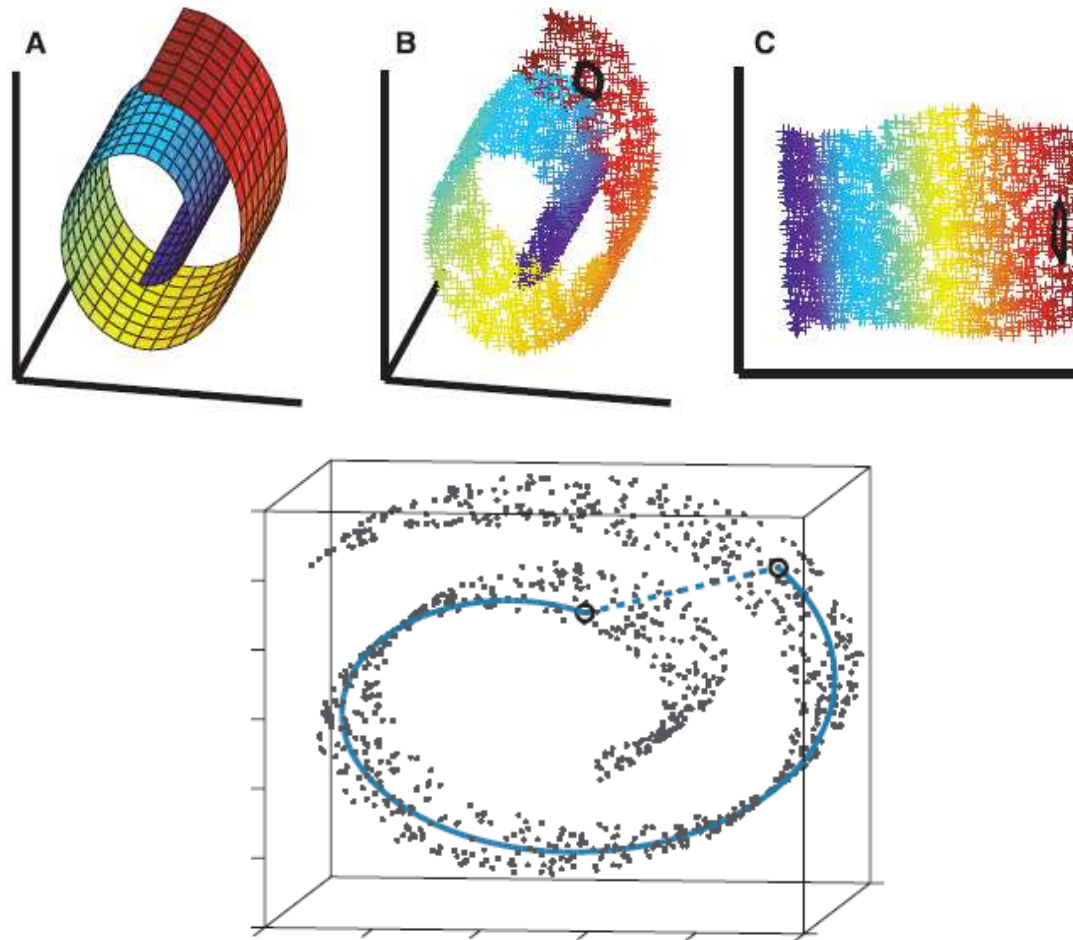feature extraction

#2 Dominant-sets
Graph-theoretic
clustering

Methods #1: Non-linear low-dimensional representation

▸ Manifold learning: Isometric Feature Mapping (ISOMAP)
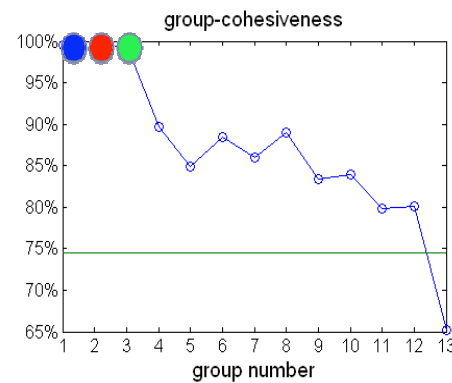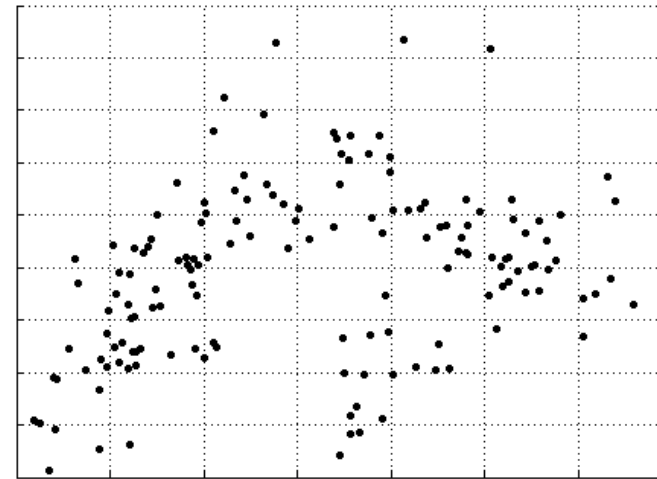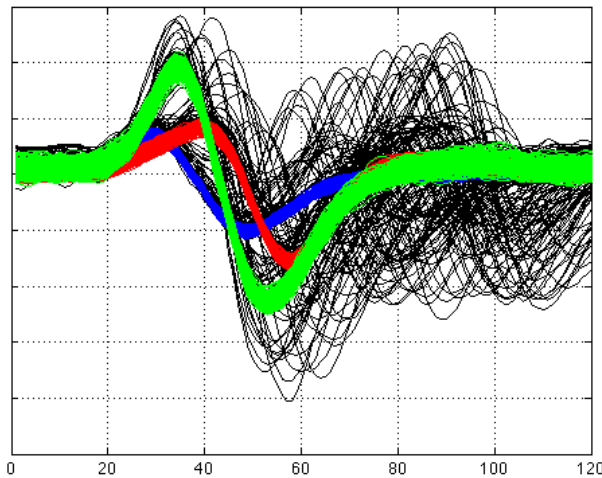
Methods #2: Graph-Theoretic Clustering

▸ **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

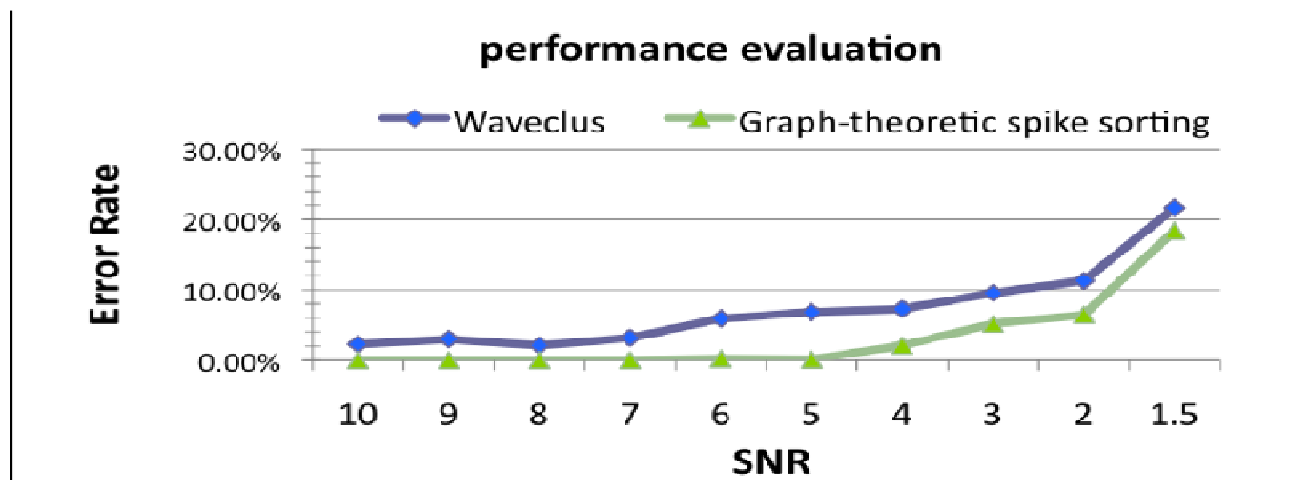   ▸ **Similarity** is represented by weights:

K-means   Dominant-Sets
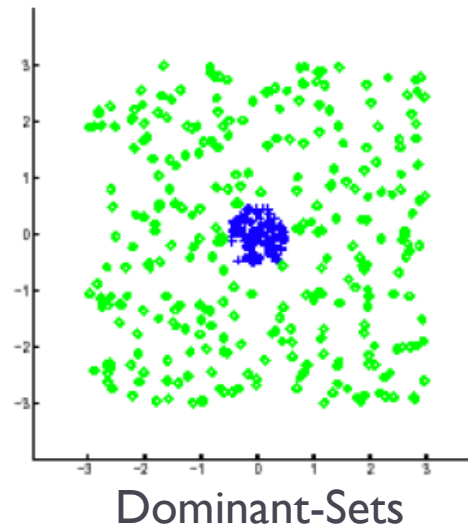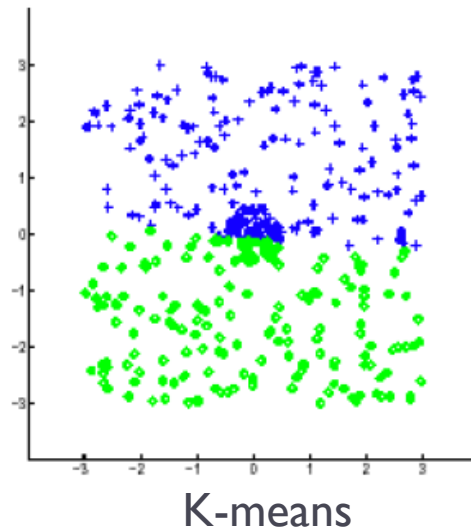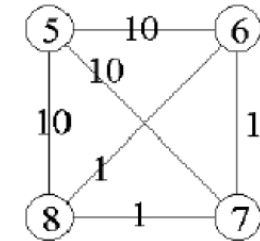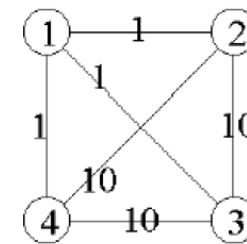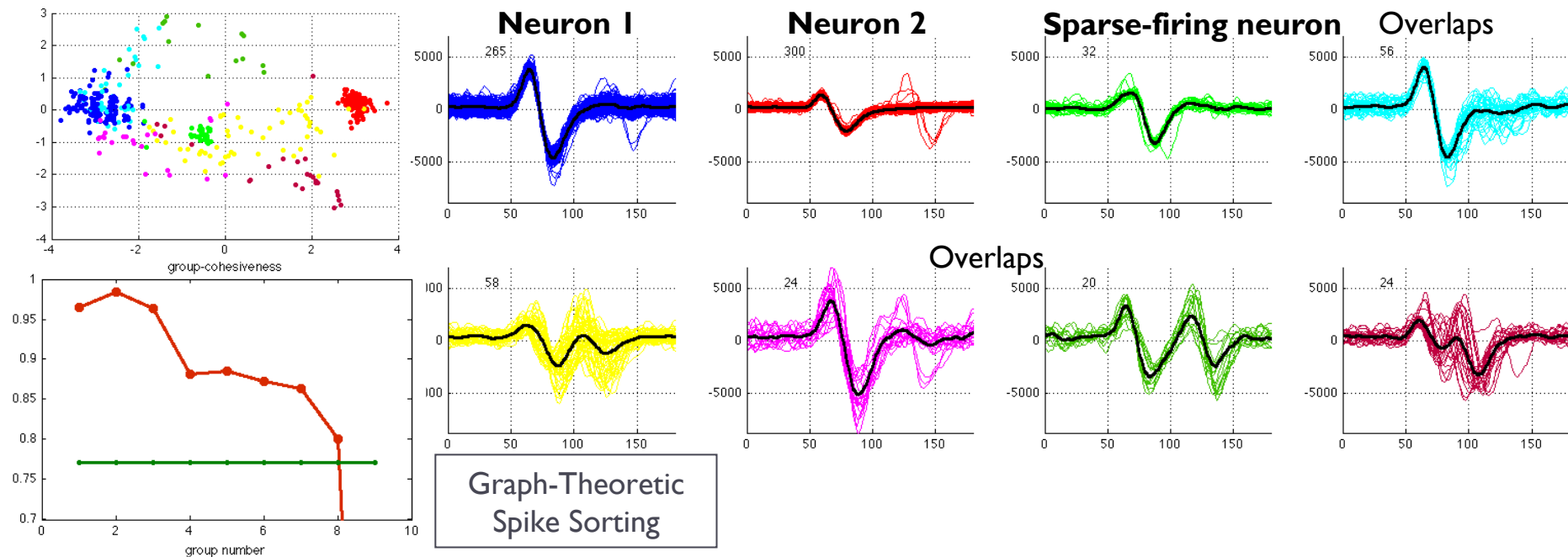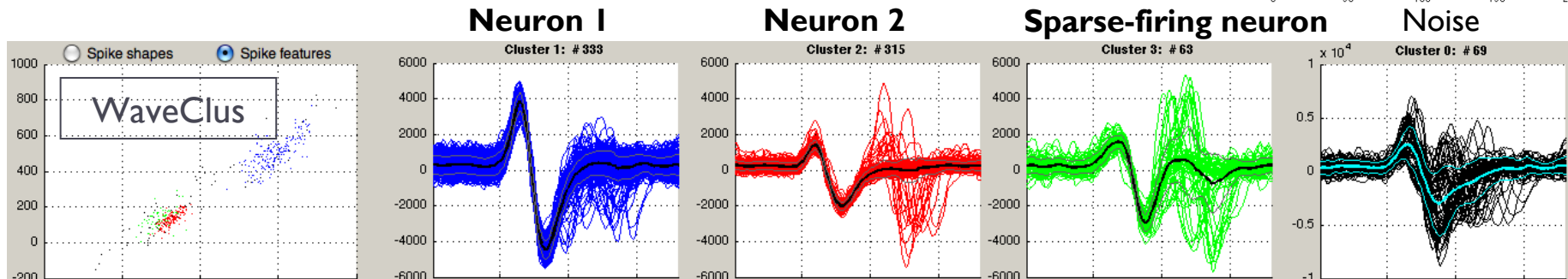
Algorithm

▸ Replicator Dynamics approach
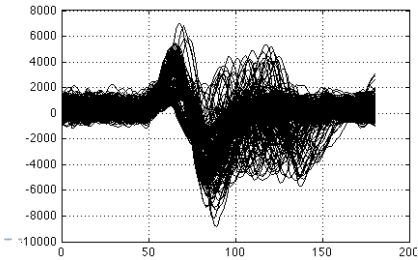
Comparative evaluation

▸ 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