Artificial neural networks and multidimensional approach in the classification: 2D images of neurons from the human dentate nucleus

Authors

Nebojša T. Milošević

Department of Biophysics, Medical faculty, University of Belgrade;

Veličko Vraneš

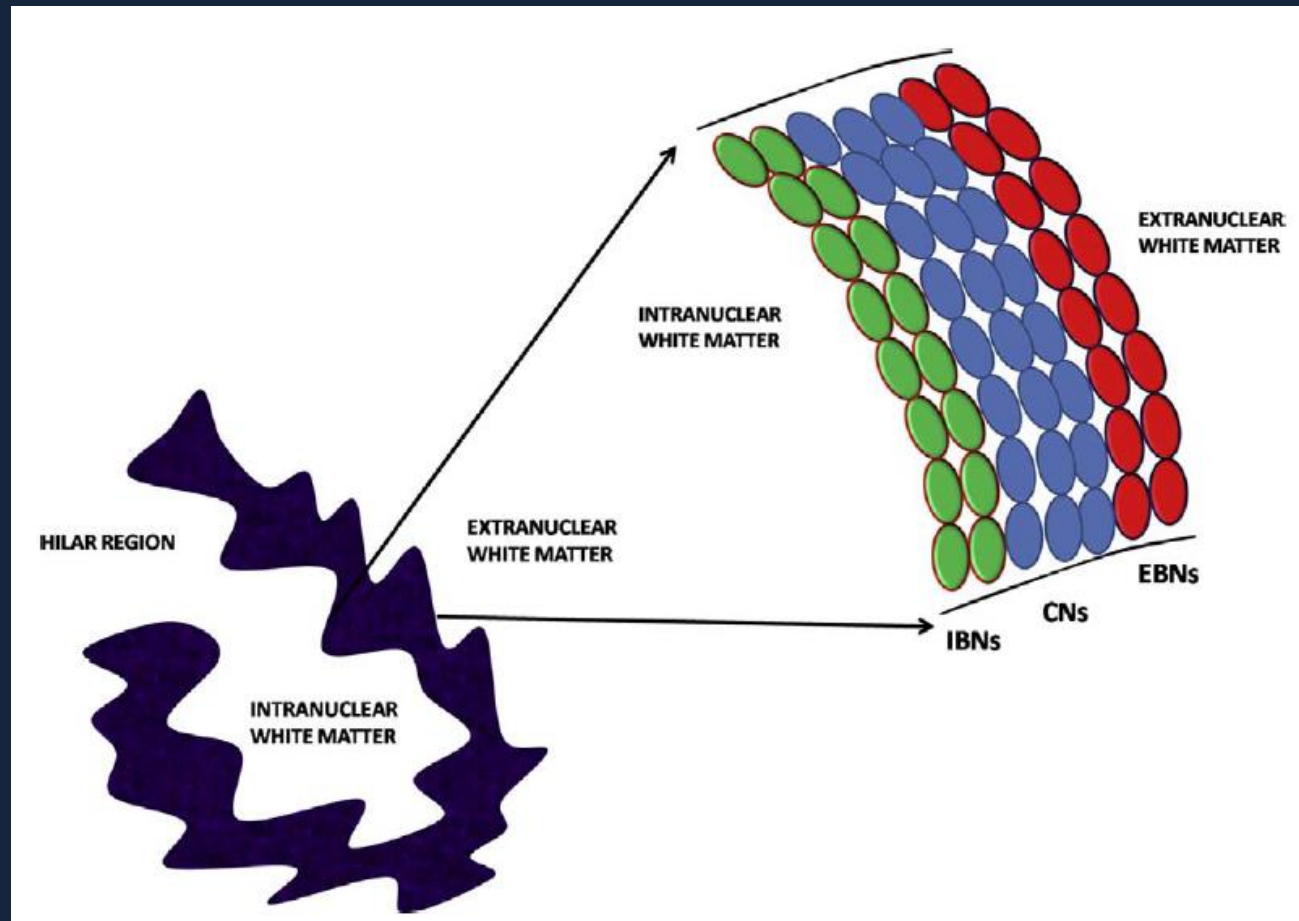- Laboratory for Image Analysis, Institute of Biophysics, Medical faculty, University of Belgrade;

Damjan Stojić

- Laboratory for Image Analysis, Institute of Biophysics, Medical faculty, University of Belgrade;

The dentate nucleus (2014-2017)

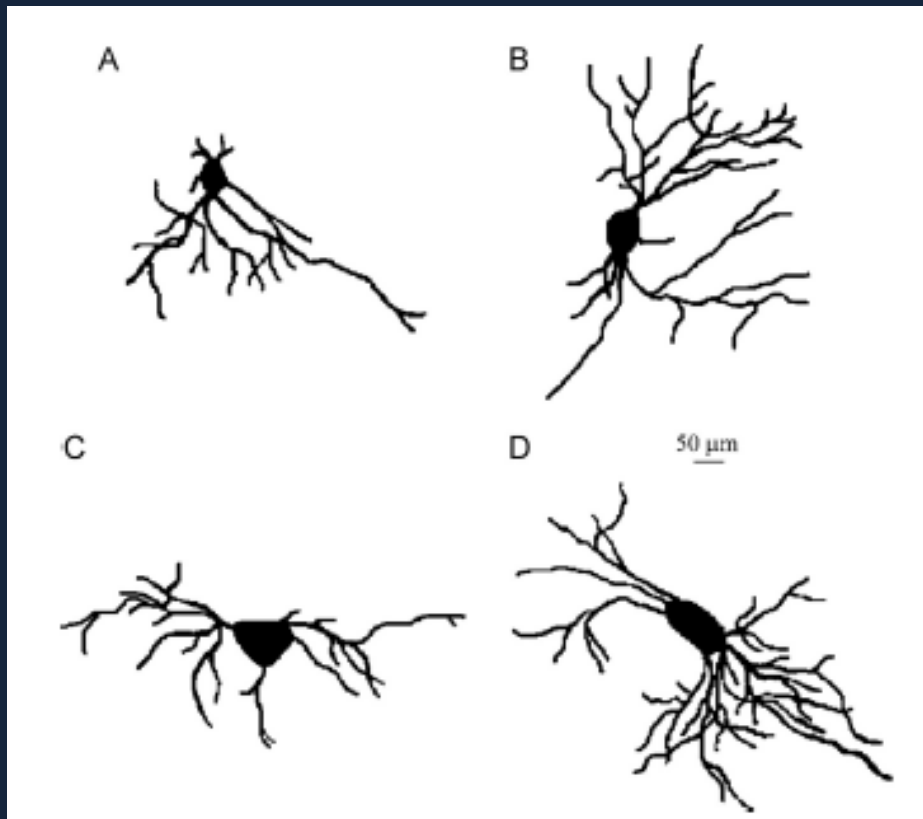## The qualitative analysis ⟹ Topological classification

- Central neurons – **CNs**;
- Exterior border neurons – **EBNs**;
- Interior border neurons – **IBNs**;

- **There is no *histological difference* in between central and border neurons.**

Topological vs. Morphological classification?

- A_S – **surface area of the soma;**
- L – **highest length of dendrites;**

- **Type I** (small soma, short dendrites);
- **Type II** (small soma, long dendrites);
- **Type III** (large soma, short dendrites);
- **Type IV** (large soma, long dendrites);

Materials

- Neurons were investigated and digitized under the light microscope and processed thereafter.

Methods

- Seventeen parameters quantifying various aspects of neuron morphology

- **The surface area** - 5 parameters; **The shape** – 3 parameters;

- **The complexity** – 4 parameters; **The length** – 2 parameters;

- **The branching** - 3 parameters.

Multidimensional approach

- Artificial neural networks,
- Separate unifactor analysis,
- Cluster analysis,
- Principal component analysis (PCA),
- Discriminant analysis,
- Correlation–comparison analysis.

Grbatinić, Marić, Milošević
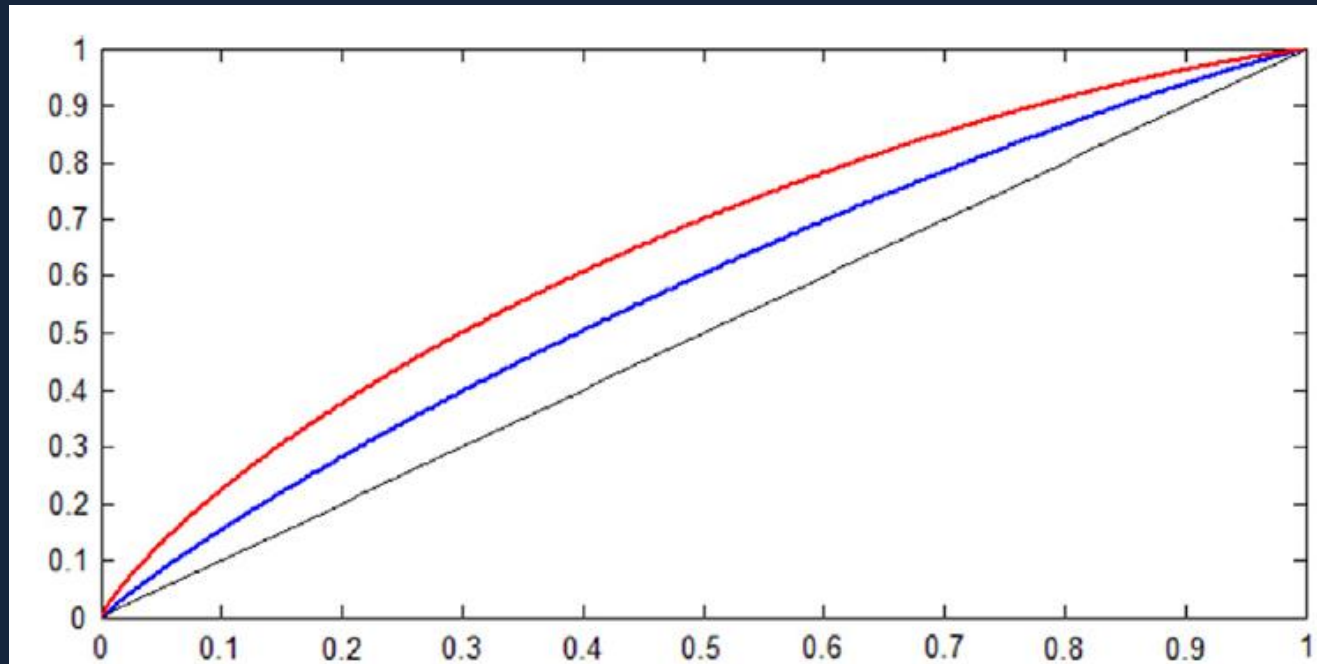*J Theor Biol*. 2015; 370: 11-20.

Grbatinić, Milošević
J Theor Biol. 2016; 404: 273-284.

CNs (201 cells) vs. BNs (119 cells)

- Neural network **misclassified the most of the border type** of neurons.

- **ROC** (Receiver Operating Characteristic) curves
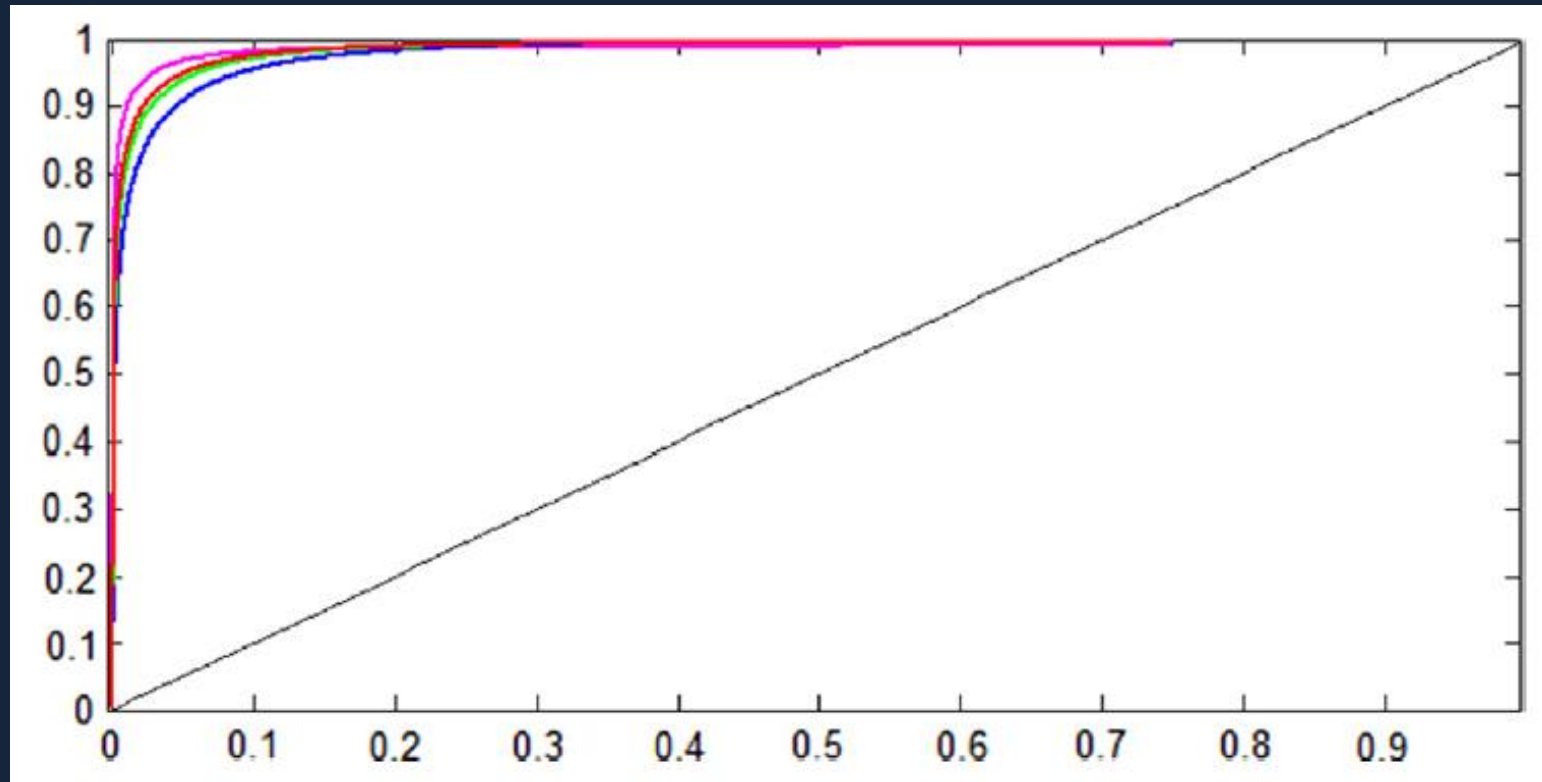 – *low true positive rate of classification*.

- Correctly classified:

- Central neurons – 61.9% and Border neurons – 2.7%;

Morphological classification

- 96.7% neurons were classified correctly and ROC curves showed very **high true positive rate** of clusterization.

EBNs (71 cells) vs. IBNs (48 cells)

- **Goal:**

- An attempt to classify BNs to two groups according to 17 morphological features, as **predictors of its topological classification**.

- Methodology of **multidimensional statistical analysis is used** according to multidimensionality of the data.

- **Separate factor analysis:** to find **extract relevant factors** for the classification.

- 6 parameters: A_n, A_{nf}, A_{dt}, A_{df}, L and N_m

- **Cluster analysis:** to estimate the *degree of separation between the clusters* - to determine *Euclidian inter-cluster distances*.

- Depending on its value, the quality of clustering can be determined as **poor**, **good** or **excellent**.

- **Two-step cluster analysis**, with method of **Silhouette measure of cohesion and separation**,

- BNs can be classified into two clusters/groups and that **the cluster quality was as fair**, with **the cluster strength of 45%**.

• **Principal Component Analysis**

- reducing multivariate data as vector forces that drive the system into clusters along the major principal components
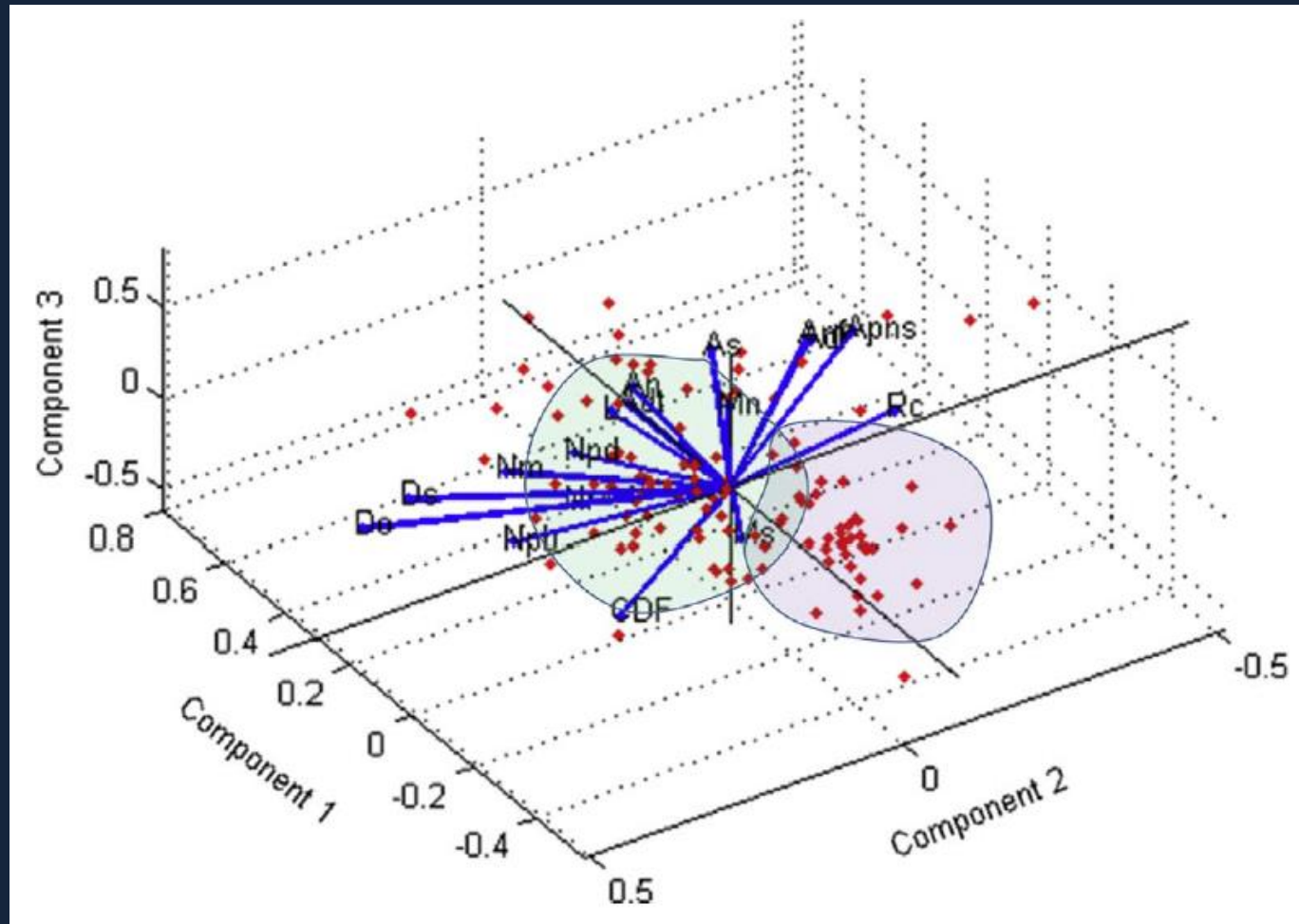
- The IBN cluster (violet) is **better shaped** and **nested** than the EBN cluster(green–blue) which is has more outliers.

- **Greater** *morphological similarity* (*homogeneity*) **between the neurons of IBN cluster.**

- **Functional Linear Discriminant Analysis**

- by finding the adequate linear parameter combinations according to which object can be classified in separate groups or clusters.

- **Aim**: to determine **which set of factors _in which relationship_** is **the best classificatory predictor**.

- Four steps: A) 17, B) 6, C) 3 and D) 2 $\Rightarrow$ **still without significance**.

- *Integrated FLDA is a much rougher method and thus unable to detect those differences.*

- **Correlation-Comparison Analysis**

- **Aim**: to **precisely define** and **describe the inter-parameter relationships** in two neuron groups separately by **comparing their correlation matrices**.
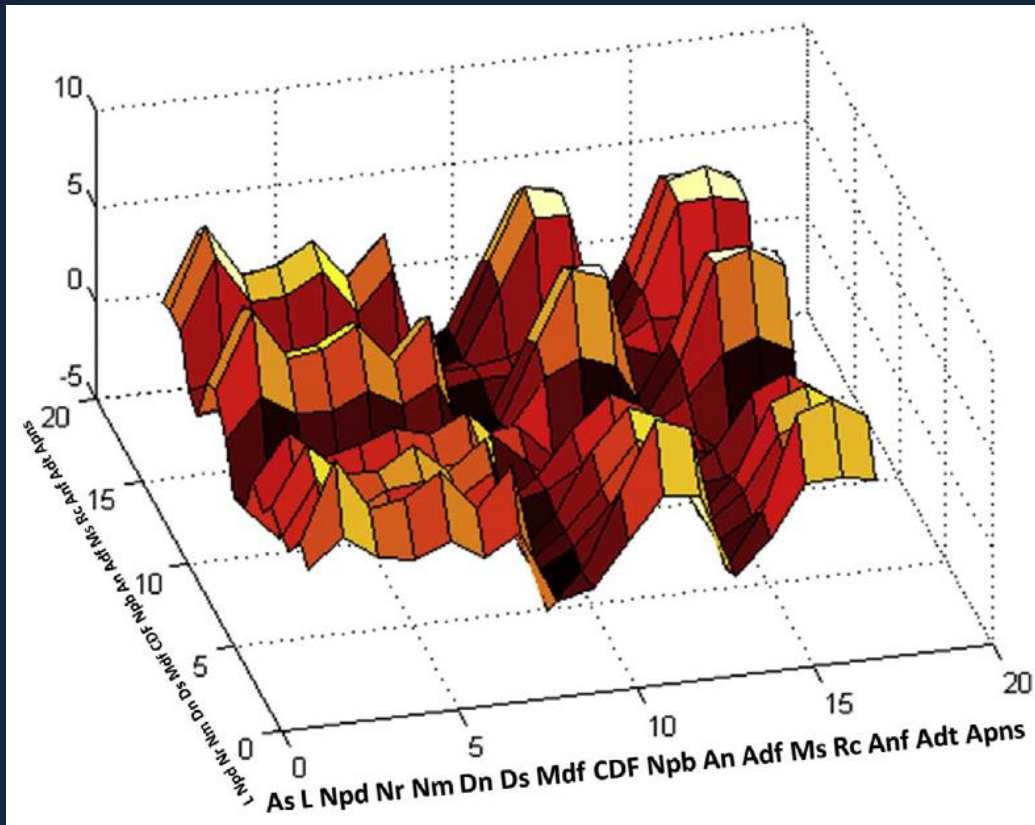
- **Large percent** of the inter–parameter relations are **pretty disturbed** between the groups.

- *Different functional behavior of neurons during development...* **(?)**

Conclusion

- **All results point into one question:**

- *How it is possible that neurons belonging to different topological compartments <u>are not differing</u> while neurons belonging to different sub-compartments <u>are significantly different?</u>*

- The answer probably lies ***<u>partially in embryonic neurological development</u>*** and ***<u>partially in adaptation to synaptic inputs</u>***.

- EBNs are mainly ***<u>input receivers</u>*** and IBNs are predominantly ***<u>output neurons</u>***.

- *More subtle statistical methods/analyses are able to catch these different inter–parameter relations between EBNs and IBNs.*

Future works

- 2017 – Department of Anatomy (University of Novi Sad, Serbia) gained **new microscope**…
- **New set of images**,
- **New set of parameters**: **size** of the neuron, **shape** of the neuron and **density** of dendritic tree.
- New classification: **histogram** or **cluster analysis**?

Thank you!