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Multi-spectral characterization of thalamic nuclei using 3T MRI

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Big Data, Multimodality & Dynamic Models in Biomedical Imaging Workshop
Isaac Newton Institute, Cambridge

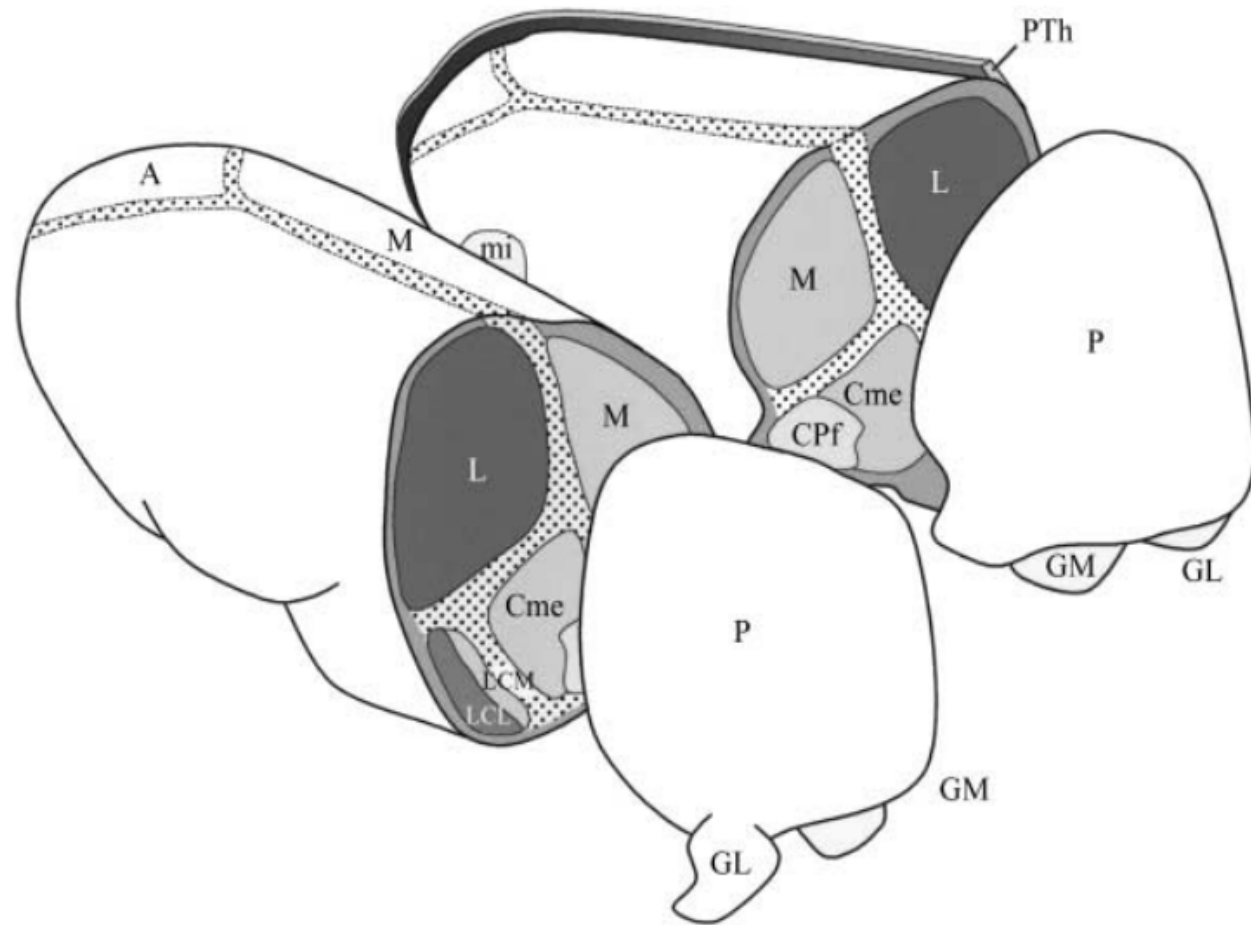
March, 9th 2016

Joint work with:

- Dr. Carola-Bibiane Schönlieb (DAMTP, University of Cambridge)
- Prof. Jan Lellmann (Institute of Mathematics and Image Computing, University of Lübeck)
- Dr. Julio Acosta-Cabronero (German Center for Neurodegenerative Diseases (DZNE), Magdeburg)
- Prof. Peter Nestor (German Center for Neurodegenerative Diseases (DZNE), Magdeburg)

Thalamus

- Two lobes
- Deep grey matter
- Subdivisions
- Major nuclei:
 - Anterior (A)
 - Medial (M)
 - Lateral (L)
 - Posterior (P)

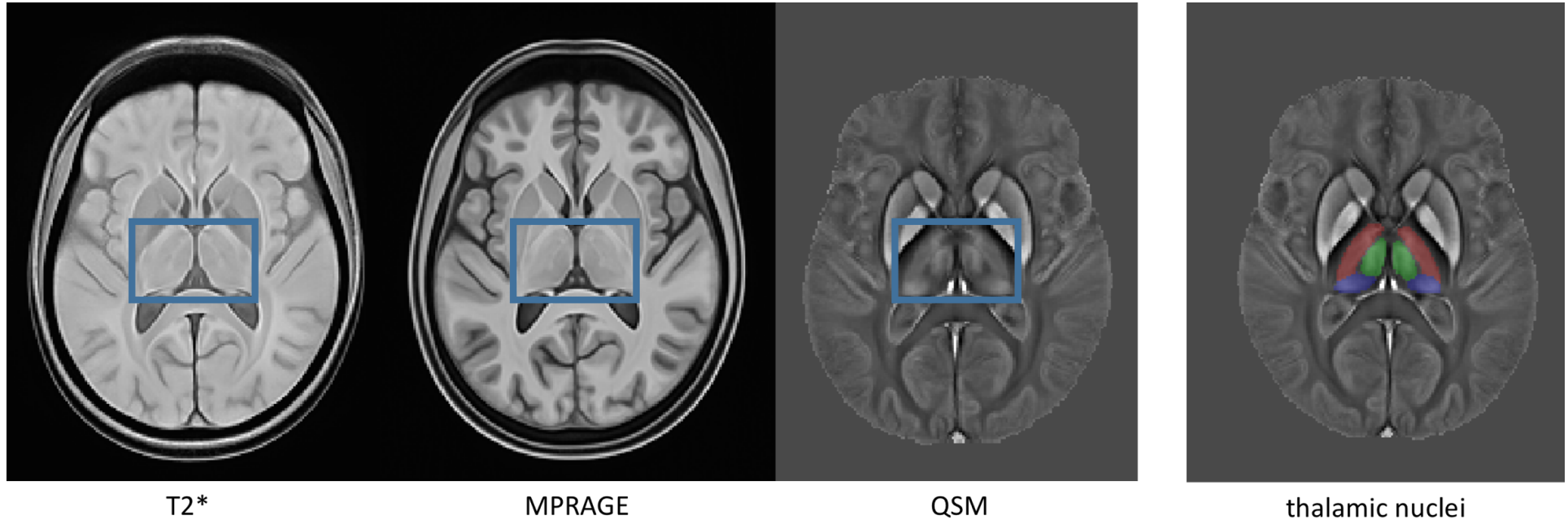


References: Mara-Trinidad Herrero, Carlos Barcia, and Juana Mari Navarro. Functional anatomy of thalamus and basal ganglia. Childs Nerv Syst, 18(8):386 {404, Aug 2002}

Thalamic changes: atrophy and iron accumulation

- Related to **neurodegenerative diseases** (Alzheimer, Parkinson, multiple sclerosis, dementias)
- Identification for:
 - pre-surgical planning and deep brain stimulation (DBS)
 - specific biomarkers for early diagnosis and assessment of short and long term disease progression
- Traditionally post-mortem studies: histological atlas (**Morel Atlas**, ETH Zurich)

In vivo imaging: MRI



Multi-contrast mechanisms:

- T2*-weighted
- MPRAGE
- QSM

GOAL: identify the major nuclei in the thalamus

Problems/Challenges

- Identification of thalamic nuclei is difficult due to low intrinsic contrast and small size
- Manual segmentation is subjective and time consuming
- Automatic segmentation not based on histological atlas (**Morel Atlas**)

Methods: strategy

- Volume of interest containing the thalamus
- **Step 1** - Supervised learning
 - 4-class classification
 - manual segmentation is the groundtruth
- **Step 2** - Convex segmentation

Step 1: classification

4-class classification problem:

- 0: background, outside the thalamus
- 1: lateral nuclear group (red)
- 2: medial nuclear group (green)
- 3: posterior nuclear group (blue)

Classifiers: k-NN and Parzen



Step 1: feature space

Contextual information:

- Intensity value from 3 contrasts
- Mean and standard deviation in the 26-neighborhood in each contrast
- 6 (closest) neighbors intensity values in each contrast

27 features in total

Step 2: convex segmentation

- Finite labeling problem
- Variational approach:

$$\min_{u:\Omega\rightarrow\{1,\dots,L\}} \underbrace{\int_{\Omega} s(u(x), x) dx}_{\text{data term}} + \underbrace{\lambda \text{TV}(u)}_{\text{regularizer}}, \quad \lambda > 0$$

nonconvex.

- **Convex relaxation:** hard decisions are replaced by soft labeling, allowing u to assume fractional values between 0 and 1. The problem is then considered in the relaxed constraint set \mathcal{C}

References: Lellmann et al. Convex Multi-Class Image Labeling by Simplex-Constrained Total Variation, 2009

Step 2: convex segmentation

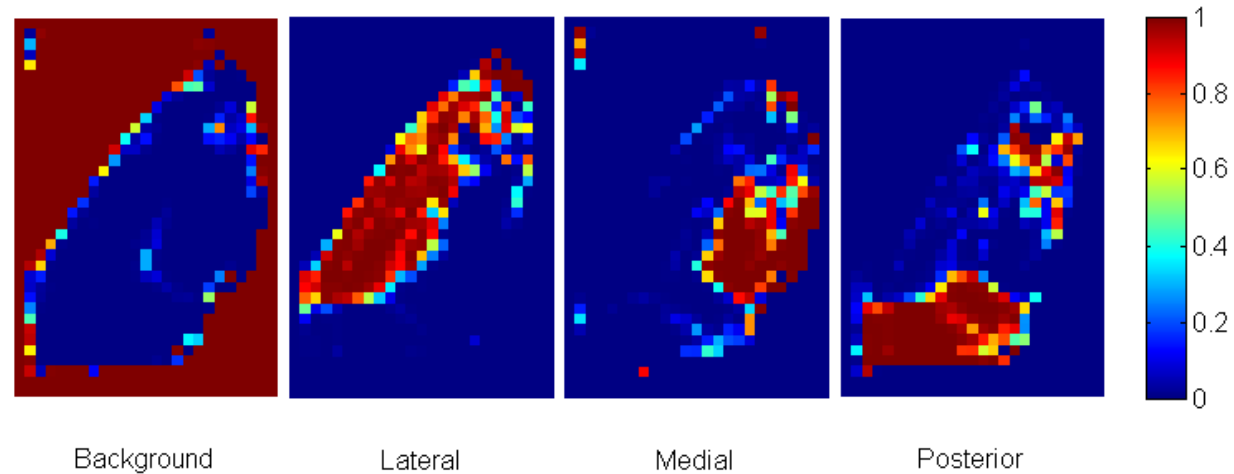
$$\inf_{u \in C} f(u), \quad f(u) = \underbrace{- \int_{\Omega} \langle u(x), s(x) \rangle dx}_{\text{data term}} + \underbrace{\lambda \text{TV}(u)}_{\text{regularizer}}, \quad \lambda > 0$$

f and C are convex \longrightarrow the problem is convex \longrightarrow global optimum

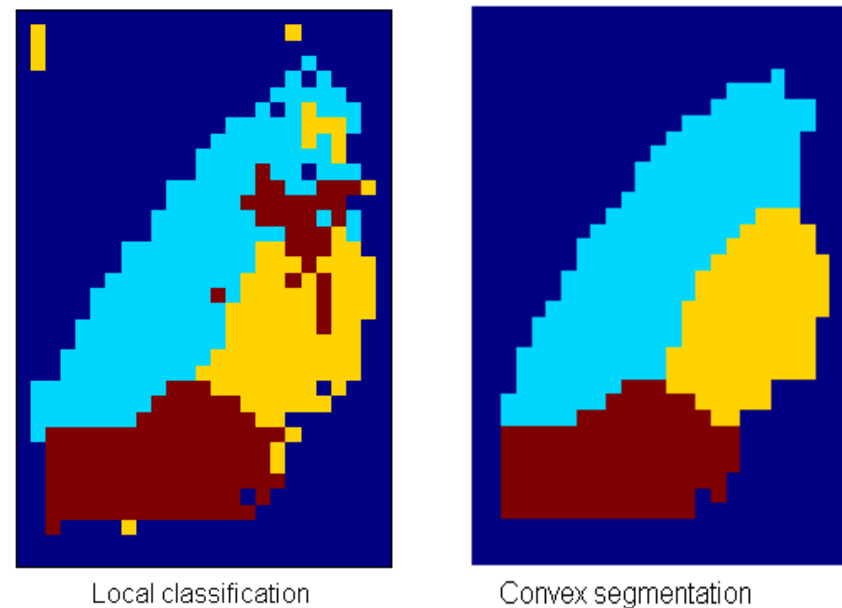
Data term is provided by the probabilistic classifiers as posterior probabilities per class

Results: automatic segmentation of thalamic nuclei

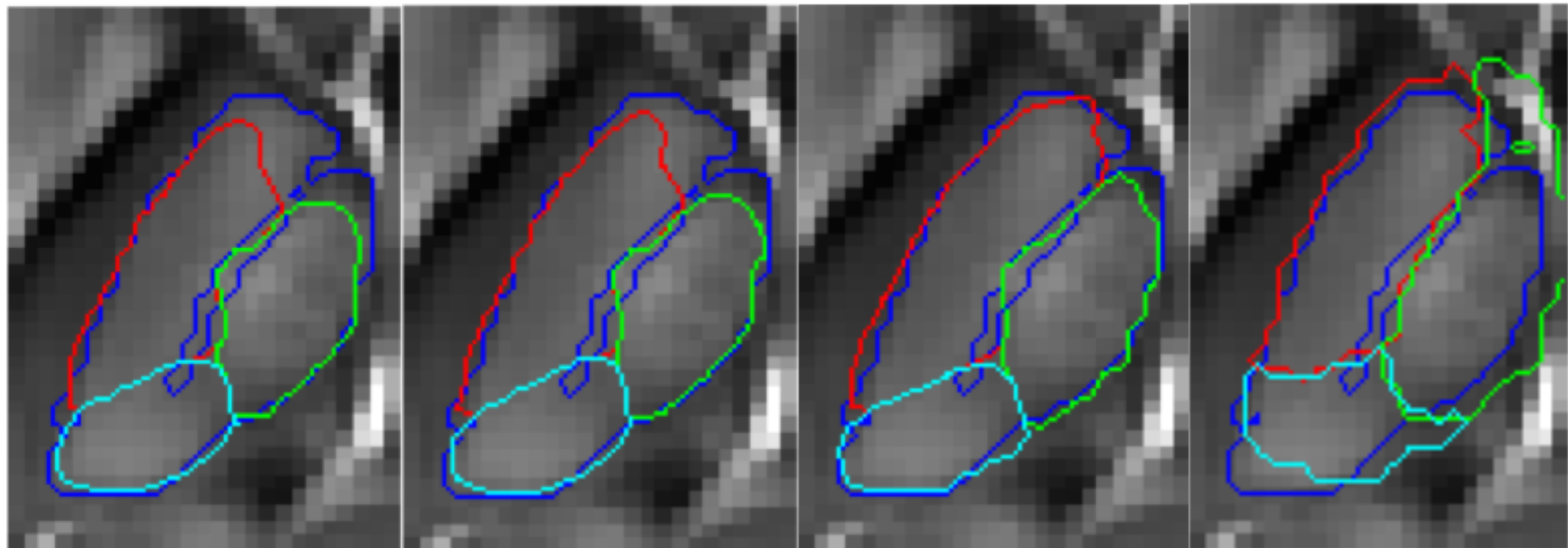
- Supervised learning:
- **posterior probability maps**
- **labels**



- Multi-class convex segmentation



Results: classifiers' performance



3-NN

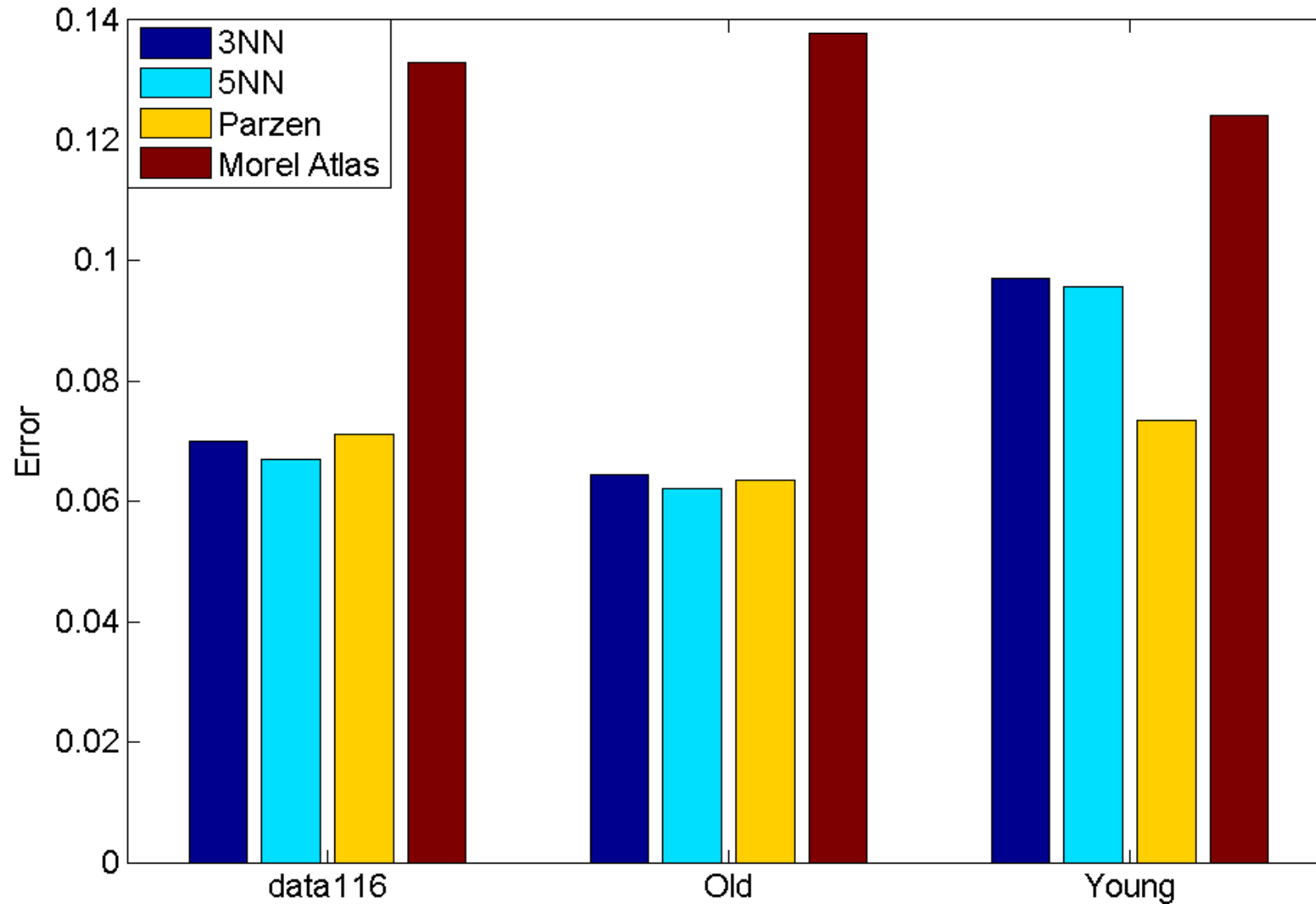
5-NN

Parzen

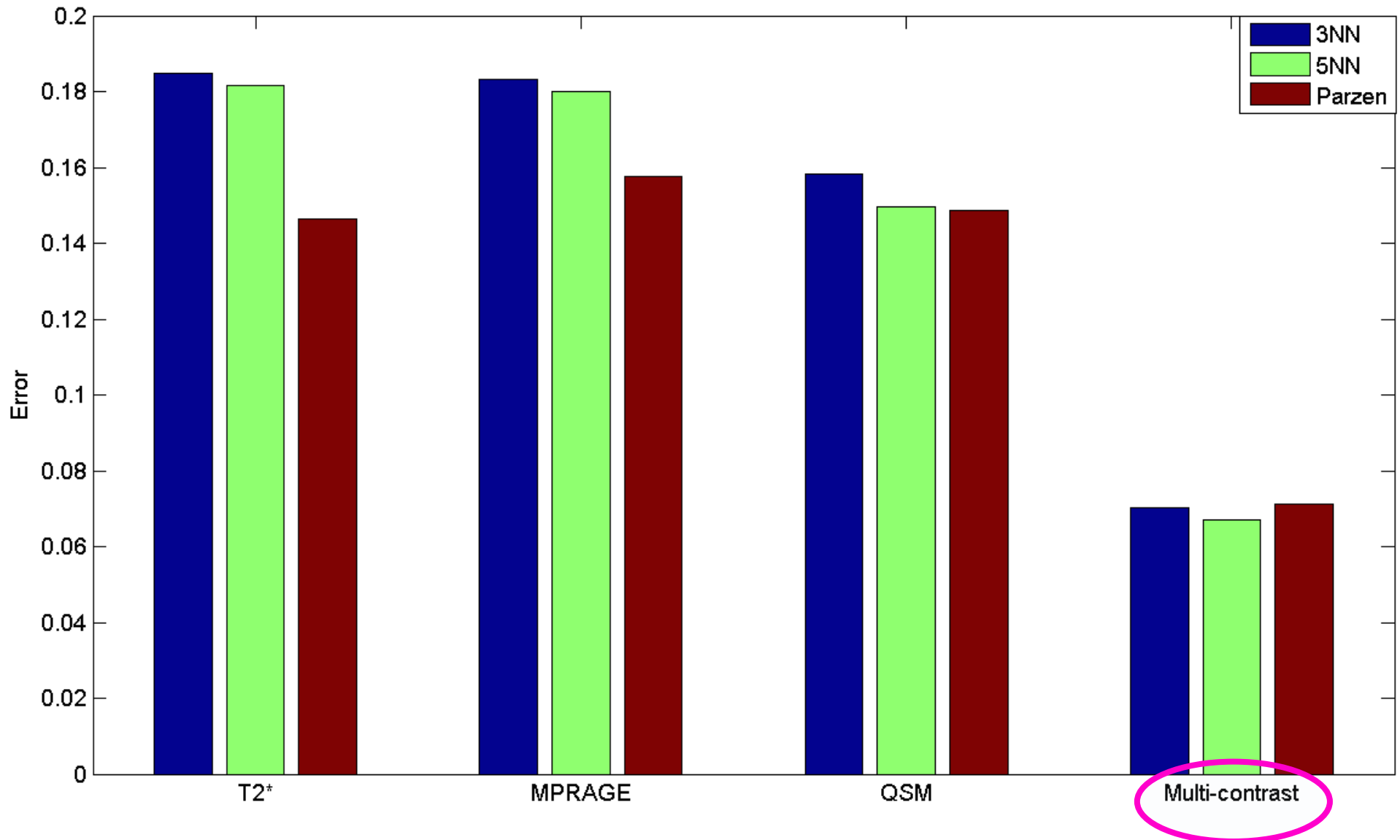
Morel Atlas

Classifiers	% classification error	% TP (nuclei)
3-NN	7.01	74.77
5-NN	6.69	77.03
Parzen	7.12	88.40
Morel Atlas	13.29	69.68

Results: test in different populations



Results: multi-contrast aspect



Future Work

- Improvements in classification and convex segmentation
- Quantitative analysis on volume and iron content in QSM images
- Additional subdivision in the major nuclei. 7T studies



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Thank you for your attention!

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