

Spatio-temporal behaviour of MS lesions in MRI images

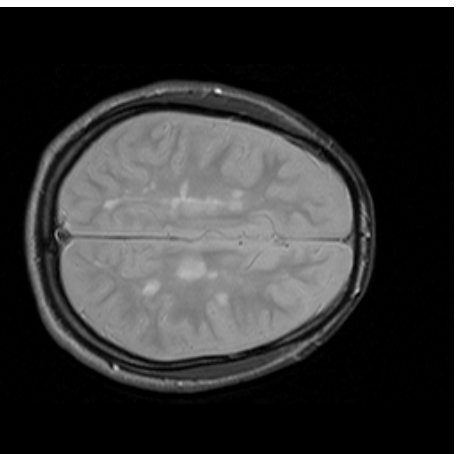
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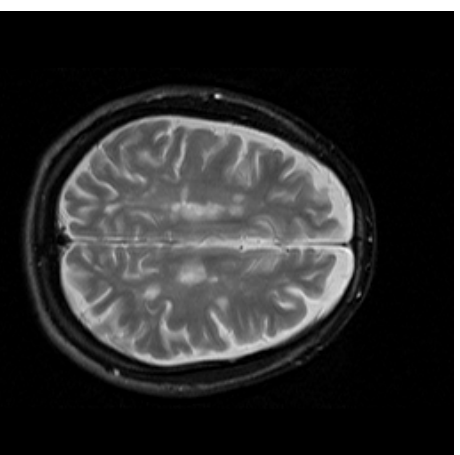
- Problems in segmentation of MS lesions from MRI data
- Data collection
- Data preparation / pre-processing
- 4D time series analysis
- Alternatives for tissue contrast generation

Problems of intensity based segmentation

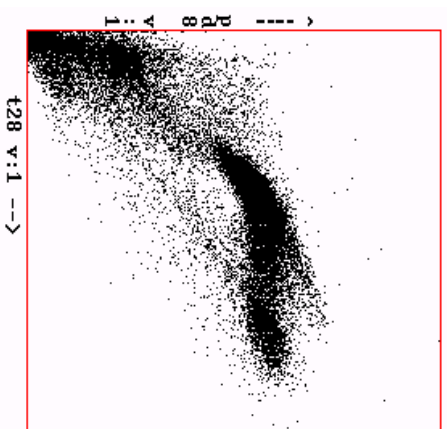
- Diffuse MS lesions
- Overlapping grey value ranges of different tissues
- Questionable reproducibility in manual segmentation



PD



T2



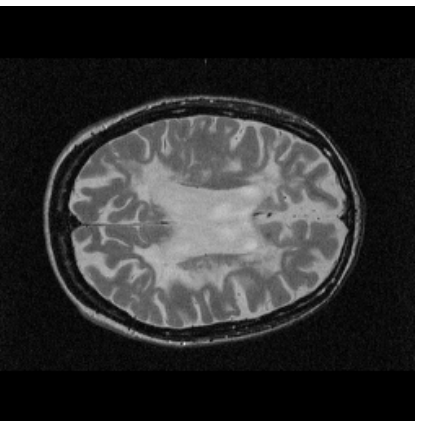
Histogram

Incorporation of the time domain

- Pharmaceutical long term studies
 - periodical examinations to assess drug treatment effect
 - small effects expected ⇒ reproducibility is a critical issue
- We are only interested in changes of the lesion load
 - ⇒ search only for changes in the time course
- Time series analysis

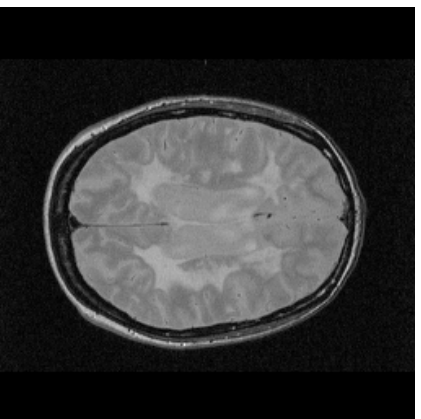
Acquisition protocol of the patient study

- Acquisition of 5 different pulse sequences
- 10 MS patients monthly over one year
- high-resolution data: $0.9 \times 0.9 \times 2.0\text{mm}^3$ (min. 57×256^2 slices)
- duration of the acquisition: about 1 hour



T2

Turbo spin-echo TR=2600ms
TE=90ms



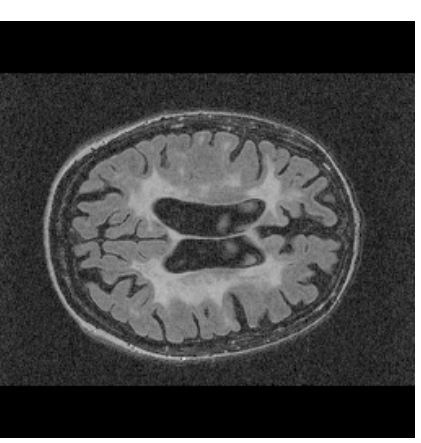
PD

Turbo spin-echo TR=2600ms
TE=45ms



T1/GD

TR=600ms TE=14ms, 0.1 mmol
gadopentetate dimeglumine



FLAIR

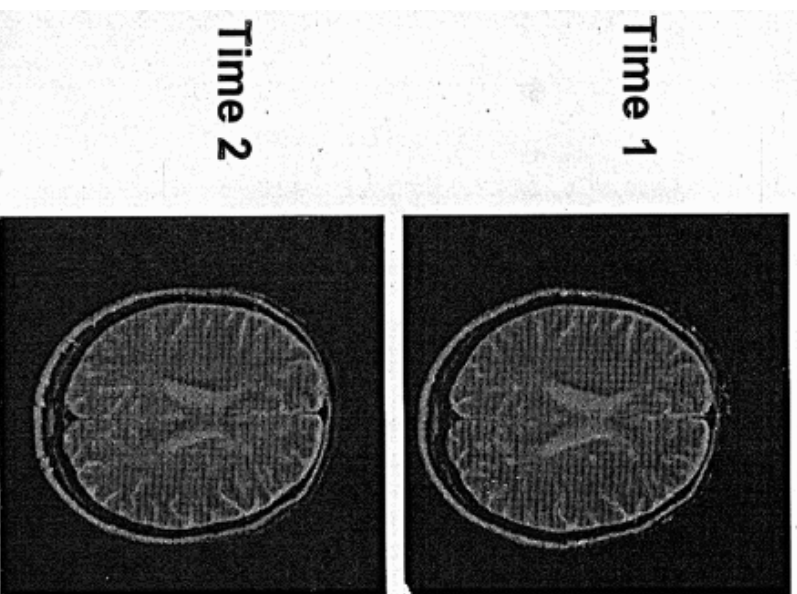
Data preprocessing

- Image quality enhancement
 - bias correction
 - noise reduction
- Special attention to influence on image texture
- Acquisition protocol is not completely reproducible
 - slight changes in patient position
 - differences in intensity normalization
- Preprocessing
 - spatial registration of the MR data sets (MIRIT, KU Leuven)
 - Intensity normalization
 - Bias Correction (ETH Software)
 - Intensity normalization
 - histogram-based intensity equalization
 - anisotropic diffusion
 - destroying texture

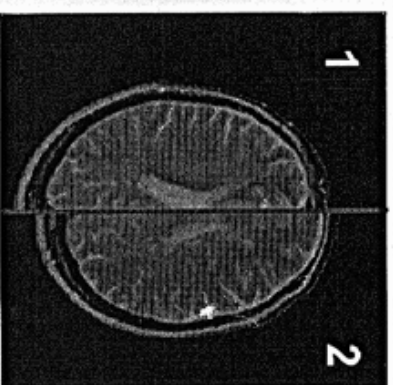
Automatic registration of multi-modality MT images

- Registration of complete 3D volumes
- Completely automatic, intensity-based procedure using mutual information, no feature extraction
- Reformatting will strongly distort texture
just the similarity transform resulted could be used

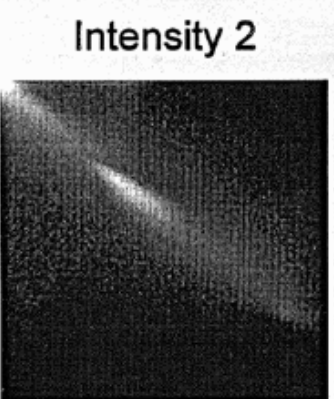
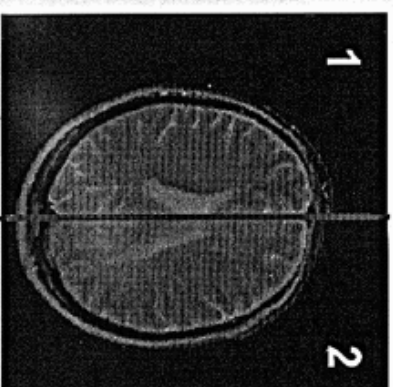
MS study
MR T2 images



Before registration



After registration

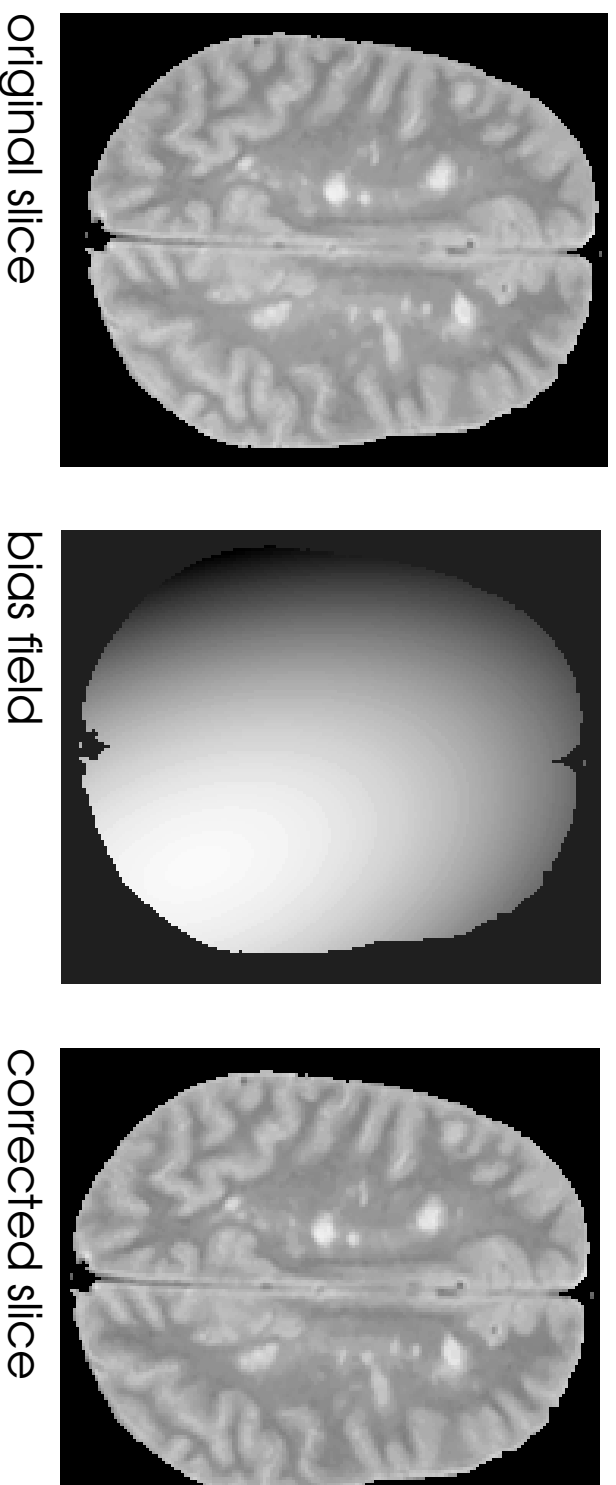


BIOMORPH-project, KU Leuven, 1997.

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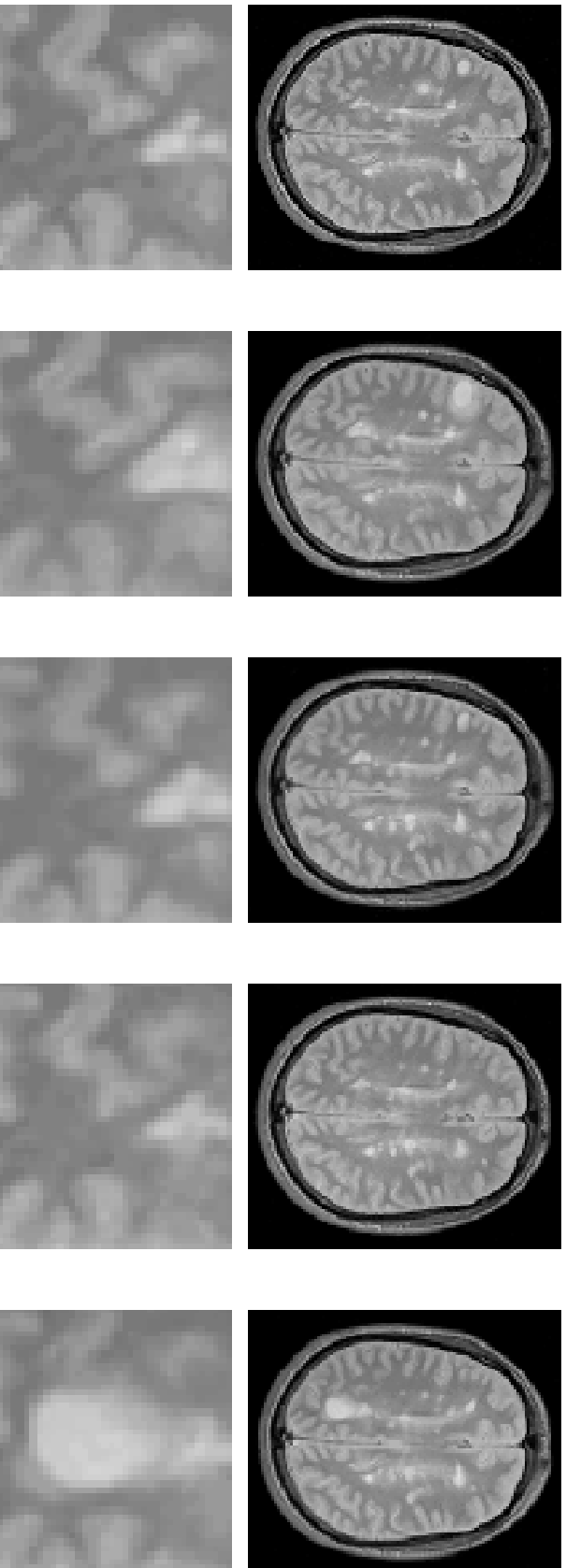
Bias correction

- Image = Bias-field \times Image-features
- Bias field: low frequency variations modeled as a polynomial field
- Polynomial coefficients: non-linear optimization evolutionary algorithms used



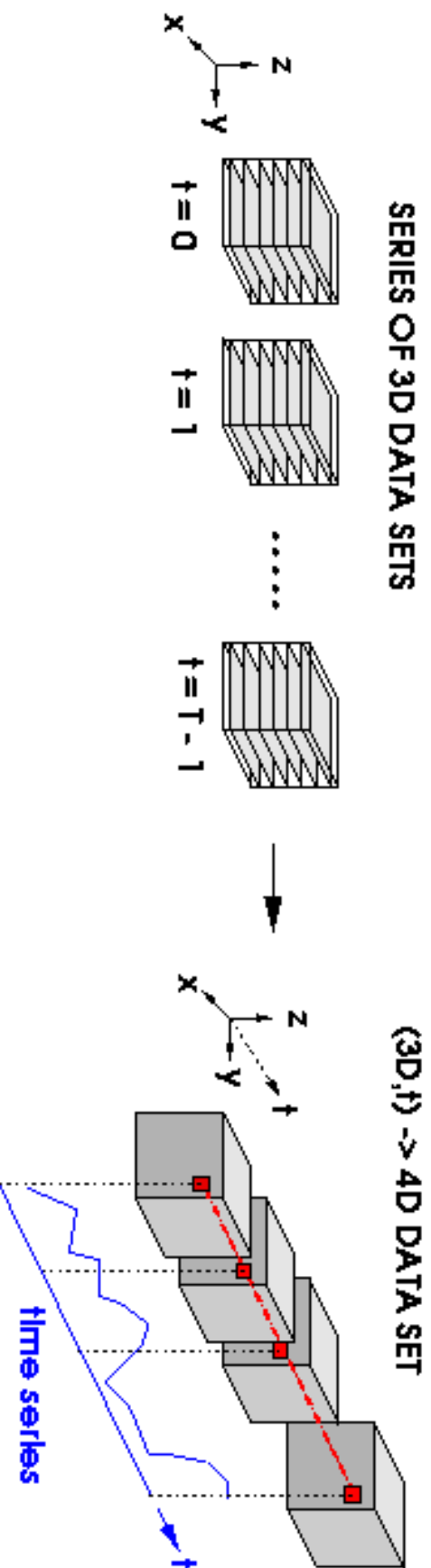
Serial MS data

- Time series of axial slices
for all acquired pulse sequences



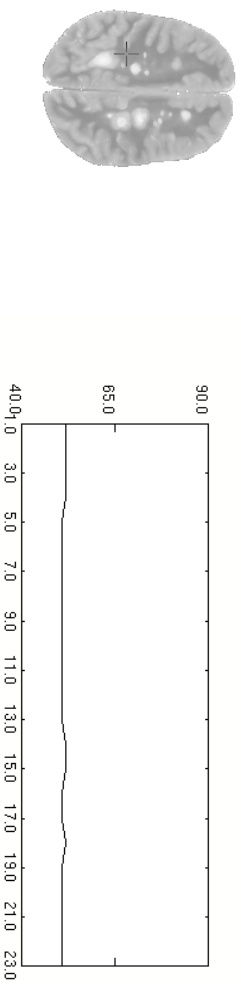
Conversion to time series

- Intensity behaviour of single pixels through time
- A 3D array of time functions results

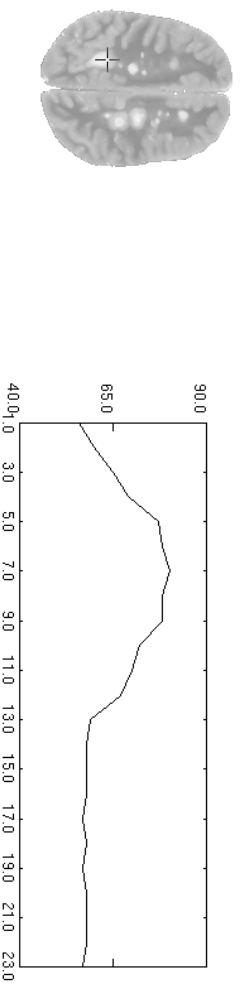


Result of the pre-processing

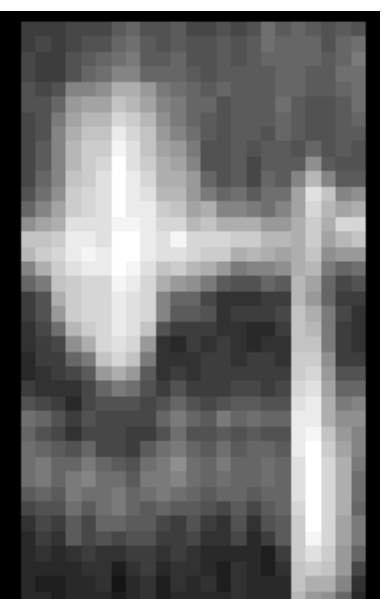
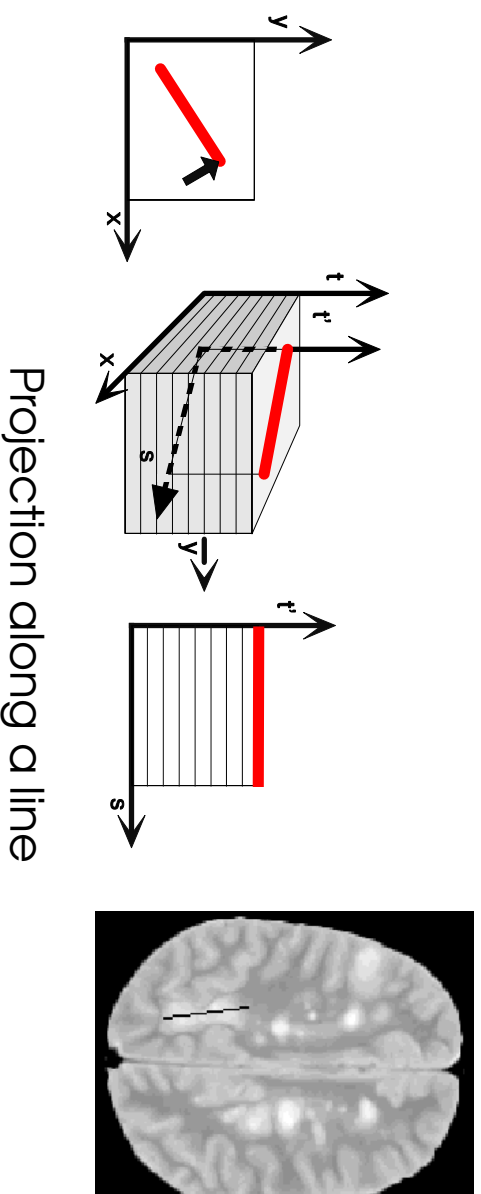
Time course of a voxel for healthy white matter



Time course of a voxel for a typical MS lesion



Time behaviour of an evolving lesion



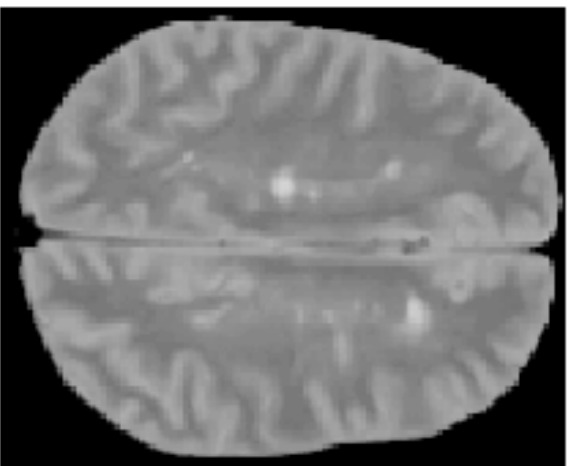
Time series analysis to detect fluctuating lesions

Measures used to characterize time changes

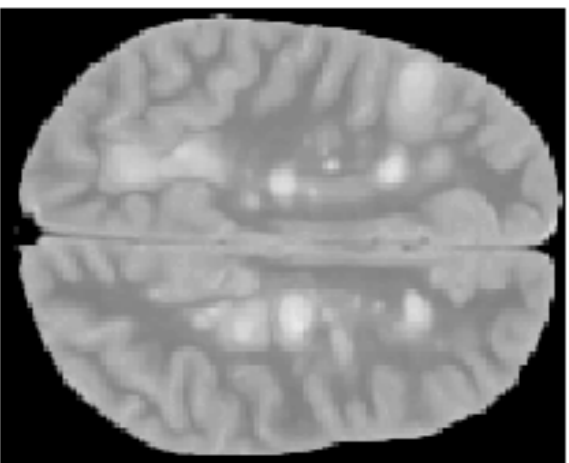
- Simple intensity based features
- Statistical features
- Time derivatives
- Measures of fluctuation

Intensity based measures

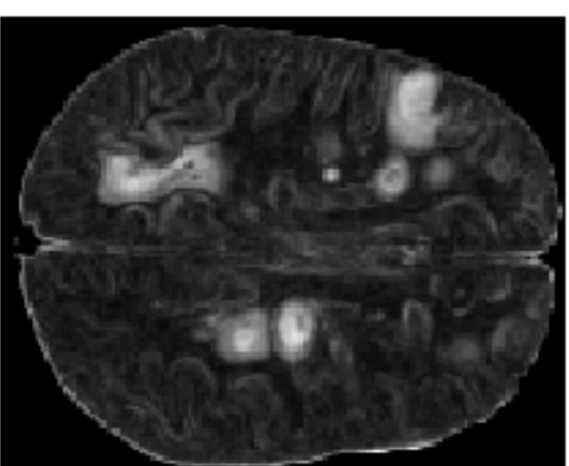
Minimum



Maximum



Difference

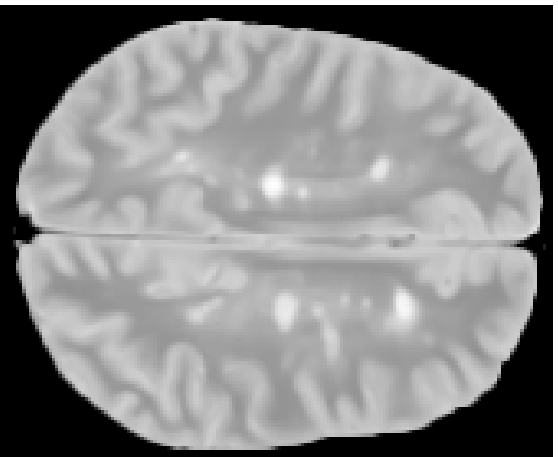


$$I_{min}(\vec{x}) = \min_t I(\vec{x}; t)$$

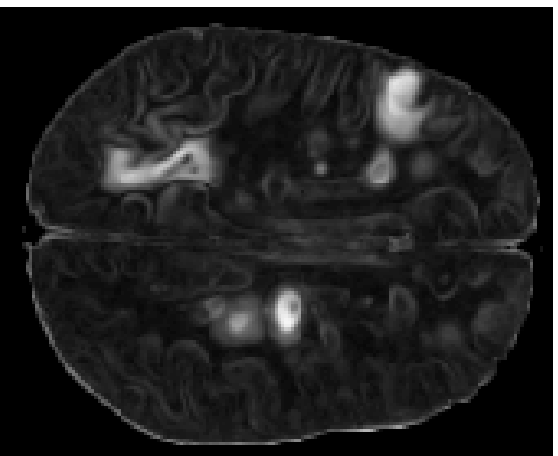
$$I_{max}(\vec{x}) = \max_t I(\vec{x}; t)$$

$$\Delta I = |I_{max} - I_{min}|$$

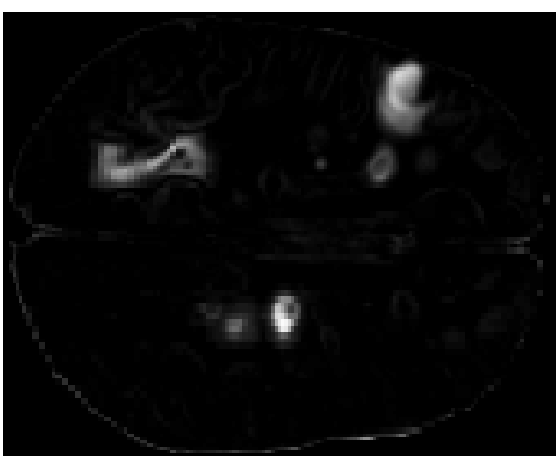
Statistical features



a



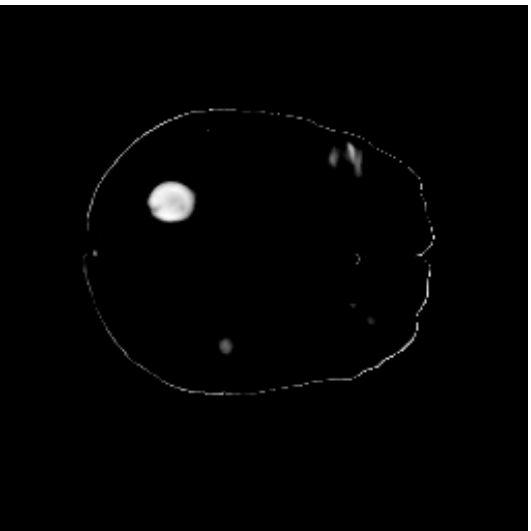
b



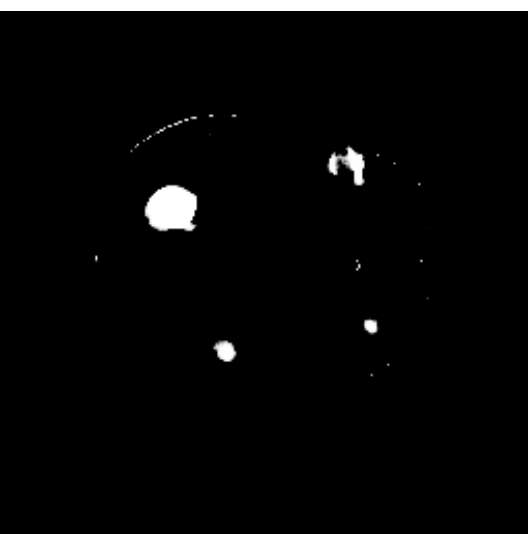
c

Mean (a), standard deviation (b) and variance (c)

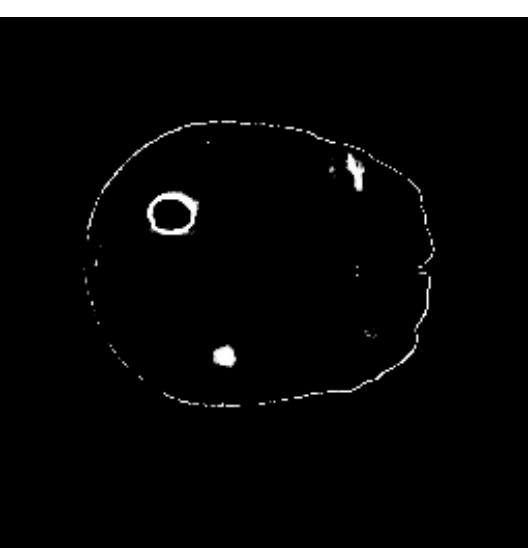
Time derivatives



Standard Deviation

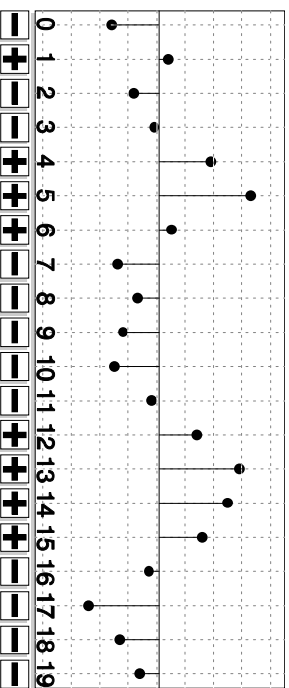


Gradient Maximum



Gradient Minimum

Measures of fluctuation

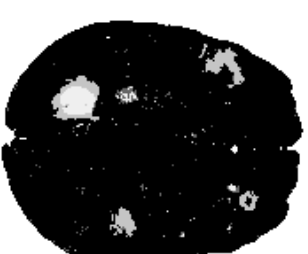


Evaluation of sign changes:

Maximal run length

Number of runs

Definition of "run"



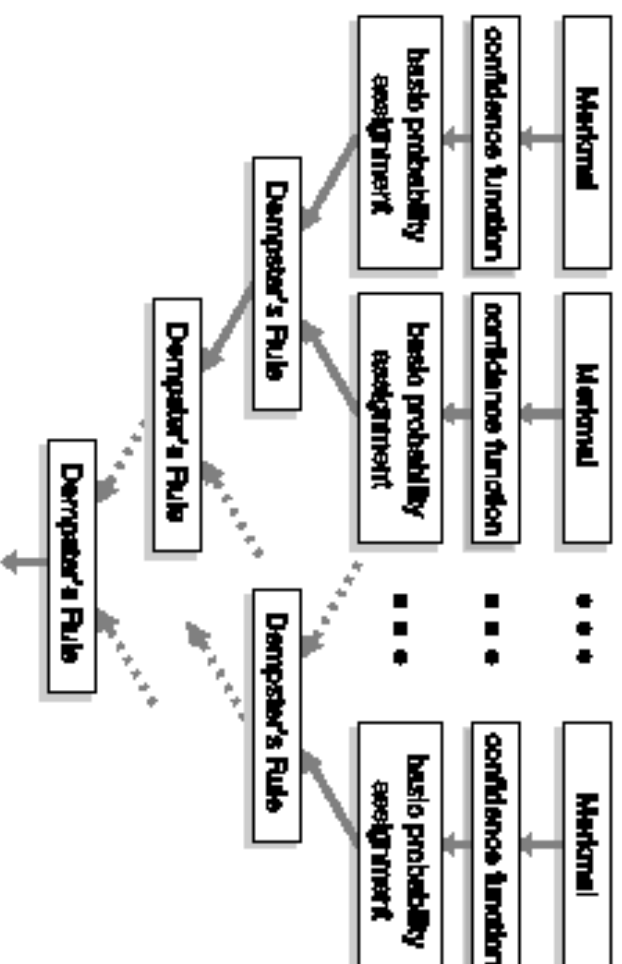
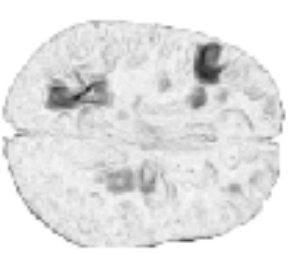
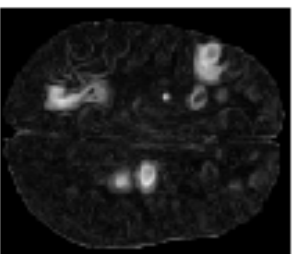
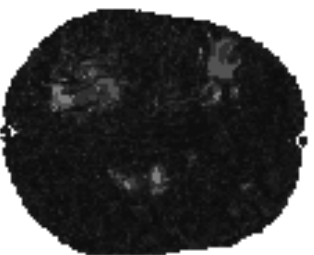
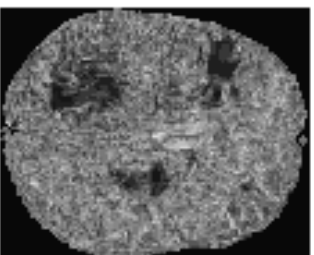
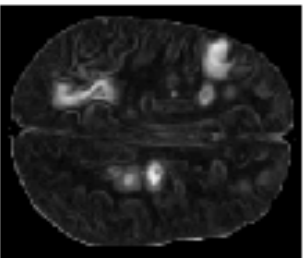
Observation: Low frequency variations (lesions)

→ large differences from mean

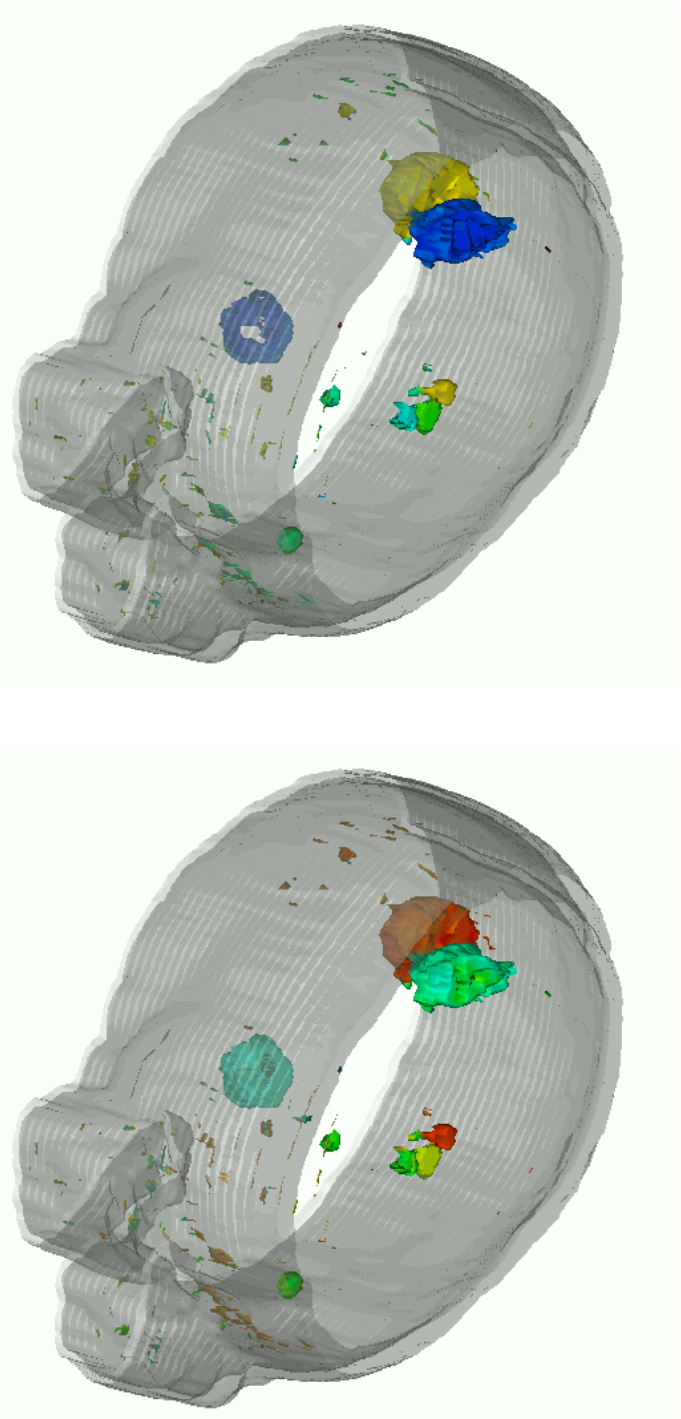
→ small number of sign changes

Final detection of time-dependent changes

- Combination of the single fuzzy features using Dempster-Shafer rule
- Final probability map for time changes
- Detection based on thresholding



Results



Appearance of MS Lesions

Disappearance of MS Lesions

Summary

- Availability of normalized multi-channel MRI series for MS
- Spatio-temporal data base for active lesions
 - possibility to test predictive features
- Automatic lesion segmentation method for 4D datasets (10 min)
- Possibility to identify active lesions
 - course of disease (lesion appearance and disappearance)
 - analysis of time correlations (lesions and clinical assessment)
 - lesion localization with respect to anatomy/functionality
 - change of total lesion load vs. time

Outlook

- Complex spatio-temporal lesion characterization
- Fundamental goal: better correlation with clinical symptoms
 - More precise description of the spatio-temporal pattern of lesions
 - More information about the pathophysiology of the lesions
- MRI as partial replacement for histology?
 - More specialized pulse sequences
 - Extraction of additional image features from images with “traditional” contrast
 - Texture has some promises: link between macroscopic (morphological) and microscopic (“sub-pixel”) features