Project A3

Image and signal processing in medicine and biosciences

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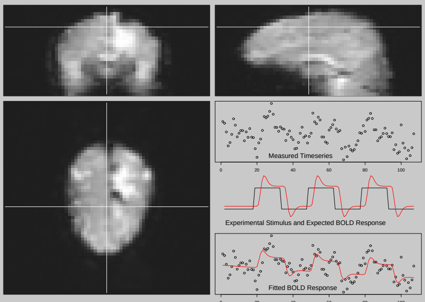
Medical imaging

Medical imaging includes a variety of techniques, like X-Ray, CT, and MRT. A high noise level and very low signal-to-noise ratio together with heteroskedastic tissue dependent variance is often a serious problem. Objects and signals of interest are often very weak and can hardly be detected. Methods and algorithms to handle this kind of data should be able to reduce noise while preserving important structure like edges and homogeneous regions. Structural adaptive smoothing removes the noise without loosing the structural information. This leads to substantial improvements in the analysis of various types of medical images.

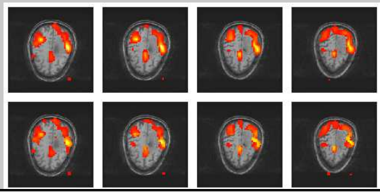
fMRI

Data from functional magnetic resonance imaging (fMRI) consists of time series of brain images which are characterized by a high noise level and a low signal-to-noise ratio. In order to reduce the noise, improve signal detection and to solve the multiple test problem fMRI data is spatially smoothed. We developed a structural adaptive smoothing procedures that significantly improves the information on the spatial extent and shape of the activation regions compared with common non adaptive filtering.

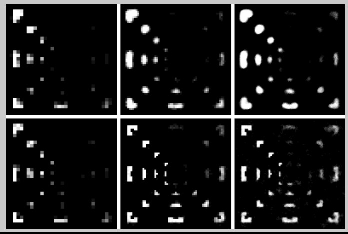


Properties of fMRI data

Structural adaptive smoothing

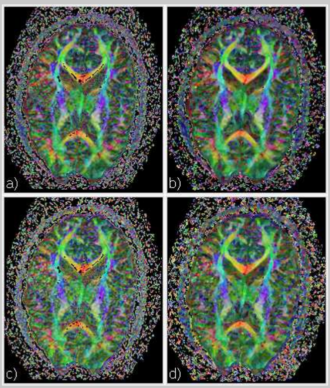


Signal detection in fMRI analysis for non-adaptive (upper row) and adaptive smoothing (lower row)



Probability of signal detection on simulation data after non-adaptive (upper row) and adaptive smoothing (lower row) for increasing (left to right) resolution and thus decreasing SNR.

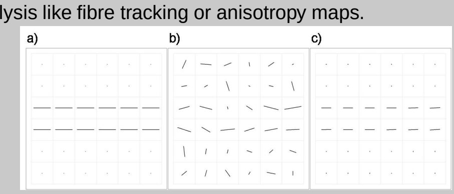
DTI Experiment



Reconstruction of the diffusion data using 55 (a,b) and 30 field gradients (c,d) without smoothing (a,c) and with structural adaptive smoothing (b,d).

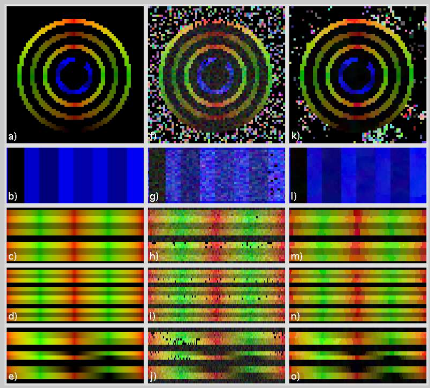
DTI

Diffusion Tensor Imaging suffers from significant noise, which effects subsequent medical analysis with fiber tracking or anisotropy maps. However, noise reduction with commonly applied non-adaptive smoothing methods tend to oversmooth fine anisotropic structures of interest. Using an adaptive smoothing method that identifies and uses anisotropy information in the data is therefore essential, to improve subsequent medical analysis like fibre tracking or anisotropy maps.



Vector field of main diffusion direction in simulation data (a), disturbed by noise (b), after structural adaptive smoothing (c).

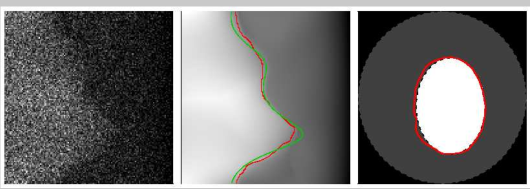
DTI Simulation



Reconstruction of a numerical phantom mimicing features of experimental DTI data. Directionally encoded color FA maps obtained from the phantom (a)-(e), voxelwise reconstructions from noisy data (h-j), and smoothed results (k-o).

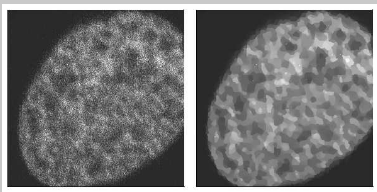
PET

The observed data follow a Poisson distribution whose intensity is the Radon transform of the objective tissue. Theoretical results suggest a reconstruction algorithm based on smoothing and edge detection under Radon transform.



Microbiological images

Microbiological images are often characterized by a high noise level and a bad signal to noise ratio. The distribution of gray values strongly depends on the imaging technique.



The Figure shows a slice of a 3D image of a cell nucleus obtained by confocal microscopy and its reconstruction by a local constant AWS procedure.