P 200

Probabilistic fibertracking in deep brain stimulation

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Purpose: Deep Brain Stimulation (DBS) is a well established treatment option for movement disorders such as Parkinson disease, and increasingly applied in psychiatric disorders. Additional information provided by the calculation and visualization of fiber tracks in the brain is of increasing importance. Therefore we have implemented a standardized procedure to perform probabilistic fiber tracking. This information is helpful in both the precise definition of target regions and the prevention of adverse side effects. A typical side effect is the stimulation of the internal capsule in the treatment of Parkinson's disease which could result in motor or speech disturbance.
Methods: We present a procedure for the implementation of probabilistic fiber tracking for the planning process of DBS. It is based on the software library of the Oxford Centre for Functional MRI of the Brain, FSL v5.0.
In addition to the diffusion imaging with 40 gradient directions, the input data comprise additional B0 images for distortion correction, and are supplemented by the structural imaging in a conventional manner. We present a highly structured and automated workflow, which has been realized by an extensive set of Unix scripts and runs with minimal user interaction. The results of this process, the individual fiber tracks, are finally converted back into the DICOM format.
Results: The final DICOM export allows us to provide arbitrary fiber tracks for a variety of stereotactic planning systems, including Cranial3 and SurePlan from Medtronic (Dublin, Ireland) and iPS from Inomed (Emmendingen, Germany). The integration of these results might be used pre-operatively in the actual planning process, as well as post-operatively to explore the regions stimulated by active electrodes, which is particularly useful in the treatment of psychiatric indications.

P 201

Detection of image plane orientation during two-photon laser scanning microscopy in brain tissue of mice using the geometry of stimulation and recording electrodes

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Two-photon laser scanning microscopy (2-PLSM) has become an important and widely used methodology to study network activities in the healthy and pathological brain in vivo. Repeated imaging sessions allow to follow single cell responses in long-term processes, e.g. during development, in disease or rehabilitation progression. So far, special head holders and biological landmarks at the brain surface, such as the pattern of the vasculature, have been used for precise re-positioning the experimental animal in repetitive imaging sessions. Here, a mathematical approach (implemented in MATLAB®) is presented that facilitates detection of brain tissue orientation. This method promises to be more flexible and robust against landmark changes. The advantage of a rectangular observation window of cortical surface microelectrodes for electrical stimulation or recording during 2-PLSM in brain tissue of mice was taken. Three corners of the electrodes observation window were used as marker points for calculating a local coordinate system acting as stationary brain tissue reference system. Calculating the rotation angles between the local coordinate system and the global coordinate system of the microscope leads to an exact definition of tissue orientation and reliable detection of cellular structures. On computational and practical level the new method was verified. The results showed the capability of the method to identify the orientation of the coordinate system related to the brain tissue. In addition, the required rotation precision for repeated detection of cellular structures is calculated and will be presented with general requirements in marker design. Finally, current limitations in practical use and possible improvements to optimize the proposed approach will be discussed.

P 203

A novel algorithm for efficient detection and segmentation of metals for artefact reduction in computed tomography

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Artefacts due to high-density metals are a major hindrance to image quality and diagnostic accuracy in computed tomography (CT). Since it is common to have metal implants in the aging population, efficient and accurate metal artefact reduction algorithms are necessary. The state of the art algorithm for metal artefact reduction is projection completion. Here, metals pixels are segmented in projection images and replaced with interpolated values from non-metal pixels. One of the crucial components of metal artefact reduction algorithm is to segment the metals in the projection images. Currently, metals are segmented in prior reconstructed volumes and projected metal pixels are identified by forward projection. However, this workflow is computationally expensive and may not be applicable for fast reconstruction routines. This work presents a new algorithm for detecting metals from the projection itself without reconstruction and forward projection. It takes into account three main features for enhancing and differentiating metals from the background for an easier threshold-based segmentation, by assuming that metals have higher amplitudes, gradients, and curvatures. Therefore two indicators are proposed for extracting these features and are computed for each row of projection image. The first indicator is computed using a smooth differentiation filter for slope estimation and the second indicator takes into account the amplitude and curvature of each signal row. For that, a 2nd-degree polynomial is used to fit the signal inside a sliding window around the central sample. A final indicator is then computed as a simple product between the estimated amplitude, derivative and curvature resulting in a high enhancement of the metals. The last step consist on a thresholding over the resulting indicator using a Gabor filter for increasing detection accuracy. Our preliminary results show that metals are segmented accurately for multi-slice CT, and c-arm CT data sets and metal artefacts are significantly reduced.

P 208

Interventional limited angle CT concept

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Radiography use ionizing radiation to generate images of the body, which has enough energy to cause damage to the patients DNA and increases a patient's risk of developing cancer. For image guidance in a surgery room conventional C-arm are frequently used. While these systems are movable but are very bulky, have a rather large detector - tube distance, and rarely provide tomographic images. For tool guidance purposes (e.g. needle injections, biopsy tools) a small attachable concept of a dedicated interventional X-ray system with very small detector - tube distance that is also able to provide depth information would be very beneficial. Our development intention was to design and implement a prototype intra-operative imaging system with the miniaturized low power and low dose X-ray tubes (MOXTEK 60 kV Magpro) and a flat panel detector (Teledyne Xineos-2222) capable of acquiring limited angle and limited field of view images (TOMOSYNTHESIS). A prototype was developed able to obtain planar imaging data at different x-ray tube / detector angles. The motion of the tube, attached to a mechanical arm was carried out by using a DC motor, while the detector was stationary. The DC motor was converted into a closed loop system with the help of magnetic encoder feedback into a micro-controller board achieving step angle and continues motion. All of this automation was controlled by LabView. The tomosynthesis prototype acquired data at a limited angle rotation (100°), acquiring 30 images in about 15 seconds. The obtained and with a custom developed SART (Simultaneous Algebraic Reconstruction Technique) reconstructed imaged showed the expected artefacts, but are satisfactory for the image guidance purpose while providing a very small setup, and very low dose imaging for a fraction of the cost of a conventional X-ray guidance system.

P 209

Quantitative chemical shift spectroscopy (CSI) with respect to B_0- and B_1-inhomogeneities

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Introduction: CSI is a method to visualize the metabolism of larger brain volumes, which is important for many diseases like Alzheimer, dementia, extensive tumor areas etc.
Despite the fact, that a greater B_0-field causes a linear growing of the resolution, there exist a lot of disturbance variables, which diminish the accuracy of quantitative measurements of a 3T-device in relation to 1,5T.
Due to inhomogeneities in B_0- and B_1-fieldstrength, susceptibility artifacts and information loss as a result of the digitalization procedure, it is a much challenged task gaining precise quantitative values of metabolic concentrations in CSI. In this work we present measurements and numerical evaluations of the influence of these disturbances for 3T-MRI.
Materials and methods: The CSI-measurements were performed on the 3T-MRI Skyra (Siemens) on site.
A self-made head phantom containing brain metabolites (NAA, Cr, Cho, mI, Glm) was used for simulations (VeSpa) of basic data sets. The calculation of spectra from simulated and measured datasets was made by LC-Model. Graphic results were plotted by self-made Matlab-procedures.
Results: The influence of interfered factors could be quantified. Some routines are given for correction of B_0- and B_1-inhomgeneities. As a main topic the influence of the PSF (point spread function) due to digitalization of the CSI-measurements was reduced by a correction matrix.