Development and Application of Tools for MRI Analysis - A Study on the Effects of Exercise in Patients with Alzheimer's Disease and Generative Models for Bias Field Correction in MR Brain Imaging - DTU Orbit (04/11/2019)

Magnetic resonance imaging (MRI) is the de facto modality in neuroimaging studies, due to its superior image contrast in soft tissue. These studies often employ automated software pipelines that segments the image into structures and tissue. This reduces the time needed for analysis as well as statistical bias that may arise due to disagreements in delineations made by human experts. One such pipeline is Freesurfer.

This thesis presents results from the intervention study \Preserving cognition, quality of life, physical health and functional ability in Alzheimer’s disease: the effect of physical exercise\" (ADEX), where longitudinal Freesurfer analysis was used to obtain segmentations of the hippocampal subfields and cortical regions in a subgroup of participants before and after a four-month exercise period. The participants performed moderate-to-high aerobic exercise for one hour, three times per week. The study hypothesized that the intervention would lead to reduced loss of tissue in the hippocampus and cortical regions, and that volumetric changes over time would correlate with cognitive performance measures. It was not possible to measure any effects in the hippocampus or cortical regions due to the intervention. However, it was found that exercise load (attendance and training intensity) correlated with changes in the hippocampus and in frontal and cingulate cortical thickness. Furthermore, changes in frontal and cingulate cortical thickness were found to correlate with changes in several cognitive performance measures, including mental speed, attention and verbal uency.

MRI suffers from an image artifact often referred to as the "bias field". This effect complicates automatized analysis of the images. For this reason, bias field correction is typical an early preprocessing step in many pipelines. Freesurfer currently employs the popular N3 bias field correction algorithm early in the pipeline, to solve this problem.

In this thesis, the reader is introduced to generative models for bias field correction. It is further shown how N3, which has traditionally been described as a "histogram sharpening" method, actually employs an underlying generative model, and that the bias field is estimated using an algorithm that is identical to generalized expectation maximization, but relies on heuristic parameter updates.

The thesis progresses to present a new generative model for longitudinal correction of the bias field, as well as a model that does not require brain masking or probabilistic, anatomical atlases in order to perform well. Finally, the thesis presents the realization of these models in the software package "Intensity Inhomogeneity Correction", which will be made publicly available.

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