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Tractography Based Visual Diagnostics

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Dresden, May 24, 2020

Task Description

The aim of the project is to perform visual diagnosis of healthy and diseased subjects based on fiber tracts derived from diffusion MRI (dMRI) volume of the human brain. The goals are:

1) Literature review on state-of-the-art methods and toolboxes related to dMRI volume pre-processing, fiber orientation estimation, fiber tracking and tract segmentation.
2) Pre-processing of the dMRI datasets to eliminate noise and prevalent distortion/motion correction.
3) Study and implementation of fiber orientation estimation at a single voxel resolution of dMRI volume.
4) Study and implementation of fiber tracking and segmentation methods using Region of interest (ROI).
5) Qualitative and Quantitative evaluation of tracking and segmentation methods for healthy and diseased subjects.

Note: The team consists of 4 members with 3 participants for CMS-VC-TEA.

Optional goals:

a) Study and implement a VR user interface to perform immersive evaluation of fiber tract results.

Declaration of authorship

I hereby declare that I wrote this thesis on the subject

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independently. I did not use any other aids, sources, figures or resources than those stated in the references. I clearly marked all passages that were taken from other sources and cited them correctly.

Furthermore I declare that – to my best knowledge – this work or parts of it have never before been submitted by me or somebody else at this or any other university.

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Contents

1 Introduction

TODO

- Check references of section about ad
- review glossary. any "tba"?

1.1 Alzheimer's Disease (AD)

One example for a potential application of white matter tractography is the analysis of Alzheimer's Disease (AD). Symptoms of this disease include short-term memory disorder and disorientation in space and time in its early stages, as well as long-term memory disorder, disorientation in situation and person, and semantic paraphrases later on.

The most common doctrine currently relies on the *Amyloid Hypothesis*, naming the accumulation of amyloid-β peptide Aβ42 in structures of the hippocampus, forebrain and neocortex as cause of the disease. The reasons for the amyloid-β peptide's neurotoxicity are still being discussed[Haa09].

Meanwhile, recent studies using PET imaging have contradicted this hypothesis, evaluating this accumulation to be a common process in the elderly while having only weak correlations with clinical disease syndromes. Instead, it has been suggested to view AD as a large-scale network disconnection syndrome, associated with said protein accumulation as well as cortical atrophy, and functional disconnections between brain regions. Some success in analyzing this network disconnection has been made with a novel approach called [MRD+18].

2 Evaluation

In 2009, the National Institutes of Health (NIH), a part of the U.S. Department of Health and Human Services[nihb], launched the Human Connectome Project (HCP) in ”an ambitious effort to map the neural pathways that underlie human brain function.”[niha]. Its goal is to advance the capabilities of both imaging and analysis of human brain connections, hoping this will accelerate the progress of human connectomics.

HCP is carried out by two research consortia:

- *Harvard/MGH-UCAL*: Massachusetts General Hospital/Harvard University and the University of California Los Angeles (UCLA), focuses on creating a new magnetic resonance imager optimized for measuring connectome data
- *WU/Minn*: Washington University in St. Louis/University of Minnesota/Oxford University, focuses on mapping macroscopic brain circuitry and researching its connection to behavior. That includes data acquisition from 1200 subjects with a magnetic induction of $3T$ and from 200 subjects at $7T$[ESB+13].

Main directives of both consortia also include the improvement of existing and development of new imaging protocols and processing techniques. The collected data and software are made publicly available, the process of which is managed by the Connectome Coordination Facility.

First results published only few years after the initiation of HCP inspired further projects, i.e. the Lifespan HCP acquiring imaging data across all ages split into four subprojects (prenatal, 0-5, 6-21, and 36-100+ years), as well as several projects focusing on connectomes related to diseases, such as AD.

Glossary

Alzheimer's Disease neurodegenerative disease, cf. Amyloid Hypothesis. 1–3, 5, 6

. 2, 3, 5

Connectome Coordination Facility "The Connectome Coordination Facility (CCF) houses and distributes public research data for [HCP]."[UpA]. 2, 4

Constrained Spherical Deconvolution tba. 2

Fixel-Based Analysis method for analyzing DWI data using constraint spherical deconvolution; "fixel" refers to a specific fibre population within a voxel; see [MRD+18]. 2

Human Connectome Project "Launched in 2009 as a Blueprint Grand Challenge, the NIH Human Connectome Project (HCP) is an ambitious effort to map the neural pathways that underlie human brain function. The overarching purpose of the Project is to acquire and share data about the structural and functional connectivity of the human brain."[niha]. 2, 4, 6

Lifespan HCP "HCP Lifespan Projects are acquiring and sharing multimodal imaging data acquired across the lifespan, in four age groups (prenatal, 0-5, 6-21, and 36-100+)."[UpA]. 2, 4

National Institutes of Health "The National Institutes of Health (NIH), a part of the U.S. Department of Health and Human Services, is the nation's medical research agency – making important discoveries that improve health and save lives."[nihb]. 2, 4, 6

Acronyms

AD Alzheimer's Disease. 1–4

HCP Human Connectome Project. 2, 4, 5

NIH National Institutes of Health. 2, 4

Bibliography

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[MRD+18] Remika Mito, David Raffelt, Thijs Dhollander, David N Vaughan, J-Donald Tournier, Olivier Salvado, Amy Brodtmann, Christopher C Rowe, Victor L Villemagne, and Alan Connelly. Fibre-specific white matter reductions in alzheimer's disease and mild cognitive impairment. *Brain*, 141(3):888–902, 01 2018.

[niha] Connectome programs.

[nihb] Who we are.

[UpA] UpAndRunning. Connectome - homepage.

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