Pediatric Brain Age Prediction from Diffusion MRI Data

Data 695 Project Proposal

Introduction

The project, "Pediatric Brain Age Prediction from Diffusion Magnetic Resonance Imaging (MRI) Data," is undertaken within the Department of Pediatrics at the University of Calgary, under the guidance of Dr. Matthias Wilms. The aim of this research project is to leverage machine learning and image analysis techniques to predict the brain age of pediatric subjects based on diffusion MRI data. Individuals with chronic conditions like Autism and attention-deficit/hyperactivity disorder (ADHD) exhibit distinctive patterns of brain aging. To illustrate, ADHD can result in the brain aging more slowly than the person's actual age. This novel approach will provide valuable insights into the microstructural neurodevelopmental differences in children and adolescents aged 5-20 years. The project's goal is to contribute to the understanding of neurodevelopmental conditions such as autism spectrum disorder and ADHD.

The significance of this research lies in its potential to provide early diagnosis of neurodevelopmental disorders, which can significantly impact the timely treatment of these conditions. Moreover, this project addresses a combined analysis of macro- (T1w) and microstructural (diffusion) properties of the brain, potentially increasing model accuracy. Success in this research could open new perspectives on the analysis and detection of atypical neurodevelopment in children and adolescents.

Objectives

The project has the following key objectives:

1. **Develop a CNN-Based Machine Learning Pipeline for pediatric brain age prediction:** Achievement will be measured by higher model accuracy with both T1-weighted and diffusion map inputs. Careful monitoring will be conducted to prevent overfitting.
2. **Dataset Utilization:** Challenges include the sample size limitation imposed by the specific age group (5-20 years) and the requirement for healthy subjects (not suffering from neurodevelopmental disorder). This novel approach necessitates adapting existing CNN architectures to suit our unique requirements.
3. **Performance Evaluation:** Success will be gauged by the model's ability to predict the actual brain age compared to the chronological age of the subjects. Additionally, the project sets the stage for the application of explainable AI for validating predictions and future diagnostic applications.

Dataset

The dataset for this research project is pivotal, consisting of diffusion MRI scans, and pertinent clinical details from over 2000 pediatric subjects aged 5-20 years.[1]

1. **Data Collection:**
    - **Sample Size:** Comprising 2000+ pediatric subjects, aged 5-20.
    - **Inclusion Criteria:** Limited to subjects without neurodevelopmental diagnoses, focusing on healthy individuals.
1. **Data Preprocessing:**
    - **Voxel Spacing Alignment:** Ensuring that the spacing between voxels (the three-dimensional pixels that make up the MRI image) is consistent and standardized.

- **Multichannel Input:** Using diffusion maps as well as integration of diffusion maps with T1-weighted MRI images, facilitating multi-channel input for our ML model.

Methodology

1. **Data Collection and Preprocessing:** To ensure the quality and homogeneity of the dataset, we standardize the dimensions and voxel levels of the images and aligning spacing. The diffusion maps are combined with the T1-weighted MRI images to create multi-channel input for our model.
2. **Model Development and Enhancement:** Our model development journey begins with the implementation of a Simple Fully Convolutional Network (SFCN)[2], initially intended for single-channel input. However, as one of our objectives is to attain higher accuracy through the combination of diffusion maps and T1-weighted MRI images, we proceed to adapt and enhance the architecture. This adaptation involves the modification of hyperparameters, the addition of convolution blocks, etc., to accommodate multi-channel inputs.
3. **Model Training and Evaluation:** The dataset is divided into three distinct sets: a training set, a validation set (extracted from the training set), and a testing set, ensuring data segregation. During model training, we use mean squared error as the primary metric. By utilizing the validation set approach, we can effectively fine-tune our model to enhance its accuracy and generalize its predictions.
4. **Microstructural Neurodevelopmental Analysis:** Following the model development and evaluation phase, we delve into the core of our research objectives—combined macrostructural (T1w) and microstructural (diffusion) neurodevelopmental analysis. The in-depth analysis of the results aims to identify patterns, associations, and trends within the dataset, shedding light on neurodevelopmental differences in pediatric subjects.

This logical and structured methodology not only aligns with the project's objectives but also facilitates the accomplishment of the learning objectives, including the attainment of technical proficiency, advanced data interpretation, effective collaboration, and problem-solving skills.

Intended Research Results

The anticipated outcomes of this research project include:

1. **Enhanced Pediatric Brain Age Prediction Model:** Building a model that combines T1-weighted MRI images with diffusion maps to accurately predict the brain age of pediatric subjects, aiding in early diagnosis.
2. **Microstructural Neurodevelopmental Insights:** Through in-depth data analysis, we aim to uncover neurodevelopmental differences among pediatric subjects.
3. **Potential for Future Diagnostic Applications:** The project sets the stage for future research focused on the application of explainable AI for validating predictions and, ultimately, for diagnosing neurodevelopmental conditions in pediatric populations.

References

1. Richie-Halford, A., Cieslak, M., Ai, L., Caffarra, S., Covitz, S., Franco, A. R., … Rokem, A. (2022). Retrieved from https://www.nature.com/articles/s41597-022-01695-7
2. Peng, H., Gong, W., Beckmann, C. F., Vedaldi, A., Smith, S. M., & model. (2020). Retrieved from https://www.sciencedirect.com/science/article/pii/S1361841520302358

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Research Project - Faculty Supervisor Approval Form

Student Information:

Student Name: Daksh Patel

Work Term Dates: 11/09/23 to 11/12/23

UCID: 30190603

Supervisor Information:

First and Last Name: Dr. Matthias Wilms

Position Title: Assistant Professor

Report Type: Project Proposal

Supervisor Consent:

I have reviewed the attached report and approve the progress of the student in the project.

Digitally signed by Matthias Wilms
Date: 2023.10.17 19:29:58 -06'00'

Signature(s)

17/10/23

Date (DD/MM/YY)