**Spinal Cord Structural Analysis Pipeline**

This repository contains the code for pre-processing structural **T2-weighted**, **T2-star**, and **magnetization transfer MRI**images. The primary goal is to estimate biomarkers such as **spinal cord atrophy**, **gray matter atrophy**, and **white matter injury** in patients with **degenerative cervical myelopathy** (DCM). This pipeline is designed to provide reproducible, standardized, and localized measures of spinal cord injury.

**Objectives**

1. **Reproducible Analysis Pipeline**: A user-friendly pipeline for batch processing of spinal cord morphometrics.
2. **Standardized Measures**: Generate standardized and normalized morphometric using the PAM50 spinal cord template measures for comparison between patients and controls.
3. **Clinical Insight**: Provide clinical insights into white matter changes, with **magnetization transfer (MT)** being particularly sensitive to white matter changes in non-compressed regions.
4. **Localized Evaluation**: Provide spinal cord level-specific metrics to enable precise localization of spinal cord pathology.

**About the OU Spine Dataset**

The **OU Spine dataset** was acquired using the [The Spine Generic Protocol](https://spine-generic.readthedocs.io/). The study is ongoing, involving patients diagnosed with DCM and a control cohort of healthy subjects (HC). All **MRI** scans were acquired using a 3T MR750 **GE scanner**.

Due to the ongoing nature of the study, patient data is still being collected and analyzed. However, **sample patient and control data** are available. Full datasets are available upon reasonable request to the senior author.

**Data Format and Organization**

* All MRI datasets were converted from **DICOM** to **NIFTI** format and are organized following the **Brain Imaging Data Structure (BIDS)** format.
* **Spinal cord files** are renamed according to [**BIDS**](https://bids.neuroimaging.io/)standard.

For more details, see the

**Dependencies**

* **Spinal Cord Toolbox (SCT 6.1)**: Required for spinal cord segmentation and analysis.
* **Python 3.9**: The processing scripts are written in Python.
* **FSL (FMRIB Software Library)**: Required for data visualization.

**Installation**

1. **Spinal Cord Toolbox (SCT)**: Follow the SCT installation guide for instructions on how to download and install SCT, and integrate it with FSL.
2. **Python Environment**:
   * Install and activate a Python environment compatible with **Python 3.9**.
   * Install the necessary Python dependencies listed in the requirements.txt file.
3. **Directory Setup**:
   * Create a directory for processing and organize all input files as per the BIDS format.
   * Run the provided preprocessing script in **batch mode**.

**Preprocessing Steps**

1. **Spinal Cord Segmentation**: Use sct\_deepseg to segment the cervical spinal cord from surrounding neck tissues for DCM patients.
2. **Quality Control**:
   * After preprocessing, perform a **QC check** by reviewing the HTML files in the QC directory.
   * Inspect the **T2-weighted** and **T2-star** images for segmentation and vertebral level labeling errors.
   * If errors (e.g., segmentation leakage or under-segmentation) are found, manually correct them.
3. **Batch Re-run**: After corrections, re-run the batch analysis. The pipeline will automatically fetch manually corrected files from the designated folder.
4. **Result Export**:
   * The final morphometric measures will be exported to a **CSV** file.
   * The CSV file can be used for secondary analysis to evaluate metrics such as spinal cord shape, gray matter segmentation, white matter intensity, **MTR** (Magnetization Transfer Ratio), etc.

**Publications**

# Muhammad F, Weber KA, Bédard S, Haynes G, Smith L, Khan AF, Hameed S, Gray K, McGovern K, Rohan M, Ding L, Van Hal M, Dickson D, Al Tamimi M, Parrish T, Dhaher Y, Smith ZA. Cervical spinal cord morphometrics in degenerative cervical myelopathy: quantification using semi-automated normalized technique and correlation with neurological dysfunctions, The Spine Journal (2024), <https://doi.org/10.1016/j.spinee.2024.07.002>

# 2. Haynes G, Muhammad F, Weber KA II, Khan AF, Hameed S, Shakir H, Van Hal M, Dickson D, Rohan M, Dhaher Y, Parrish T, Ding L, Smith ZA. Tract-specific magnetization transfer ratio provides insights into the severity of degenerative cervical myelopathy. *Spinal Cord* (2024). <https://doi.org/10.1038/s41393-024-01036-y>

**Contributing**

Contributions to improve this pipeline are welcome. Please submit a pull request with detailed notes on any changes or improvements.