CS-512 Final Project Proposal (updated)

Automating segmentations of brain mask and labels using deep learning on Quantitative Susceptibility Mapping

Members:

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Main Paper:

- Chai, C., Qiao, P., Zhao, B., Wang, H., Liu, G., Wu, H., ... & Xia, S. (2020). Automated Segmentation of Brain Gray Matter Nuclei on Quantitative Susceptibility Mapping Using Deep Convolutional Neural Network. *arXiv preprint arXiv:2008.00901*.

Helping Papers:

- Yu, B., Li, L., Guan, X., Xu, X., Liu, X., Yang, Q., ... & Zhang, Y. (2021). HybraPD atlas: Towards precise subcortical nuclei segmentation using multimodality medical images in patients with Parkinson disease. *Human brain mapping*, *42*(13), 4399-4421.
- He, C., Guan, X., Zhang, W., Li, J., Liu, C., Wei, H., ... & Zhang, Y. (2022). Quantitative susceptibility atlas construction in Montreal Neurological Institute space: towards histological-consistent iron-rich deep brain nucleus subregion identification. *Brain Structure and Function*, 1-23.
- Jung, W., Bollmann, S., & Lee, J. (2022). Overview of quantitative susceptibility mapping using deep learning: Current status, challenges and opportunities. *NMR in Biomedicine*, *35*(4), e4292.

Problem Statement:

Quantitative Susceptibility Mapping (QSM) is a recent non-invasive modality of MRI imaging. With low contrast it is very challenging to segment labels of the brain using QSM. Though the field is rapidly expanding, for automating the process of delineation of regions in subjects, and scale down human intervention, a few deep learning models have been proposed. In this project, we propose to segment (3D)regions of the brain in two steps. First, we pre-process the image, by histogram shifting and stretching, resizing the images and then use DL architecture (such as U-net) to mask (3D) the brain, removing background (as this is another challenge for QSM) and separating the background and foreground. Finally, we will train another D-CNN model from the masked region from the previous step and labels of various brain regions. Once trained, the model will be tested and evaluated on a set of QSM images, where the images will be the input and the model will provide us with the segmented regions. For evaluation, we will depend on surface matching with their ground truths marked by the experts. These models will be tested on three different brain atlases for robustness. With more computational power and further investigation and parameters for the DL, the models will have potential to improve even though data scarcity, and computational complexity exists for QSM.

Approach:

Provided with some (100+) QSM images, and their masks in their native space, we will follow the steps mentioned below:

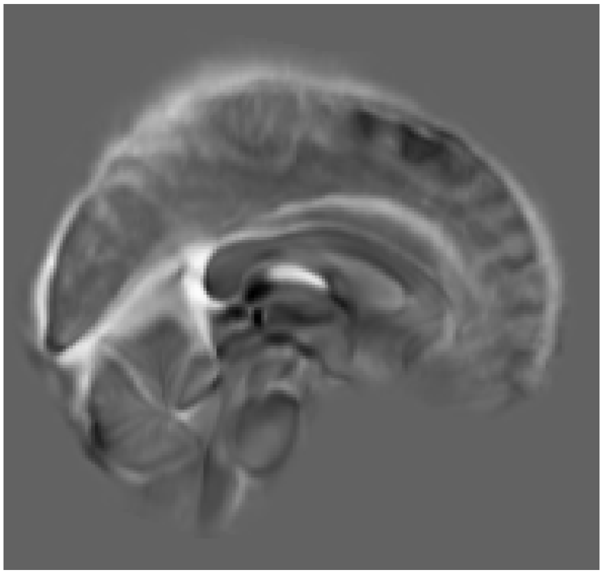
1. Transform the images to the atlas space (one at a time). This portion of the task is beyond the scope of this project, so we implement the results using ANTS toolbox and provide the transform files and scripts along with the project reports.
2. The QSM images undergo preprocessing, which involves applying histogram shifting and stretching to account for variations in background across different reconstructions for different readings, even for a same subject. Using the transformations from the previous step, the masks are also transformed to the atlas space and then transformed masks are thresholded. Next, the images and masks are downsampled (to save kernel memory) and are passed as input into a model. The model's objective is to generate a 3D brain mask of a brain, provided only the QSM image. Upon completion of training, we assess the model's performance by providing it with only a few QSM images and obtaining their corresponding 3D brain masks for the foreground.
3. Another DCNN is trained with the background deducted images and their labels of the brain (such as thalamus, red nucleus etc.) in the given atlas, following the steps of the [1]. Once trained the model will yield 3D segmented masks of the labels for QSM images. We will also implement some other popular architectures such as U-Net, and compare the model performance among them. If time allows, we will also compare the performance due to downsampling the input images.
4. Perform evaluation of the 3D segmented regions, such as Dice Similarity (surface overlapping), sensitivity, accuracy.

Data:

Data of the subjects were collected from a related study in [5]. Data of atlas spaces and labels of the brains are collected from the sources:

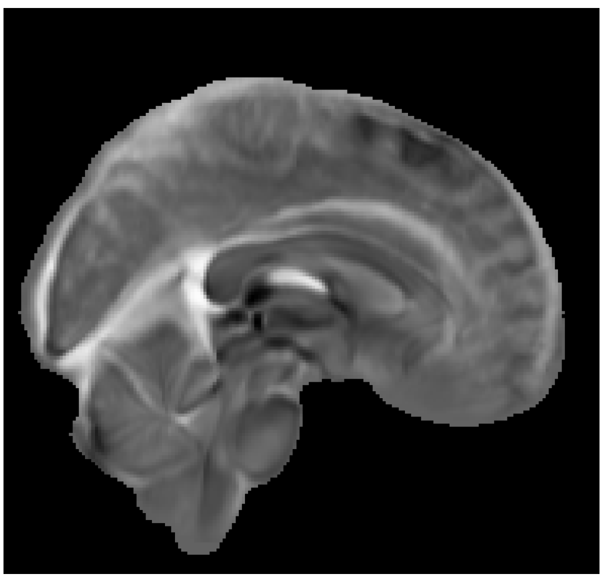
1. HybraPD [2]
2. MuSus-100 [3]
3. MIITRA [5]

Figure 1 shows an example image for QSM, their masks and labels

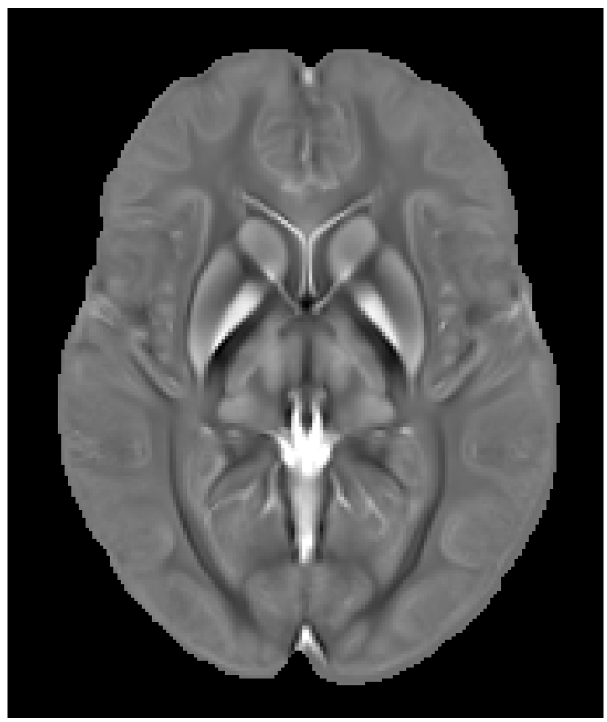


QSM without preprocessing

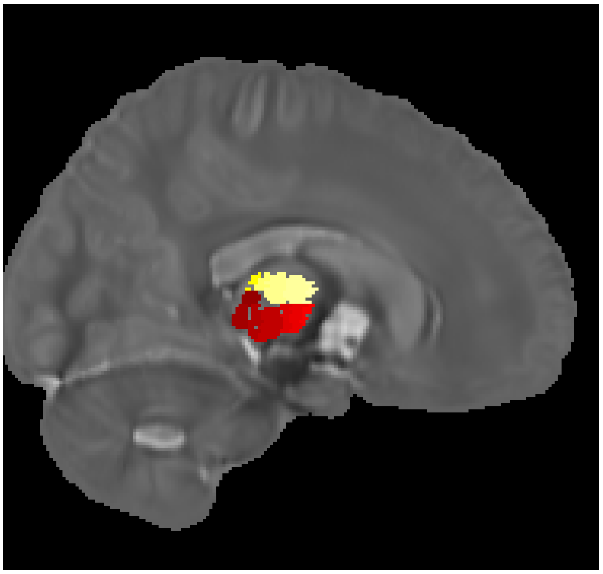
QSM brainmask



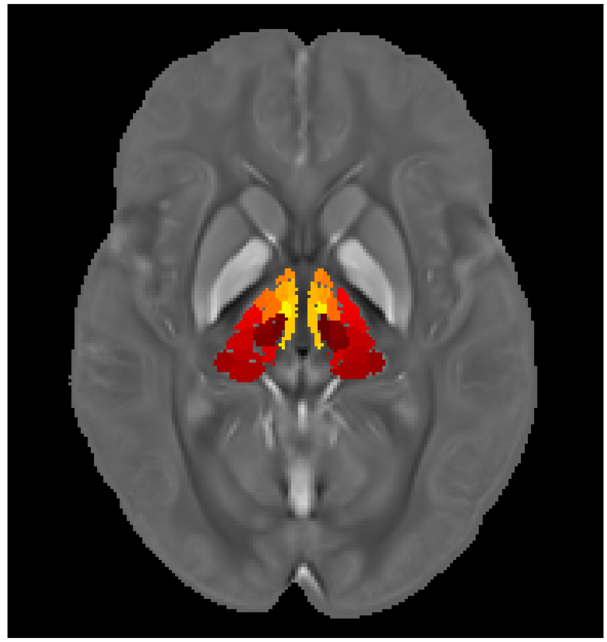
Preprocessed QSM without background and intensity scaled in sagittal view



Preprocessed QSM without background and intensity scaled in axial view



Thalamus labels in QSM in sagittal view



Thalamus labels in QSM in axial view

Figure 1: QSM images with masks and labels

Potential Challenges:

1. As QSM is relatively new, data is not in abundance. Also, much raw data is not publicly available/published yet, let alone their processed version. [4]
2. Running 3D segmentation on QSM requires massive computational power and time as there are many features to extract and evaluate. [4]

References:

[1] Chai, C., Qiao, P., Zhao, B., Wang, H., Liu, G., Wu, H., ... & Xia, S. (2020). Automated Segmentation of Brain Gray Matter Nuclei on Quantitative Susceptibility Mapping Using Deep Convolutional Neural Network. *arXiv preprint arXiv:2008.00901*.

[2] Yu, B., Li, L., Guan, X., Xu, X., Liu, X., Yang, Q., ... & Zhang, Y. (2021). HybraPD atlas: Towards precise subcortical nuclei segmentation using multimodality medical images in patients with Parkinson disease. *Human brain mapping*, *42*(13), 4399-4421.

[3] He, C., Guan, X., Zhang, W., Li, J., Liu, C., Wei, H., ... & Zhang, Y. (2022). Quantitative susceptibility atlas construction in Montreal Neurological Institute space: towards histological-consistent iron-rich deep brain nucleus subregion identification. *Brain Structure and Function*, 1-23.

[4] Jung, W., Bollmann, S., & Lee, J. (2022). Overview of quantitative susceptibility mapping using deep learning: Current status, challenges and opportunities. *NMR in Biomedicine*, *35*(4), e4292.

[5] Niaz, M. R., Wu, Y., Ridwan, A. R., Qi, X., Bennett, D. A., & Arfanakis, K. (2021). Development and evaluation of high-resolution gray matter labels for the MIITRA atlas. *Alzheimer's & Dementia*, *17*, e052575.

Team Member Responsibilities:

- **Rasheed Abid:** Background research, preprocessing, 3D mask segmentation, results evaluation.
- **Khalid Saifullah:** 3D label segmentation architecture implementation and tuning for QSM, efficiency.