Task 1

Unfortunately, our team did not take time to code the first task.

Task 2

Our method was based on previous researches conducted in our lab [1]. The first step of the pipeline is to use the eICAB software to produce a starting segmentation of the Circle of Willis (CW). This software is based on convolutional neural networks and was trained on 236 annotated images with a resolution of 0.625mm isotropic with 18 labels surrounding the CW. This software also yields a csv file containing per-label diameters information based on a diameter computation method from our lab [2]. Unfortunately, diameters produced by eICAB were slightly offset in comparison to the diameters from the ground truth. Thus, we implemented a simple harmonization algorithm where we standardize diameters from the eICAB output and finally adjusted with the mean and the standard deviation (std) from the ground truth dataset. During inference, all diameters are standardized following the mean and std from our method and adjusted to the mean and std of the CROWN method.

Once the CW is produced, we extract a rough segmentation of the whole vascular tree based on a hysteresis thresholding method. Low and high thresholds for the hysteresis thresholding method are based on a Gaussian Mixture Model of 3 components. The low threshold is found as the mean of the second Gaussian + 3 std. The high threshold is found as the mean of the last Gaussian + 0.5 std. Next, we use a watershed algorithm to flood-fill the entire brain binary mask from the labels in the CW.

The previous steps provide us three images – namely a CW segmentation with 18 labels, a whole-brain (WB) binary segmentation, and a WB segmentation with 18 labels. From that point, we do a skeleton analysis of those 3 images. Each skeleton analysis yields a skeleton image per label (18 for the CW, 18 for the WB multi-label segmentation, and 1 for the WB binary image) containing slab points, junction points, and end points.

The previous step provides us useful information concerning the geometry of the WB vasculature. Thus, we based our entire bifurcation angle computations on many heuristics extracted from the skeleton of the CW, the WB multi-label, and the WB binary images. Therefore, the a2_a1 junction angle is estimated by finding the a2_a1 junction coordinate. From that point, the average vector between the junction coordinate and every voxel in the a1 segment is used as the a1 vector. The same goes for the a2 segment. The angle is computed by taking the inverse cosine of the dot product of those vectors divided by the product of the magnitude of the a2 and a1 vectors. The ica_top junction angle is computed by using the average m1 vector and the average a1 vector provided by the CW centerline of those 2 segments. The pcom_ica angle is computed the same way as the ica_top segment, using the pcom and the ica segments. The m2_m2 bifurcation angle is computed by finding the first real junction point in the m1 segment of eICAB. From that point, we compute the two average m2 vectors using 8 voxels emerging from the bifurcation. The ba_top junction is computed the same way as the ica_top segment, using the lpca1 and rpca1 skeleton segments. Finally, the vbj_top bifurcation is computed by finding the 2 most inferior endpoints in the skeleton of the WB from the skeleton part under the center of mass of the basilar artery. From the end of the basilar artery, we found the next inferior junction point. Finally, we estimate the VBA vectors by taking the 8 voxels connecting each inferior VBA endpoints closest to the junction point.

EXPECTED RUN TIME ON CPU

~20 minutes per subject

COMMAND:

```
docker run -v /absolute/path/to/3D_TOF_MRA.nii.gz:/TOF.nii.gz -v
/absolute/path/to/output/:/output --rm -it felixdumais1/snaillab_task2
-t /TOF.nii.gz -o /output -f
```


References:

[1] F. Dumais *et al.*, "eICAB: A novel deep learning pipeline for Circle of Willis multiclass segmentation and analysis," *NeuroImage*, p. 119425, Jul. 2022, doi: 10.1016/j.neuroimage.2022.119425.

[2] A. Bizeau *et al.*, "Stimulus-evoked changes in cerebral vessel diameter: A study in healthy humans," *J Cereb Blood Flow Metab*, vol. 38, no. 3, pp. 528–539, Mar. 2018, doi: 10.1177/0271678X17701948.