A Deep Learning Technique for Estimating 3D White Matter Fiber Orientation from 2D Images

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Opportunity

Diffusion Tensor Imaging (DTI) is an imaging modality that allows us to view connections within the brain

Challenge

Current research treats microscopy as a gold standard for validating DTI data, but microscopy data is typically limited in that it is only 2 dimensional.

Action

We utilized a convolutional neural network (CNN) to estimate 3D fiber orientations from 2D images

Resolution

Our model explained 95% of the variance in pixel values on a typical brain slice from our test brain. Our work demonstrates the potential to fill in missing 3D information from 2D

Introduction

Diffusion Tensor Imaging (DTI, see Figure 1) data has been helpful in determining characteristics in brain tissue like structural connectivity (See figure 2) at a macroscopic (millimeter) scale, but new high throughput microscopy techniques are giving the opportunity to study these properties at the microscopic scale.

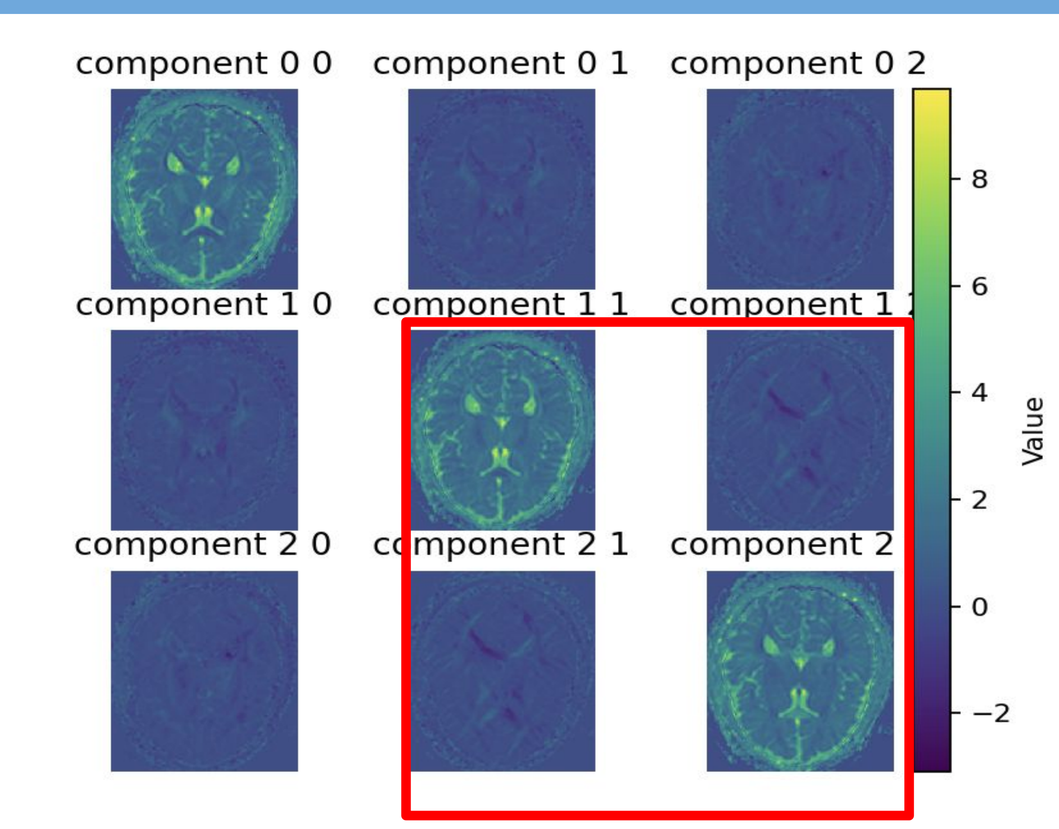

Figure 1. DTI image. Red box indicates 2x2 tensor input into network.

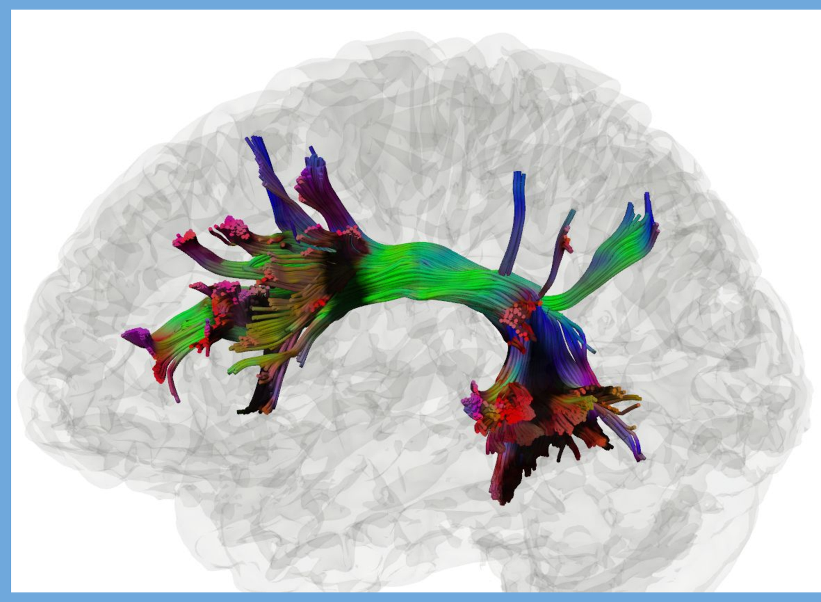

Figure 2. Example of structural connectivity (white matter fibers) inferred from DTI.

Methodology

We use a 3D human DTI dataset with 8 brains, and train the network to predict “out of plane” information. We built a CNN in pyTorch utilizing U-Net architecture with 7 layers (Figure 4), taking a 2x2 tensor valued image as an input, and predicting a 3x3 image output. We used 6 brains to train our network, and explored parameters using 1 brain for validation

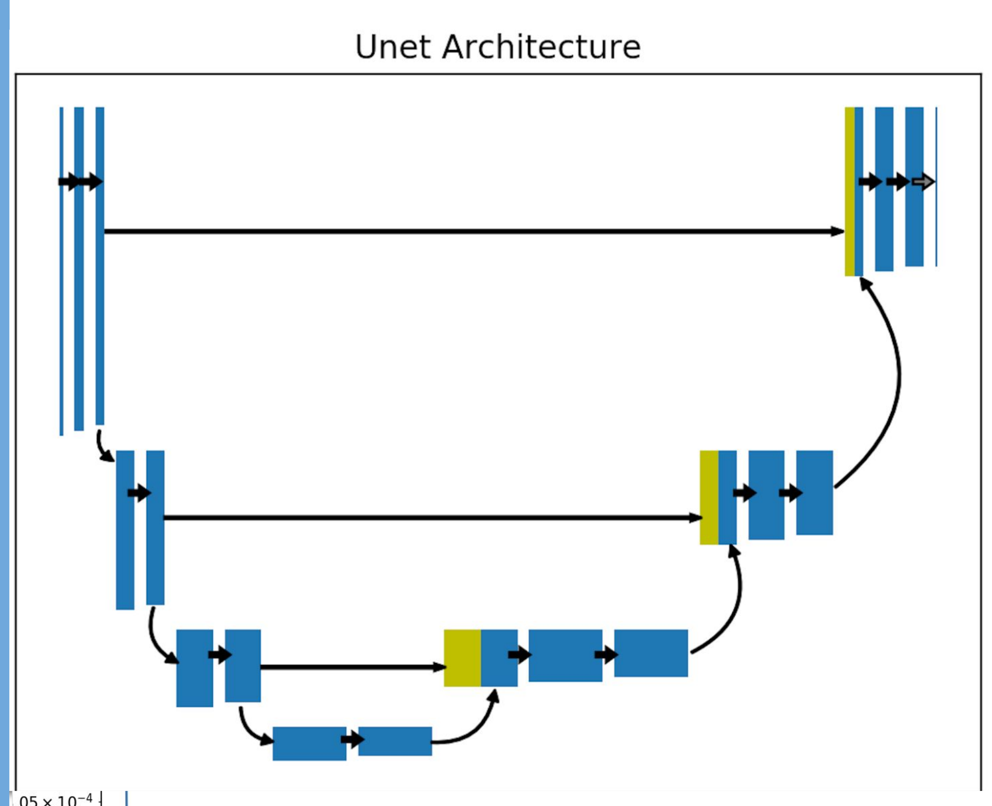

Figure 3. unet figure caption.

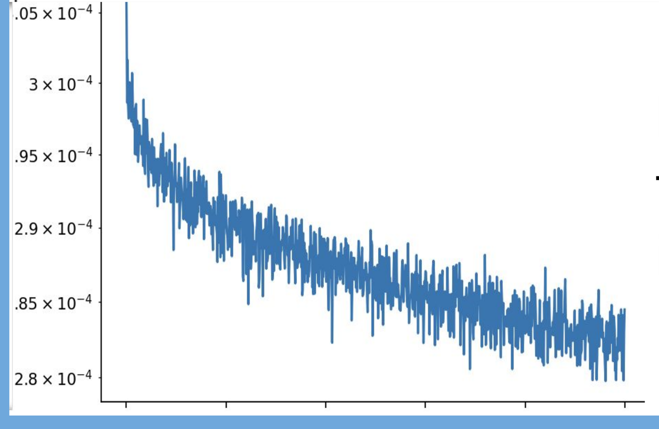

Figure 4. Loss function being optimized as a function of gradient descent iterations

Results

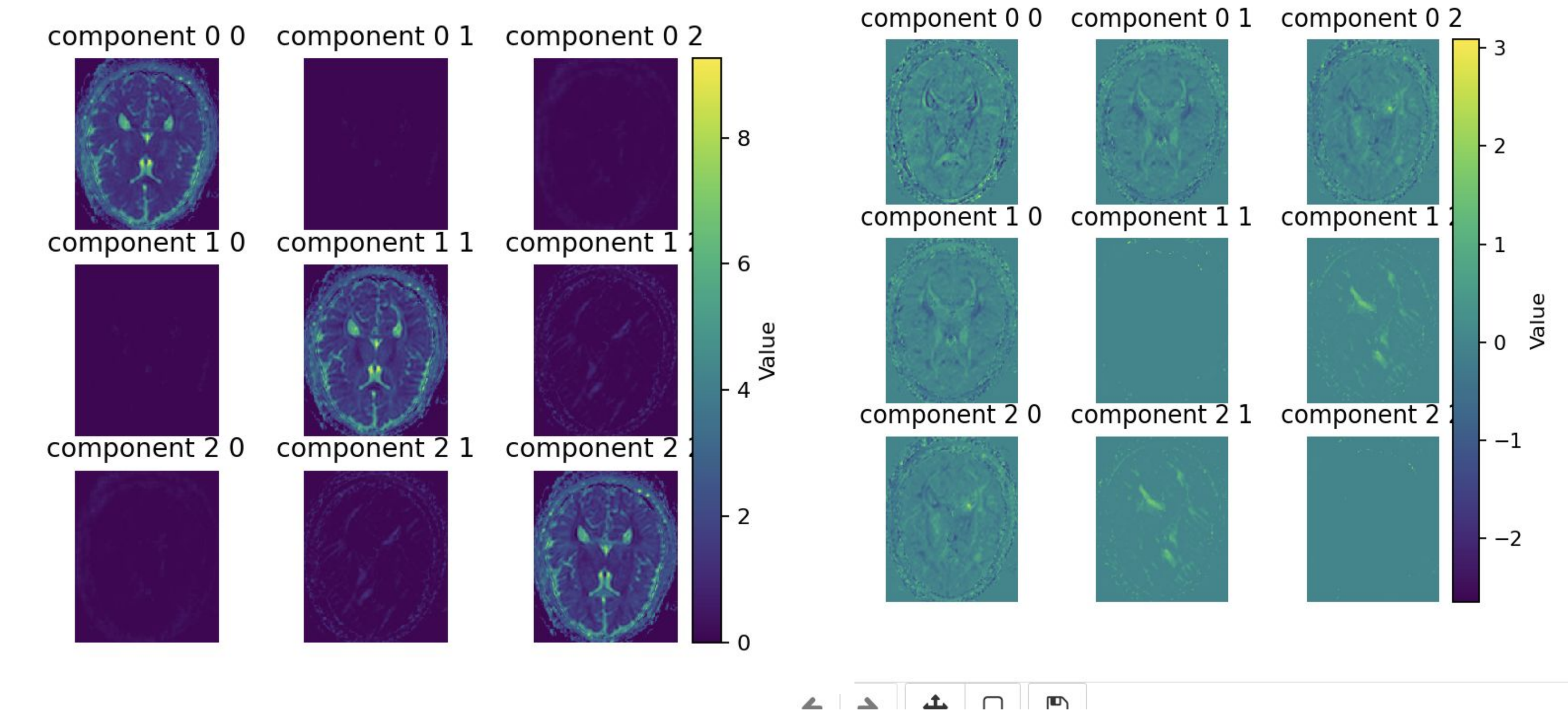

Figure 5: Left: shows the output of our network, a 3x3 tensor at each pixel. Right: shows the difference between this output and the true image we are trying to predict.

Conclusions

Our network seems to explain a high fraction of variance in our images, but does not seem to do a good job of predicting the off diagonal components. More work remains to be done to make predictions from challenging microscopy datasets like the myelin image shown in Figure 6.

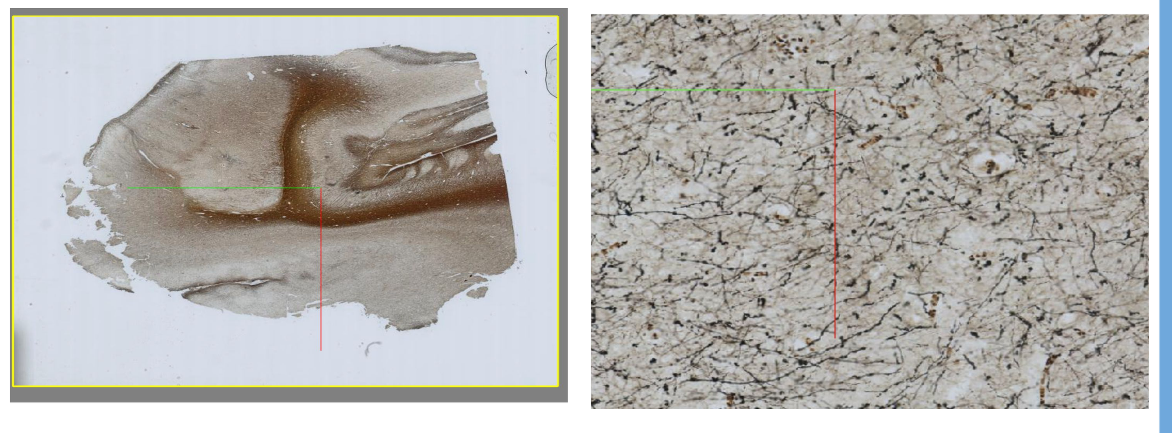

Figure 6: Left: a 2D section of human hippocampus and amygdala stained for myelin. Right: zoomed in.

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References

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