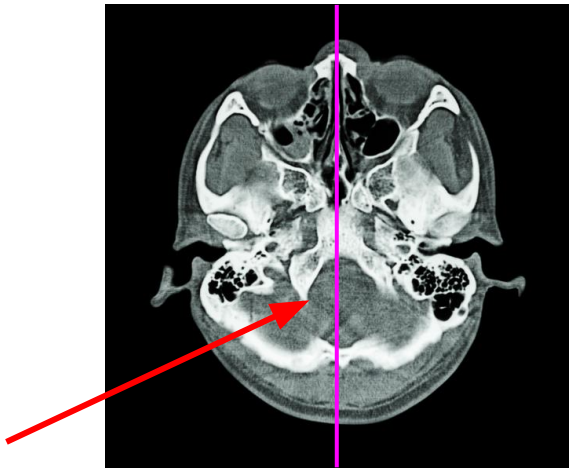
Data Synthesis and Segmentation for Midline Shift

Daniel (Zaitian) Wang

Introduction: Midline Shift

Brain centerline

- The central axis of the skull that split it in two symmetrical halves
- In practice physicians use the line connecting the top and the bottom of skull



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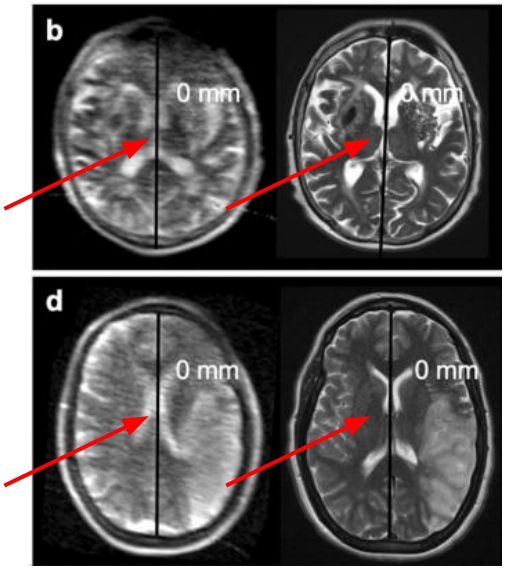
Brain midline

- The line that separates left and right brain hemispheres
- Usually coincides with the centerline of the brain



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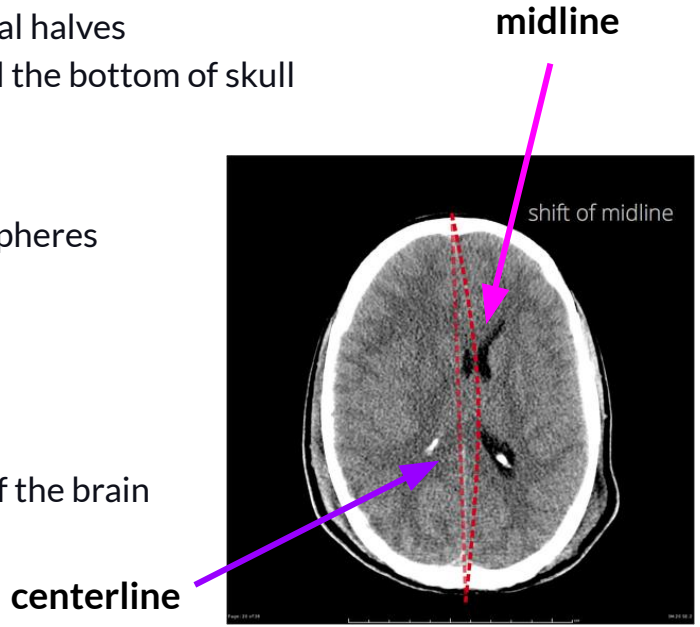
Midline shift

- A shift in brain tissue across the centerline of the brain
- Results in a misalignment of the midline and centerline of the brain



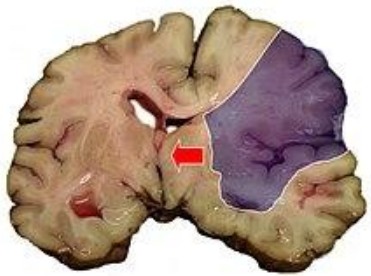
Introduction: Why Midline Shift

Causation and Effects

- Traumatic brain injury (TBI), stroke or haematoma
- High intracranial pressure (ICP)
- Distortion of brain stem and restricted blood flow

Significance

- Relates to serious and potentially deadly illnesses
- Requires immediate treatment



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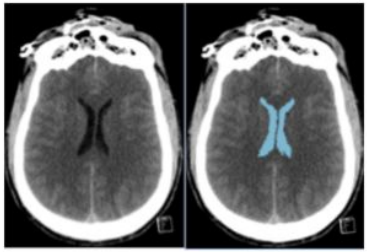
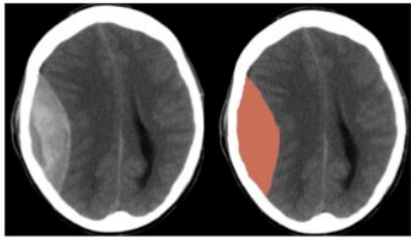


(b)



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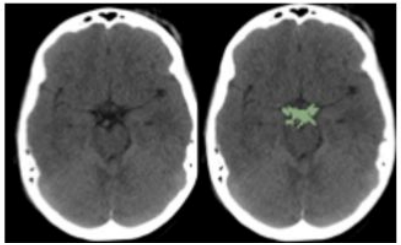

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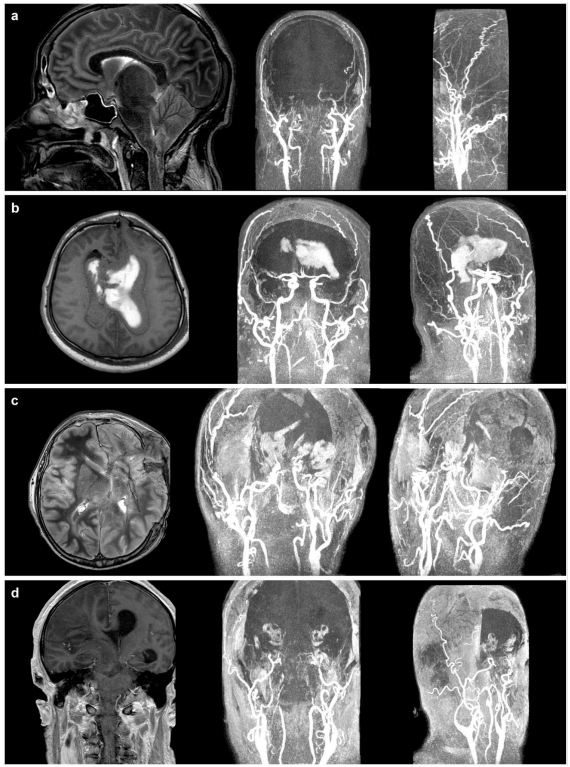
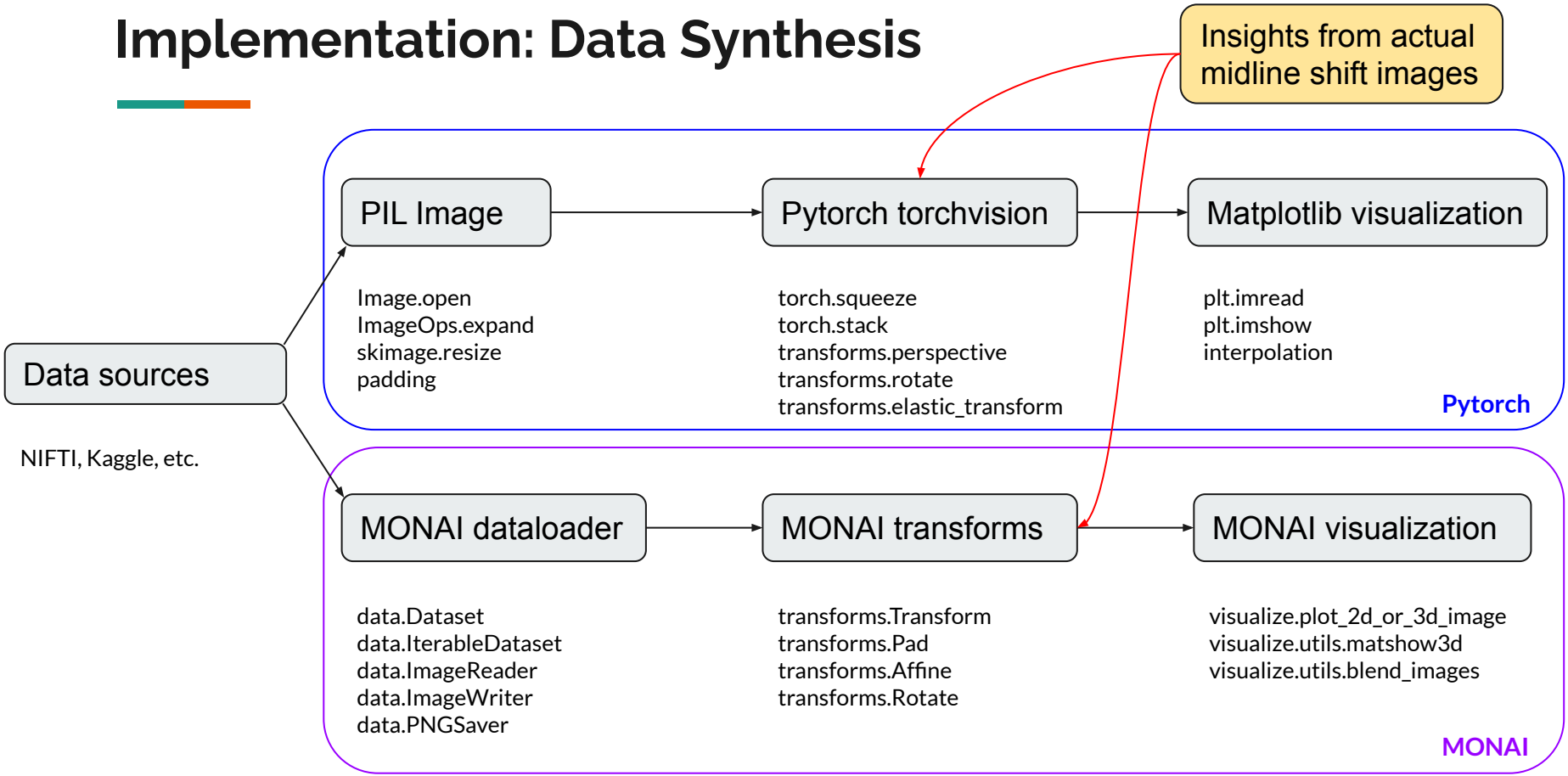
Difficulty

- Relatively small and hard to detect (starts from 3mm)
- Lack of dataset and imaging varies drastically
- Extremely time sensitive



Implementation: Data Synthesis



Implementation: Modeling

Original data

NIFTI, Kaggle, etc.

Synthetic data

From Pytorch/MONI

Variables

Segmentation

left brain seg
torch.sensor ops

Segmentation

left brain seg
torch.sensor ops

True Values

Data resample

set synthetic data ratio
train, test, validation split

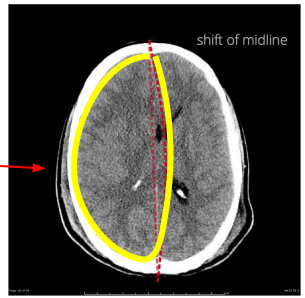
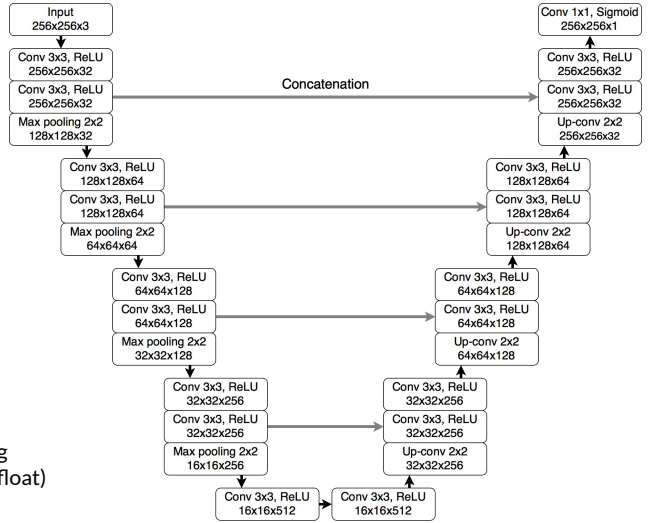


image-to-image Unet



plt.imread
plt.imshow
interpolation

dice score (image)
F-1 score (boolean)
MSE (float)
torch.sensor ops

get midline from left brain seg
calculate result (image/bool/float)
torch.sensor ops

Visualization

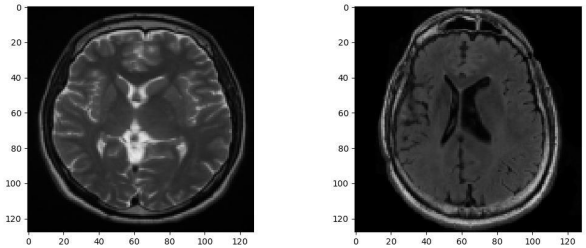
Results analysis

Midline calculation

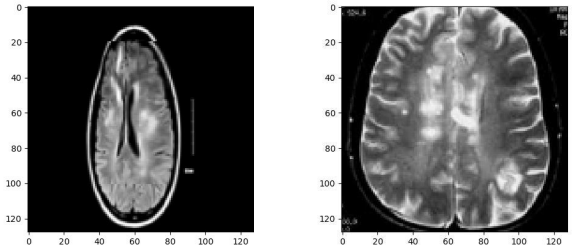
Implementation: Challenges

Data Synthesis

- Methods of transformation (perspective, rotation, elastic etc.)
- Ideal parameters
- Shift magnitude



Ideal transformations, shift=7.5mm



Less effective transformations

Implementation: Challenges

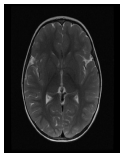
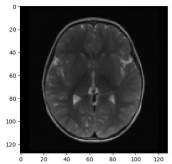
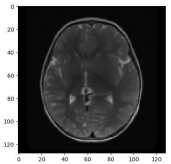
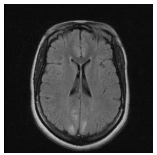
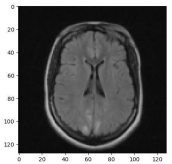
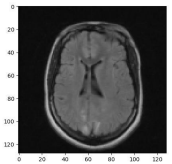
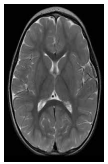
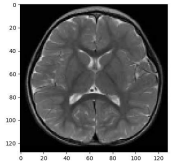
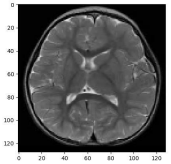
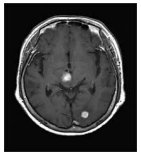
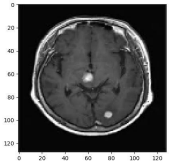
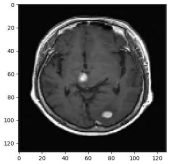
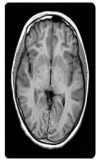
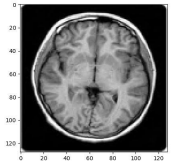
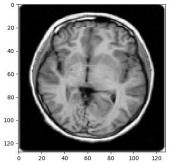
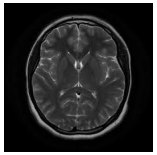
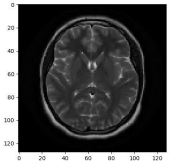
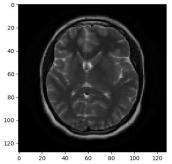
Data Synthesis

- Methods of transformation (perspective, rotation, elastic etc.)
- Ideal parameters
- Shift magnitude

Modeling

- Determine the ratio of original data (no midline shift) and synthesis data (with midline shift)
- Result analysis methods and metrics (image, boolean, float)
- Customized Unet coding

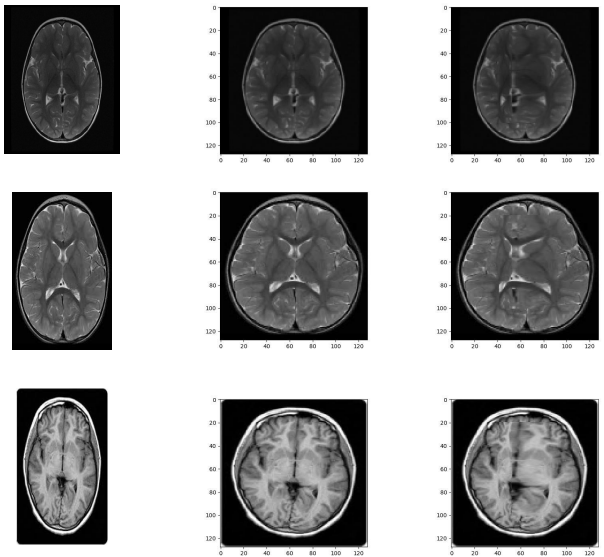
Result: Data Synthesis

Original image	Resized image	Synthetic image	Original image	Resized image	Synthetic image
					
					
					

Sample synthetic data, shift=7.5mm

Result: Data Synthesis

Original image | Resized image | Synthetic image



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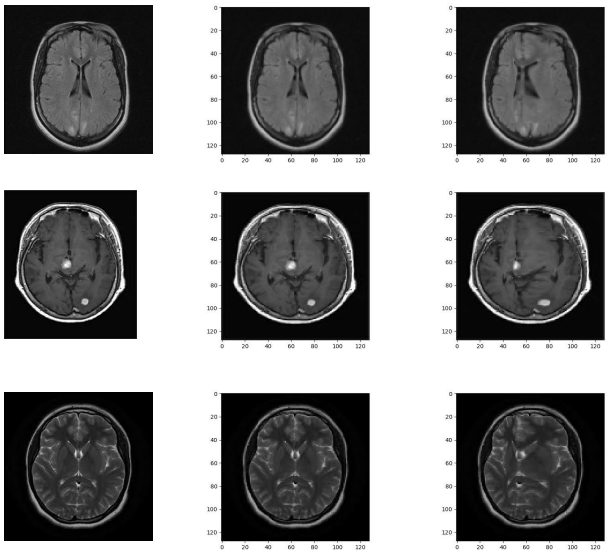
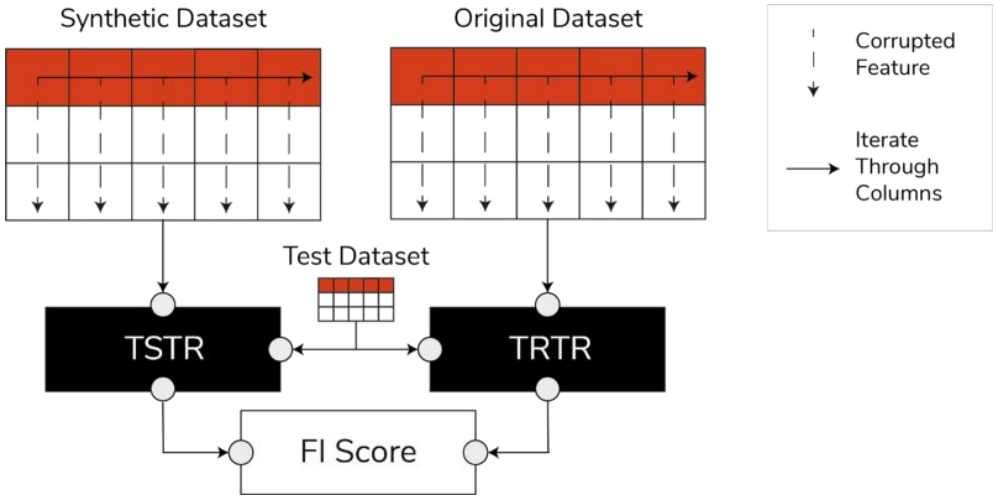


Sample synthetic data, shift=15mm

Result: Data Synthesis

Fidelity Metric

- Train Synthetic Test Real (TSTR) score and Train Real Test Real (TRTR) score
- But are there any publicly available midline shift detection model?



Result: Data Synthesis

Fidelity Metric

- Train Synthetic Test Real (TSTR) score and Train Real Test Real (TRTR) score
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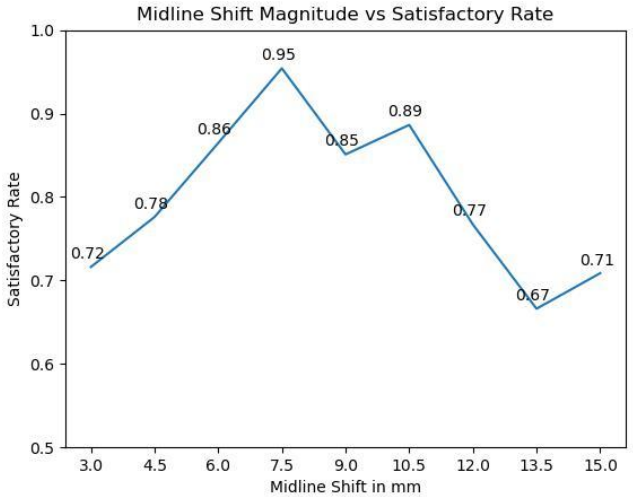
Satisfactory Rate

- Criteria:

  a) Visible shift

  b) No skull changes

  c) No visible glitch or disconnected tissues

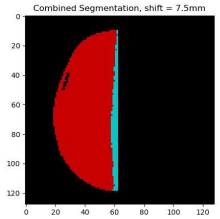


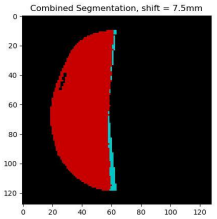
Result: Modeling

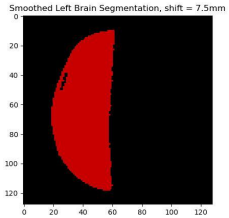
Output: left brain segmentation

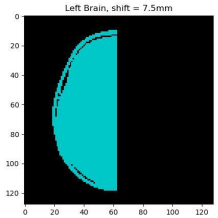
Dice Score (no additional output processing)

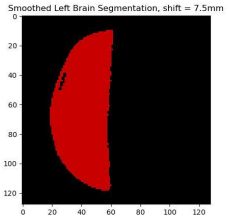
- 0.948 DCS averaged over 85 images
- Likely inflated by the large segmentation size and small midline shift magnitude

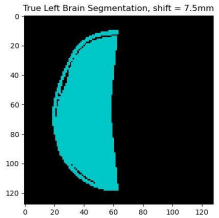












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Dice Score (no additional output processing)

- 0.948 DCS averaged over 85 images
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Accuracy and F-1 Score (output image -> boolean) ***TBD***

- Calculate midline using output image
- Set certain criteria like midline coeffs and/or DCS to determine whether midline shift occurs

RMSE (output image -> float) ***TBD***

- Calculate the farest/averaged shift of the midline and central line
- Compare the results to actual shift magnitude of the data

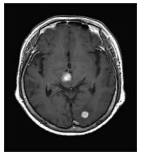
Recap: Project Accomplishments

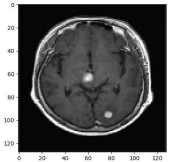
Data Synthesis

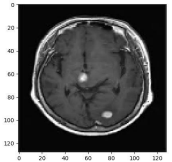
- Created (maybe the first) an algorithm to synthesize midline shift brain scans
- Created (probably also the first) midline shift dataset w/ comparison

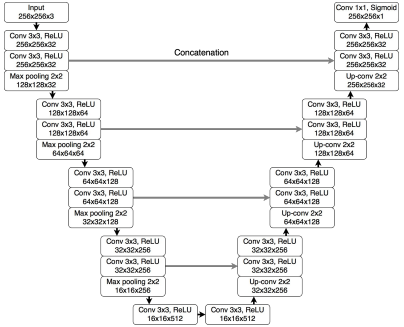
Modeling

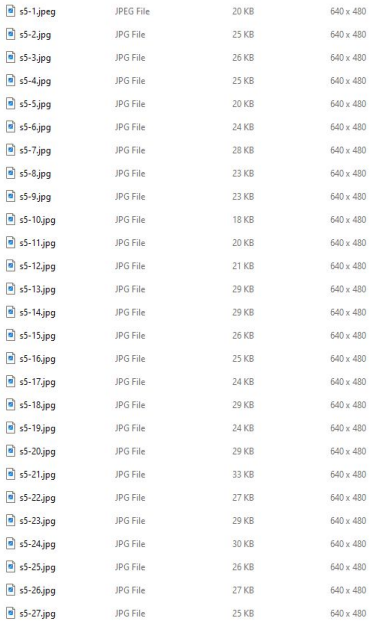
- Applied Unet to midline shift detection
- Proof-of-concept for real-time midline shift detection and alert on brain scans











Future Works

Data Synthesis

- More scientific way of measuring the fidelity instead of Satisfactory Rate
- Research additional industrial insights to form a more sophisticated synthetic algorithm
- Create a universal tool for biomedical image synthesis

Modeling

- Change the structure of Unet to directly output boolean and float instead of post-processing
- Explore methods other than left brain segmentation to describe the midline
- Integrate model into industrial brain scanner to provide immediate image analysis and alerts

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