Brain Tumor Grade Classification in MR images using Deep Learning

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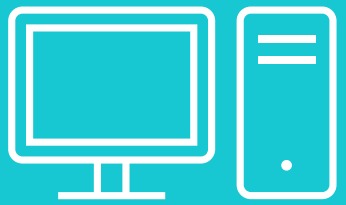
Overview

- Motivation
- Background
- Aim
- Data Overview
- Research Questions
- Progress so far
- Next steps



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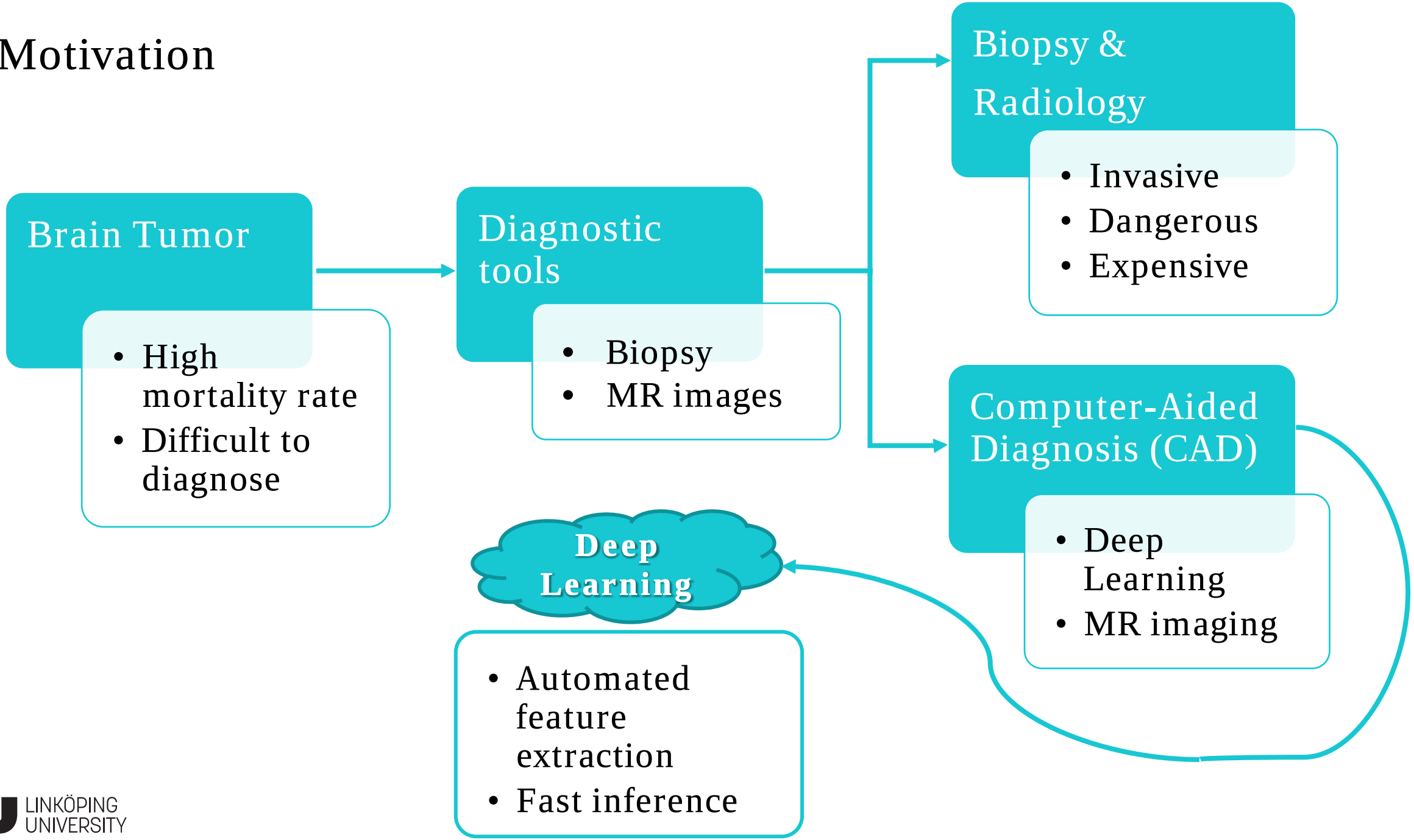
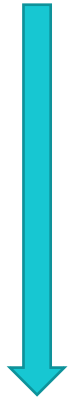
Motivation


Brain Tumor
• High mortality rate
• Difficult to diagnose
Diagnostic tools
• Biopsy
• MR images
Biopsy & Radiology
• Invasive
• Dangerous
• Expensive
Computer-Aided Diagnosis (CAD)
• Deep Learning
• MR imaging
Deep Learning
• Automated feature extraction
• Fast inference

Background

Gliomas: most prevalent type of brain tumor, classified into 4 grades (WHO 2021)

- G1 ➡ Benign tumor
- G2, G3 } Low-Grade Glioma
- G4 } High-Grade Glioma



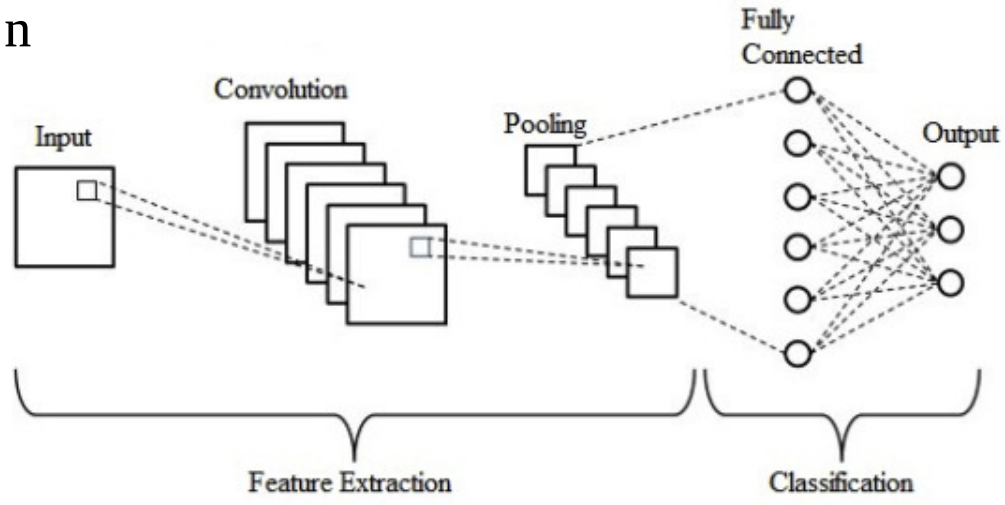
Malignancy

Magnetic Resonance Imaging: uses non-ionizing radiation during scan, offers high-spatial resolution images of different tissue contrast with varying repetition times by means of powerful magnets

Background

DL algorithms:

- inspired by structure + function of human brain
- provide state-of-the-art results in image classification
- can perform automatic feature extraction



Convolutional Neural Networks (CNNs):

- subclass of DL, used with great success in analysis of images
- require minimal preprocessing + little prior knowledge
- can achieve great levels of abstraction by stacking many layers

Image source: https://www.sciencedirect.com/science/article/pii/S2352914820305621

Aim

To classify the grade of brain tumor in MR images of different modalities from adult patients using VGG-19 and ResNet50 & compare their performance using various performance metrics

Source: https://www.philips.se/healthcare/solutions/magnetic-resonance

Data Overview

Source: The Cancer Genome Atlas (TCGA) ➡ Grade 2, 3

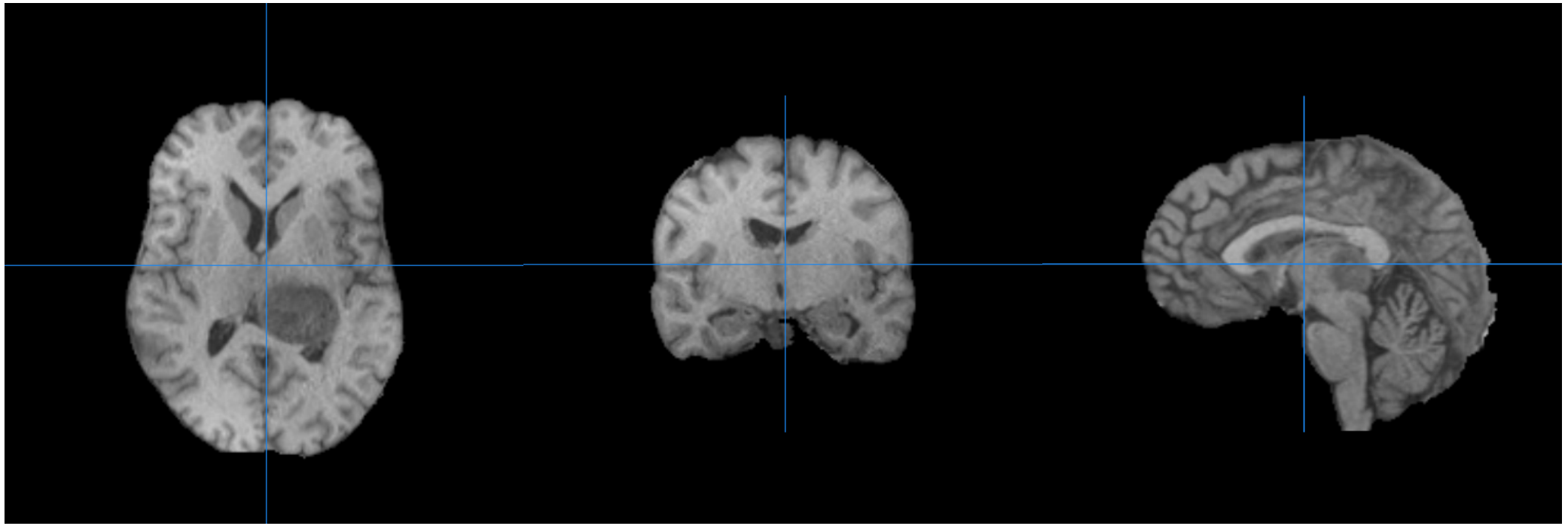
Brain Tumor Segmentation (BraTS 2020) ➡ Grade 4

- 142 subjects (47 Grade 4 cases , 45 Grade 2 cases, 50 Grade 3 cases)
- Each subject has images of 4 MRI modalities (T1-weighted, T1-weighted post-contrast, T2-weighted, Fluid Attenuated Inversion Recovery (FLAIR))
- All images are: anonymized, registered to T1-weighted image, skull-stripped, bias-field corrected
- 3D volumes of 240 x 240 x 155 voxels with $1 mm^3$ isotropic resolution
- 155 slices for each subject

TCGA dataset: https://portal.gdc.cancer.gov

BraTS 2020 dataset: https://arxiv.org/abs/1811.02629

Data Example – Grade 4 T1-weighted

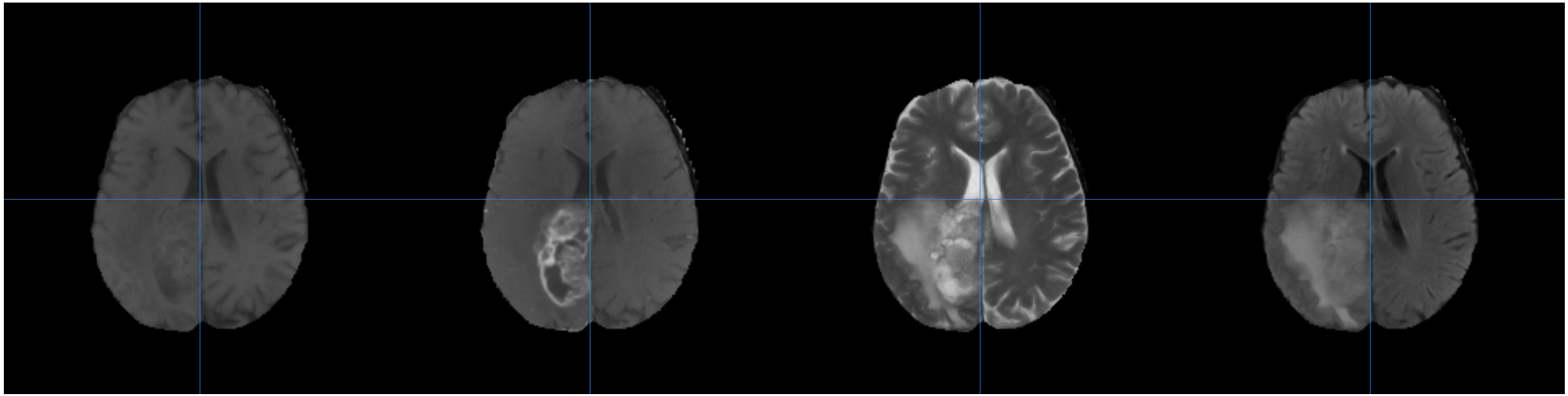


Axial view
(*x*-*y* plane)

Coronal view
(*x*-*z* plane)

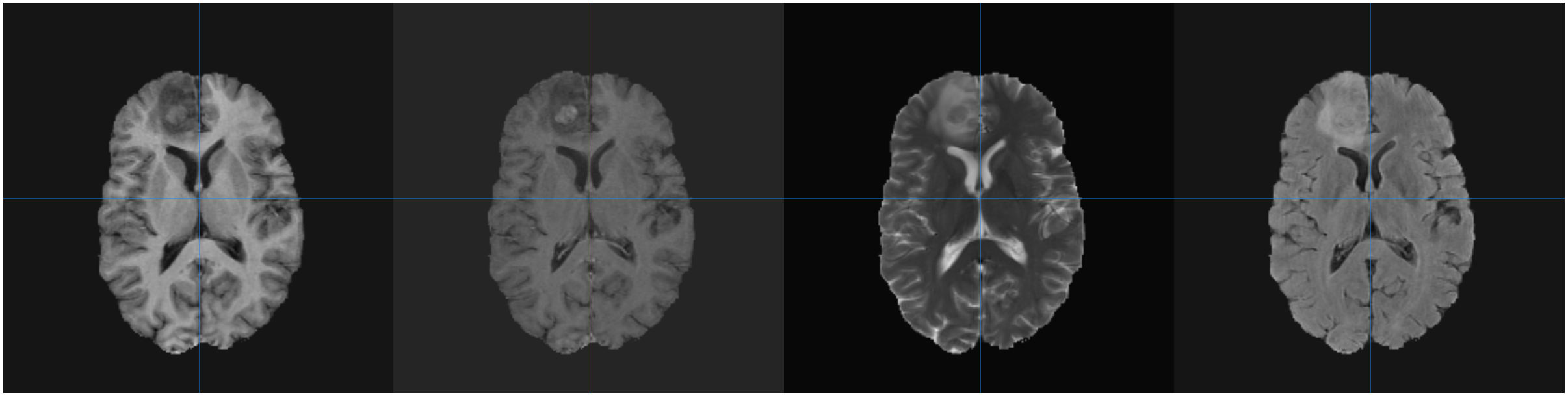
Sagittal view
(*y*-*z* plane)

Data Example – Grade 4 (axial view)



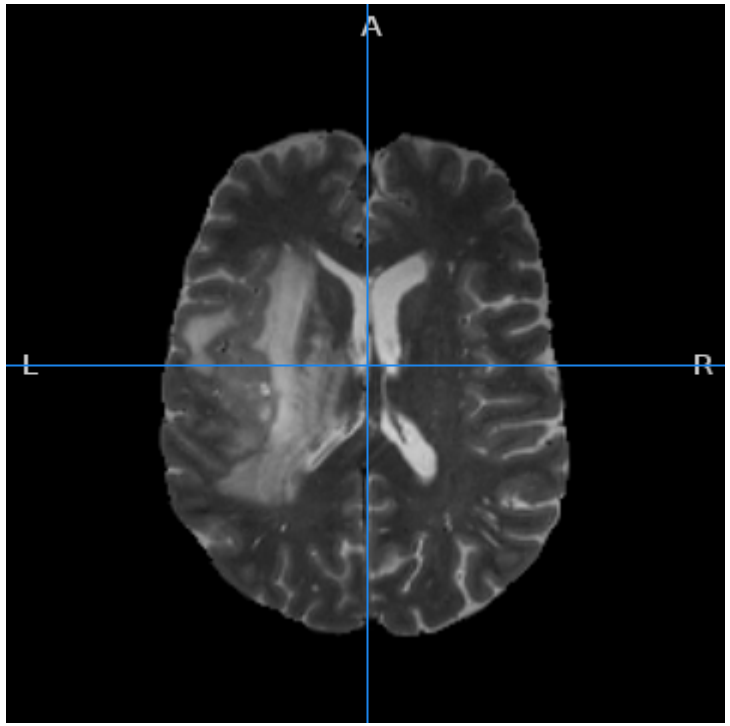
T1-weighted | T1-post_contrast | T2-weighted | FLAIR

Data Example – Grade 2 (axial view)

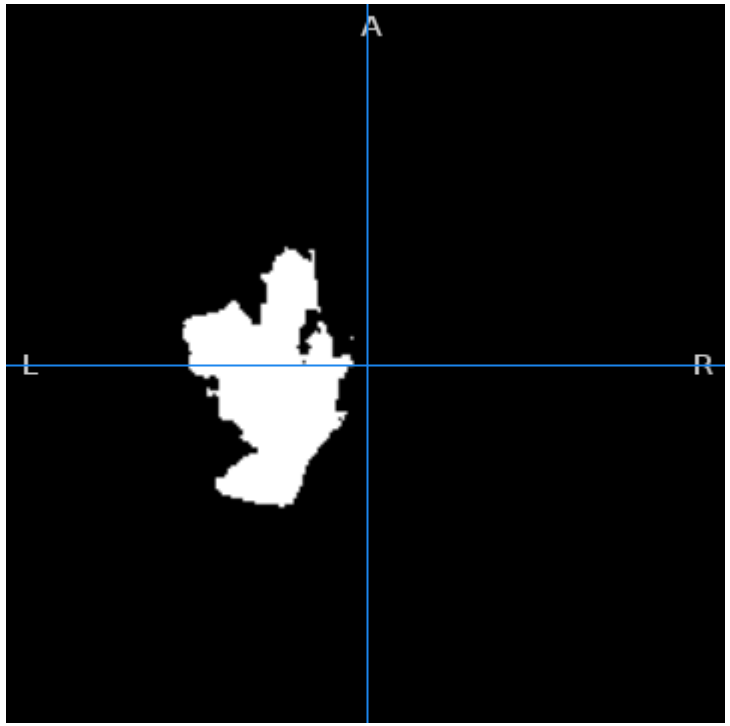


T1-weighted | T1-post_contrast | T2-weighted | FLAIR

Data Example – Grade 4 (axial view)



T2-weighted



Annotated ROI

Research Questions

1. Which of the proposed CNN models performs best for brain tumor grade classification on the available dataset?

2. Which combination of MRI modalities yields the best results for classification?

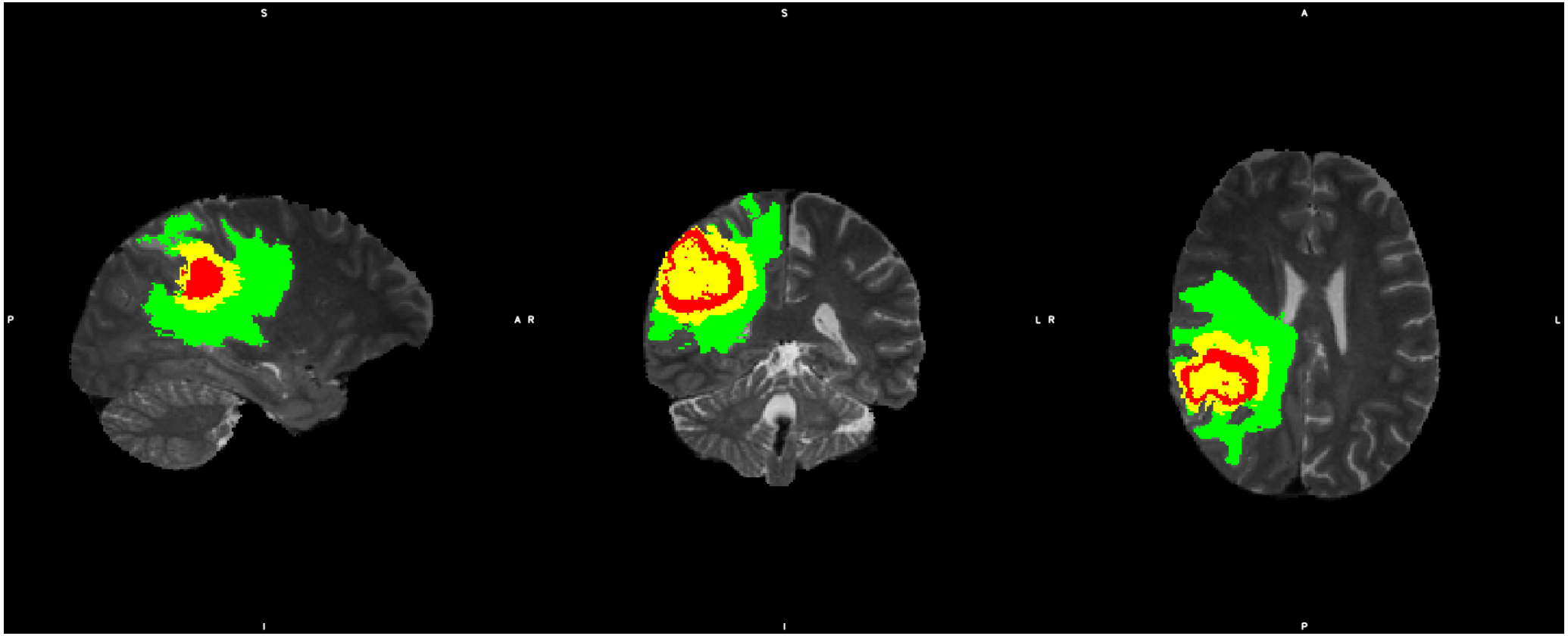
Challenges:

- Little data available ➡ need for data augmentation
- Images come from 19 different institutions
- Classification of grades in multiple classes as relatively new concept ➡ not many experiments conducted, little supporting literature

Progress so far

- Familiarizing with the data set:
    - From 3D NIfTI files to 2D PNG
    - Identifying data quality problems: no tumor annotations for cases of Grades 2, 3, images with pixel intensity values not in [0, 1] range
- Pre-processing
    - Tumor extraction using nnUnet automated framework on cases of Grades 2, 3
    - Manual tumor boundary delineation on some cases of Grades 2, 3
    - Extraction of 2D tumor slices from 3D images
    - Intensity normalization on all images
    - Resizing all 2D slices to 224 x 224 pixels

Progress so far – Extraction of tumor slices from 3D image for a Grade 4 case

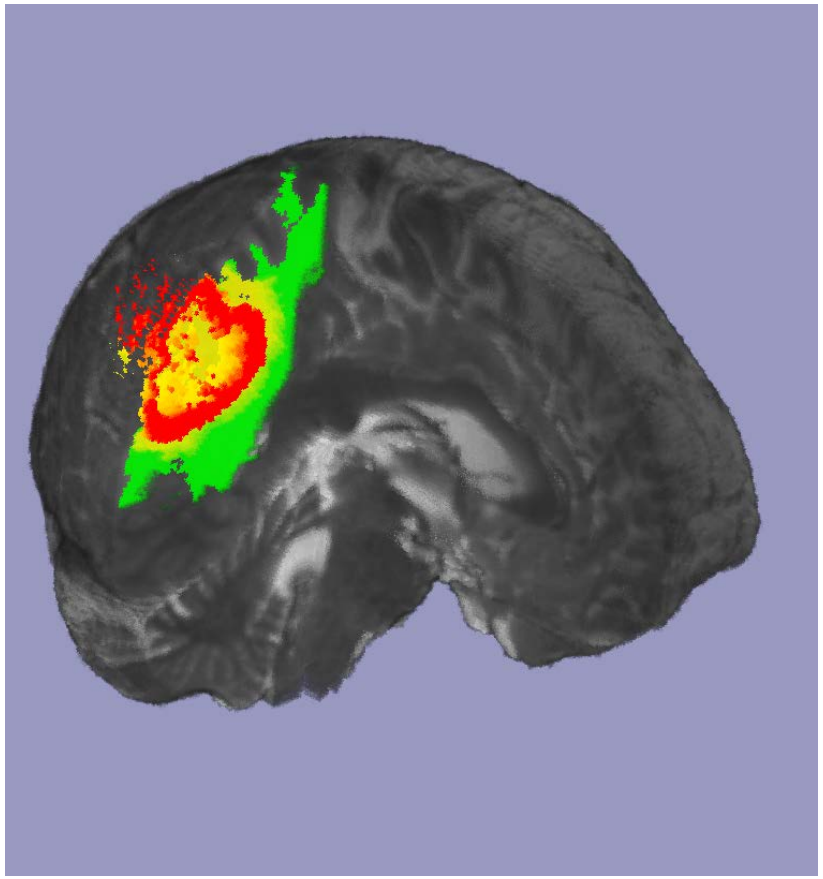


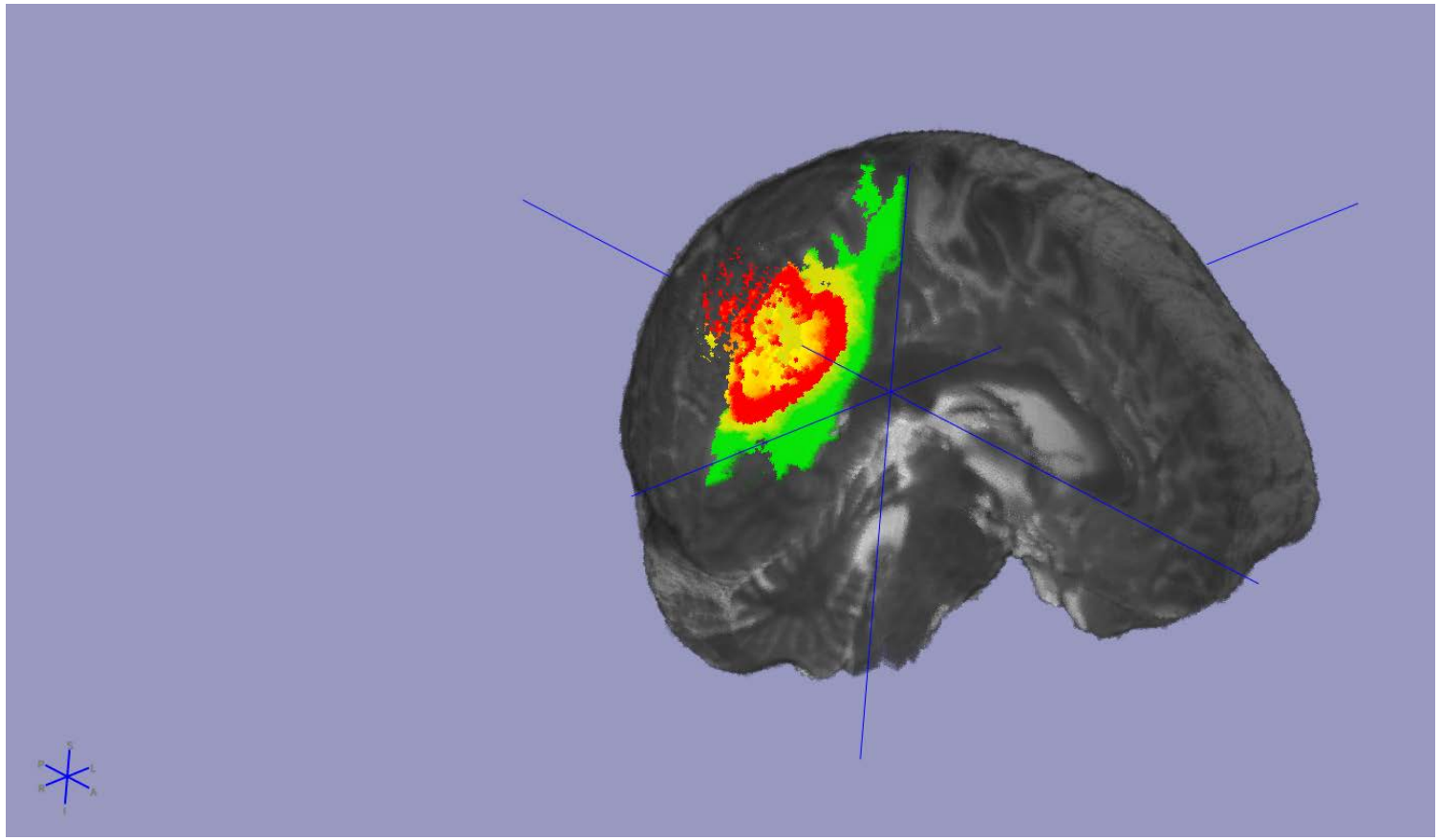
Sagittal view

Coronal view

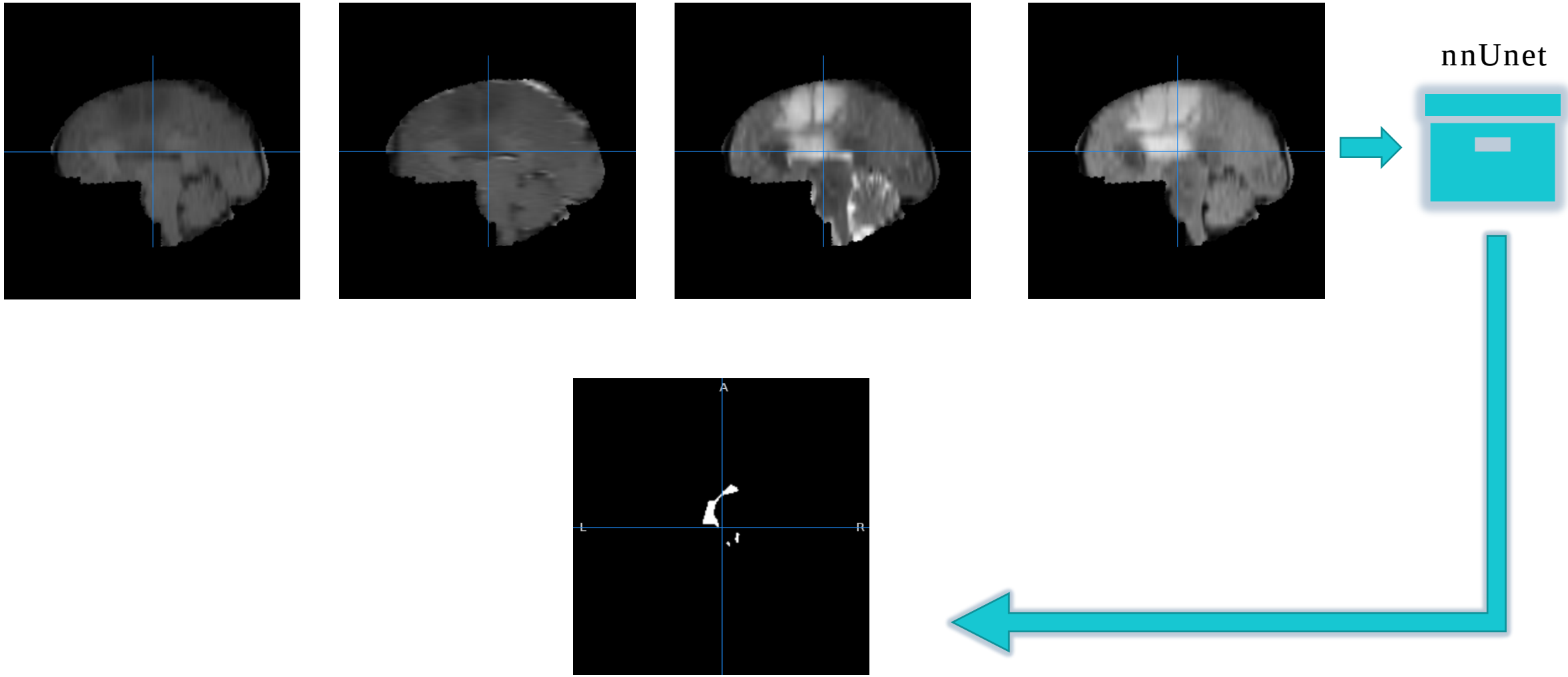
Axial View

Progress so far – Extraction of tumor slices from 3D image for a Grade 4 case



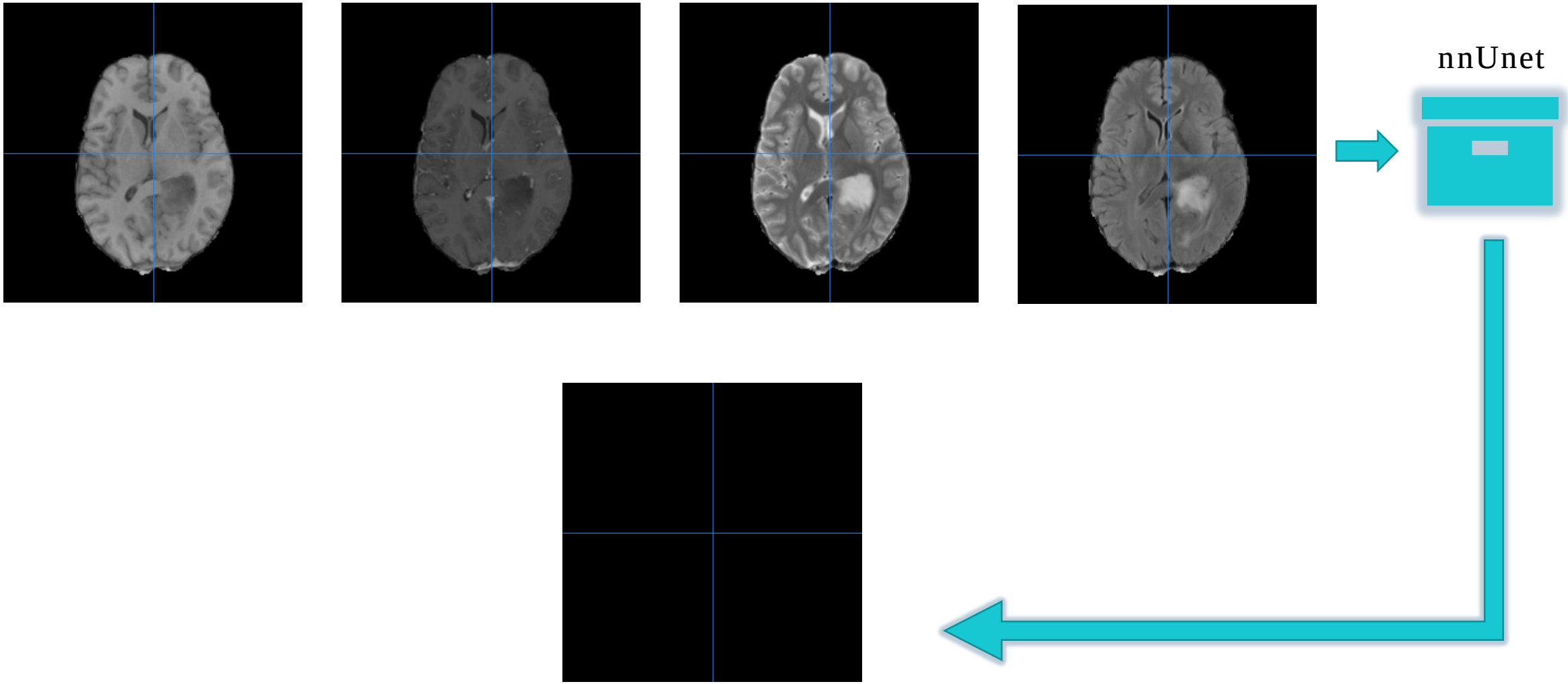


Progress so far – Tumor extraction with nnUnet on Grade 3 case – segmentation result (1)



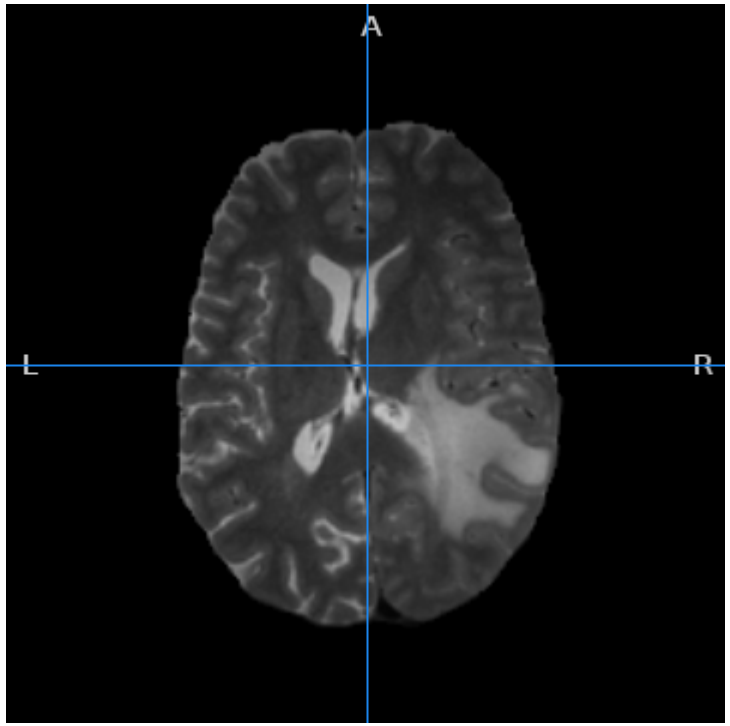
Source: https://arxiv.org/abs/2011.00848

Progress so far – Tumor extraction with nnUnet on Grade 3 case – segmentation result (2)

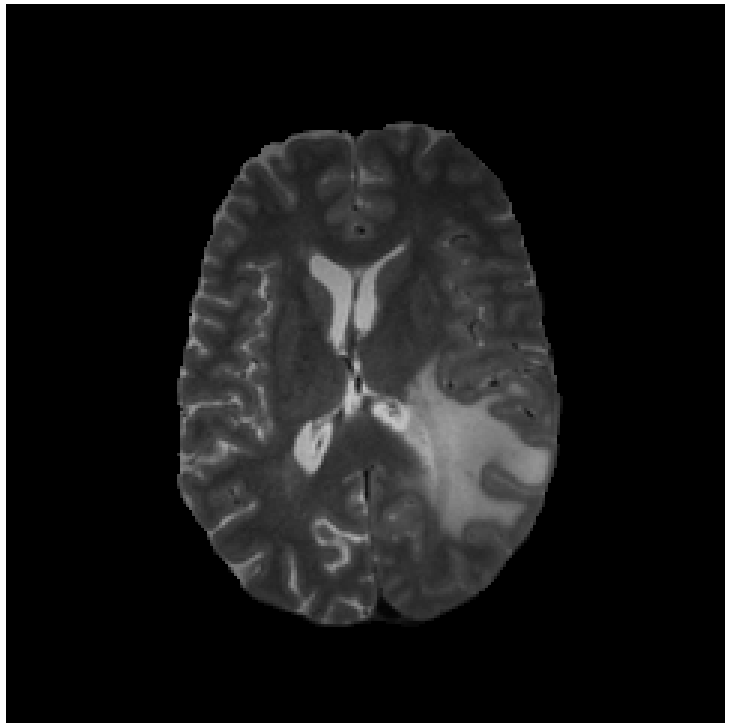


Source: https://arxiv.org/abs/2011.00848

Progress so far – Intensity normalization on Grade 4 case, T2-w, axial view



Original image



Normalized 2D slice

Progress so far – Pre-processed data set

Grade #	Frontal/coronal slices	Sagittal slices	Transversal/Axial slices
Grade 2	8,131	5,415	6,591
Grade 3	9,959	7,910	7,978
Grade 4	15,613	11,470	12,485
Total	**33,703**	**24,795**	**27,054**

- The classifier will be fed on the slices that contain only tumor
- Slices from all 3 categories will be used
- All slices are saved mentioning the percentage of the tumor in the image ➡ CNNs will be fed with images that contain more than 40% of the tumor to increase accuracy

Next steps

- Train VGG-19, ResNet50 models on pre-processed data set
    - Use Transfer Learning ➡ pre-train VGG-19, ResNet50 on ImageNet dataset
    - Perform data augmentation with vertical+horizontal flipping, rotation by 45◦ - 90◦

- Evaluate model performance with default evaluation metrics, ROC curves and hypothesis testing
    - Confusion matrix, accuracy, precision, recall, specificity, F1-score
    - ROC curves
    - Wilcoxon Signed-Rank test
    - If time permits, include Occlusion Maps

- Finish the report

Thank you!

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