Automatic detection of focal cortical dysplasia for sparse data representation

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Introduction

The general problem is detection of focal cortical dysplasia - most common cause of medically refractory epilepsy in the pediatric population and the second/third most common etiology of medically intractable seizures in adults.

FCD - drug-resistant epileptogenic lesion

Epilepsy affects 50 million people worldwide

50 new cases per year per 100,000 population

50% → **90%**

Success of surgical treatment **without detection** of an epileptogenic focus.

Success of surgical treatment **with detection** of an epileptogenic focus.

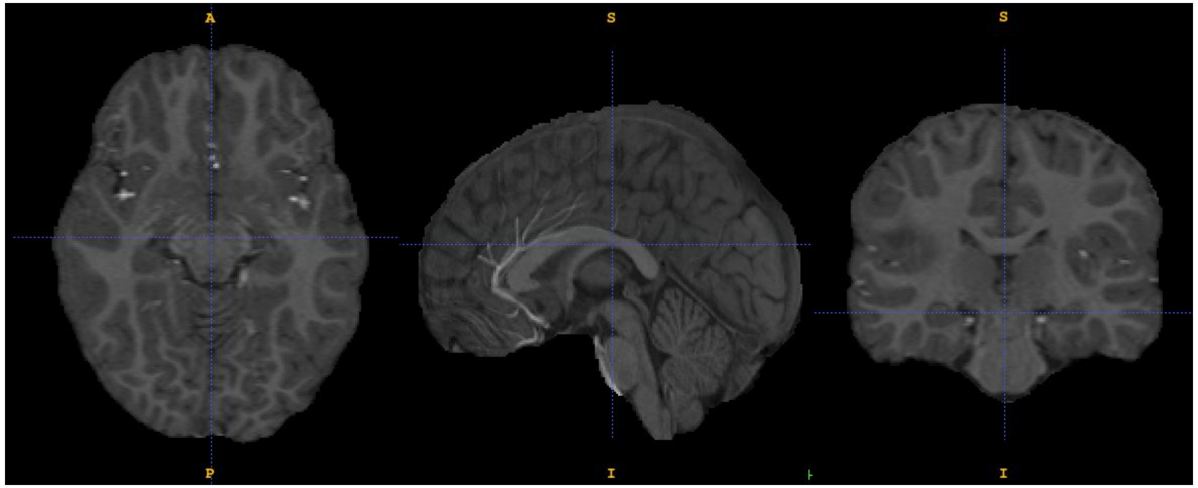
Introduction

Professional radiologist detect FCD via intent visual MRI inspection, peering multiple sequences along each projection.

1,500 brain 2D scans

2 hours per patient

subjectiveness



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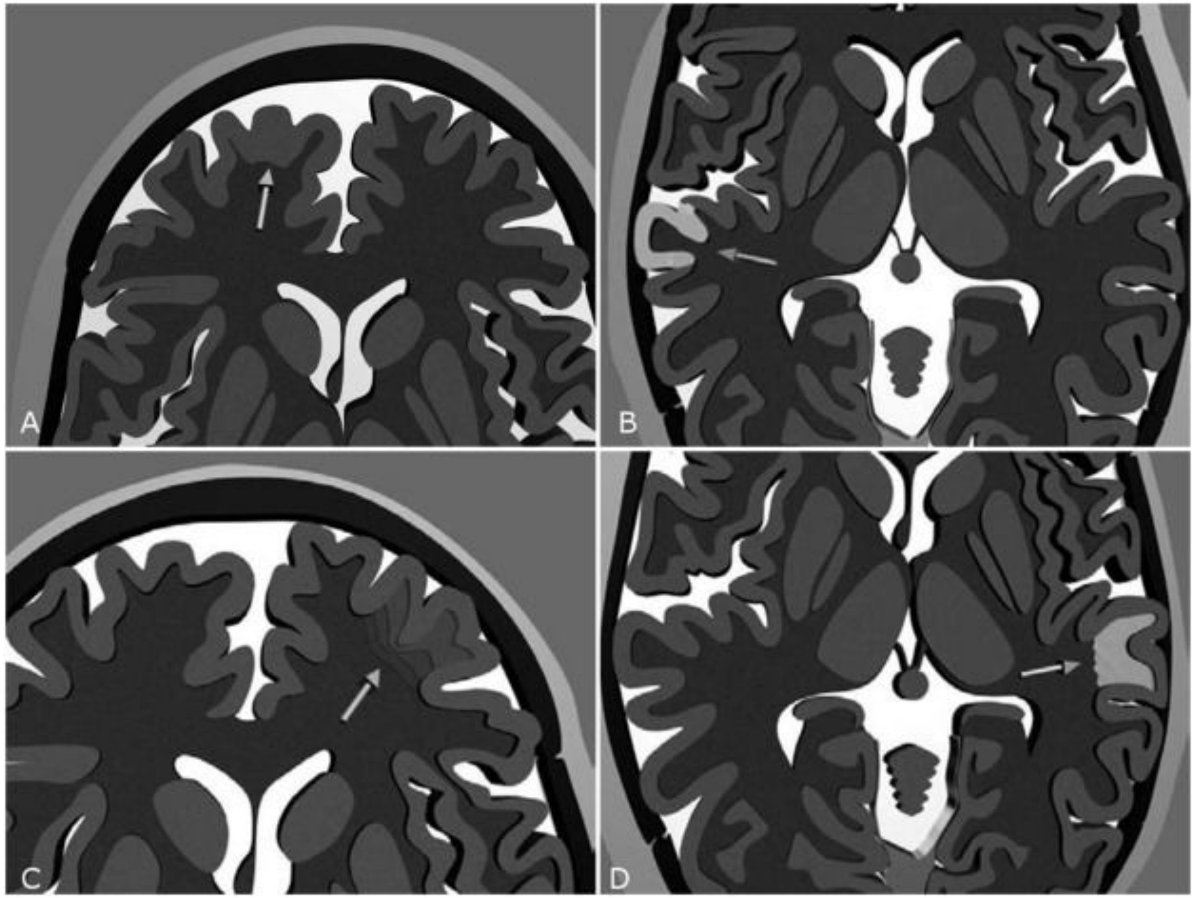
General problem



Features of FCD:

A - cortical thickening
B - alteration of gray matter signal
C - loss of differentiation between gray and white matter
D - alteration of white matter signal

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General problem

>20% FCD cases remains uncaught by radiologist

only 4% of missed opportunities to diagnose head and neck cancer on an earlier imaging exam.*

* Lu F, Lysack JT. Lessons Learned From Commonly Missed Head and Neck Cancers on Cross-Sectional Imaging. Canadian Association of Radiologists Journal. 2022;

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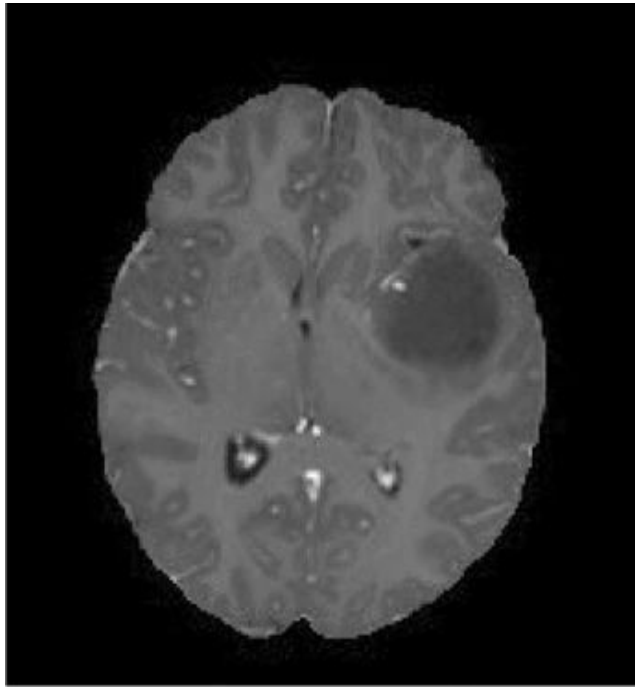
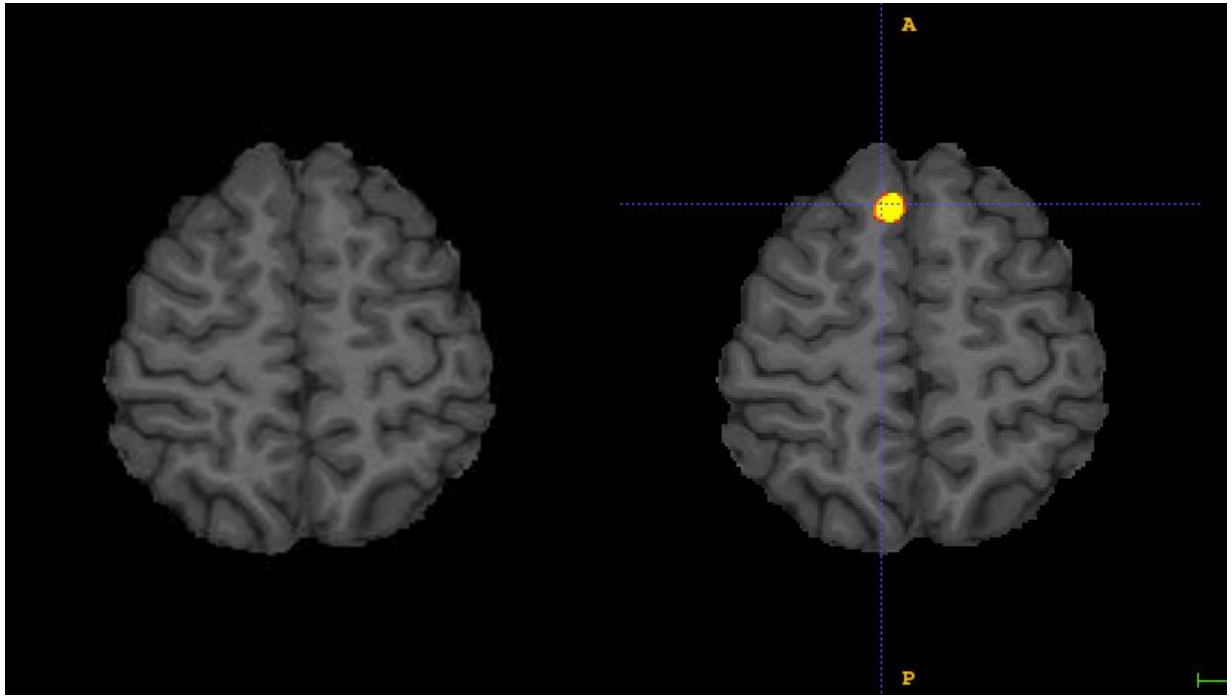
General problem

Brain with tumor



Brains with FCD



From report from the International League Against Epilepsy:
Computer-aided methods for 3D MR image analysis should be developed

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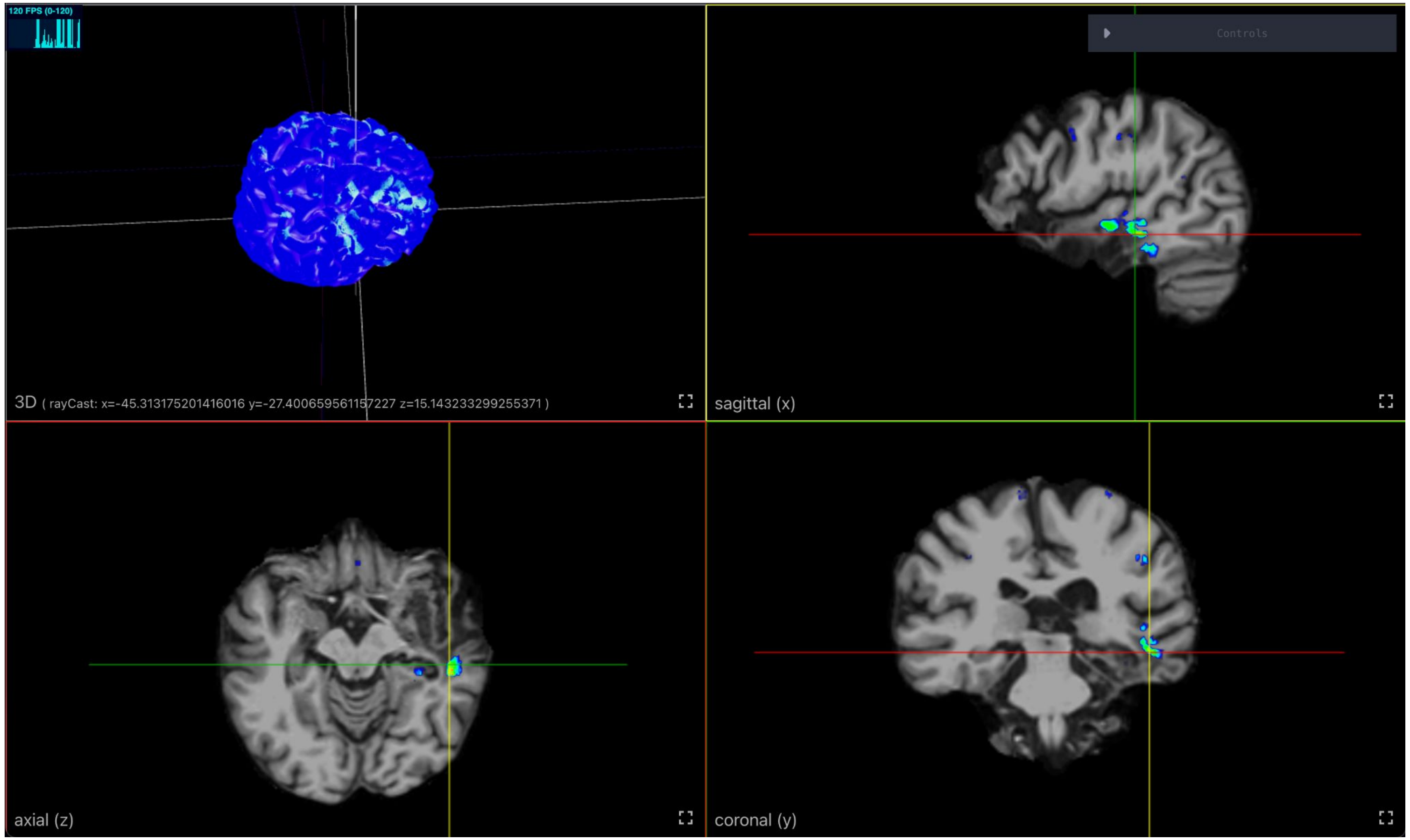
Aim of the EpiDetect project

Build a system for doctors to detect FCD on 3D MR data.



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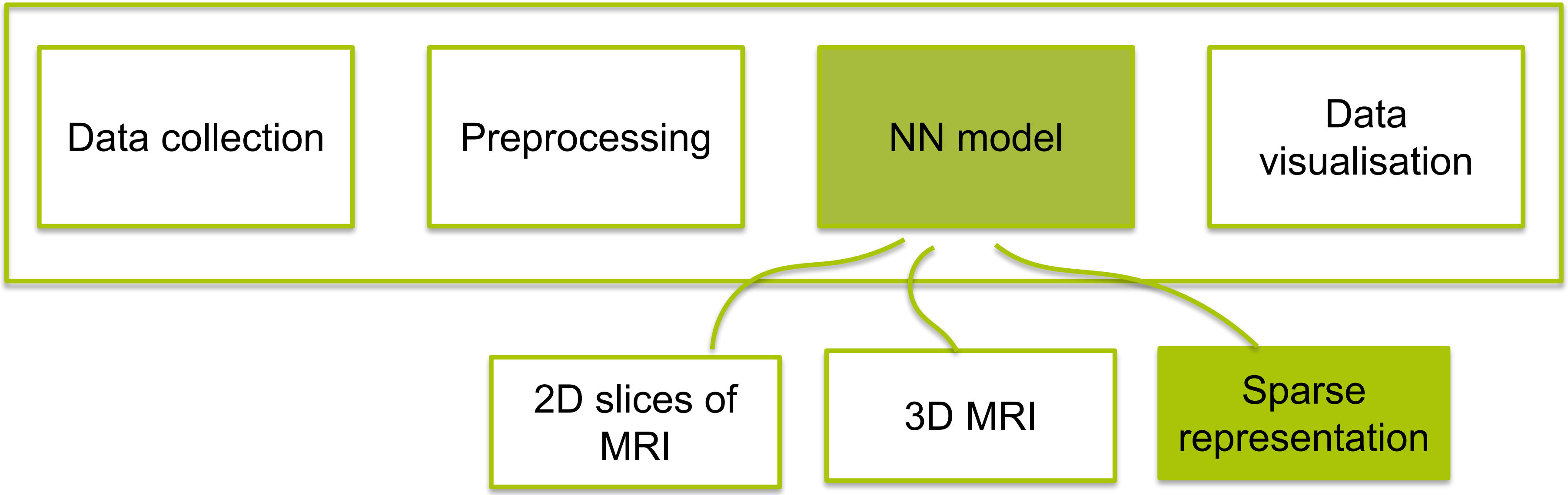
Aim of thesis

Thesis goal is to built an NN model for this system for sparse data



Dataset

204 subjects diagnosed with pharmacoresistant epilepsy.

3 MR images and label per subject

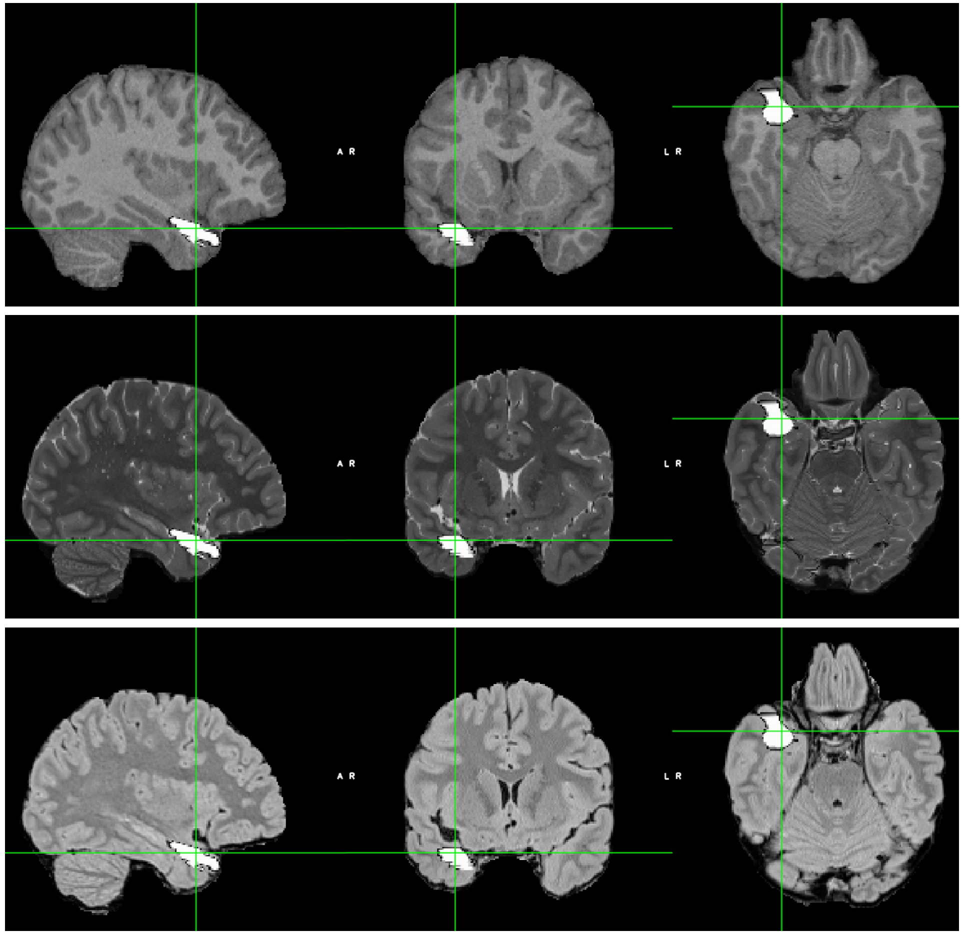
Preprocessing:

- The non-brain tissues are striped
- The bias field is corrected
- Aligned with a standard atlas
- 10 features were added

T1

T2

Flair



2 sites:

Research center for obstetrics, gynecology and perinatology named after V.I. Kulakov

National Medical and Surgical Center named after N.I. Pirogov” of the Ministry of Healthcare of the Russian Federation

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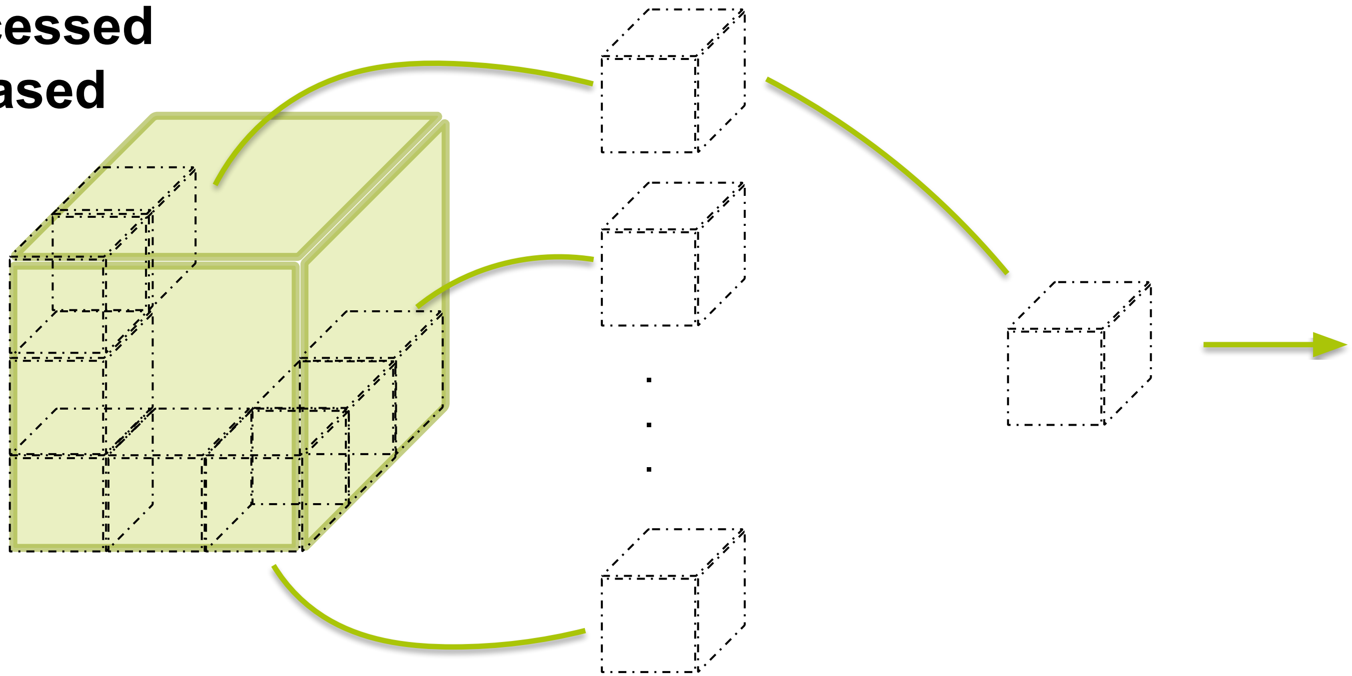
Point Cloud

Preprocessed voxel based data



Point Cloud

M

N

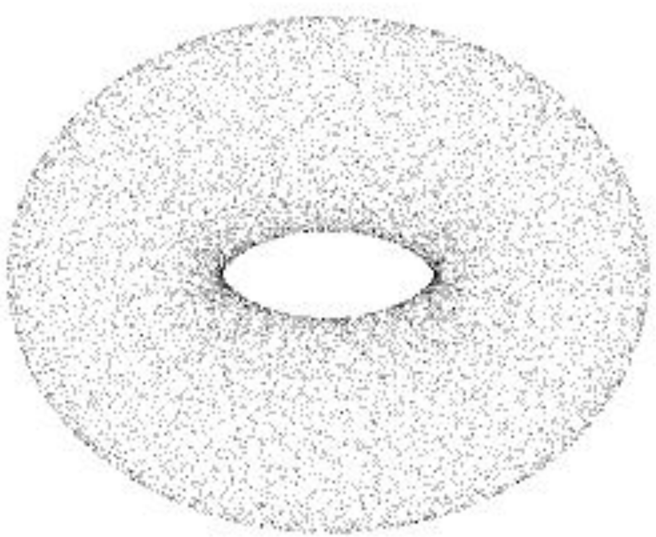
$(X_1, Y_1, Z_1, F_{11}, F_{12}, \ldots)$

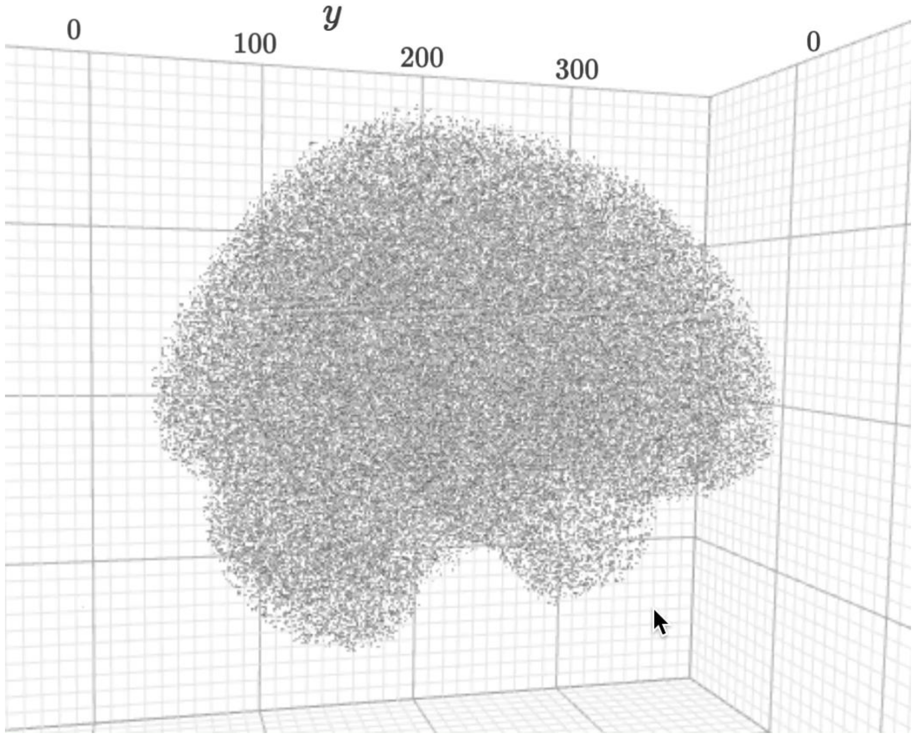
$(X_2, Y_2, Z_2, F_{21}, F_{22}, \ldots)$

$(X_N, Y_N, Z_N, I_N, F_{N1}, F_{N2}, \ldots)$

M = 3 + number of features
N = Number of points

Point Clouds





Objectives

- Build **architecture** for **sparse representation** and training pipeline for it.
- Train and evaluate this model.
- Make possible improvements.
- Compare results with SOTA model.

Pre-processing and post-processing pipelines

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Architecture and methods

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Training, evaluation and comparison

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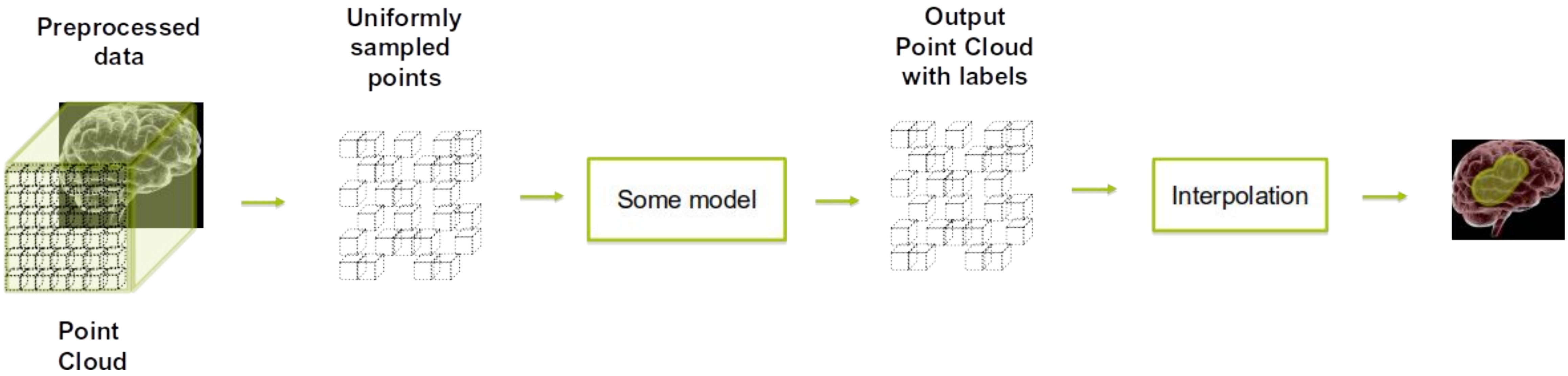
Pipeline

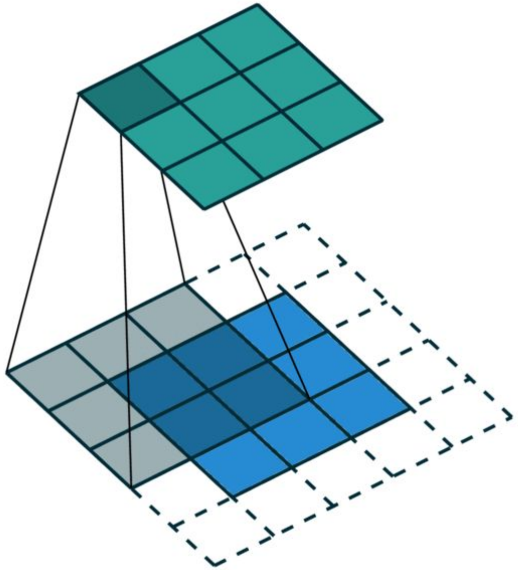

Preprocessed
data
Uniformly
sampled
points
Output
Point Cloud
with labels
Some model
Interpolation
Point
Cloud

Minkowski Engine

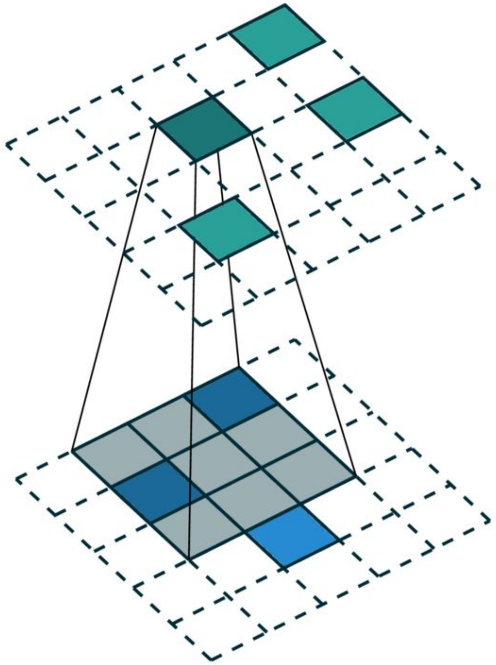
PyTorch extension that provides an extensive set of neural network layers for sparse tensors.

Features:

- Unlimited high-dimensional sparse tensor support
- All standard neural network layers (Convolution, Pooling, Broadcast, etc.)
- Dynamic computation graph
- Custom kernel shapes
- Highly-optimized GPU kernels



Dense tensor



Sparse tensor

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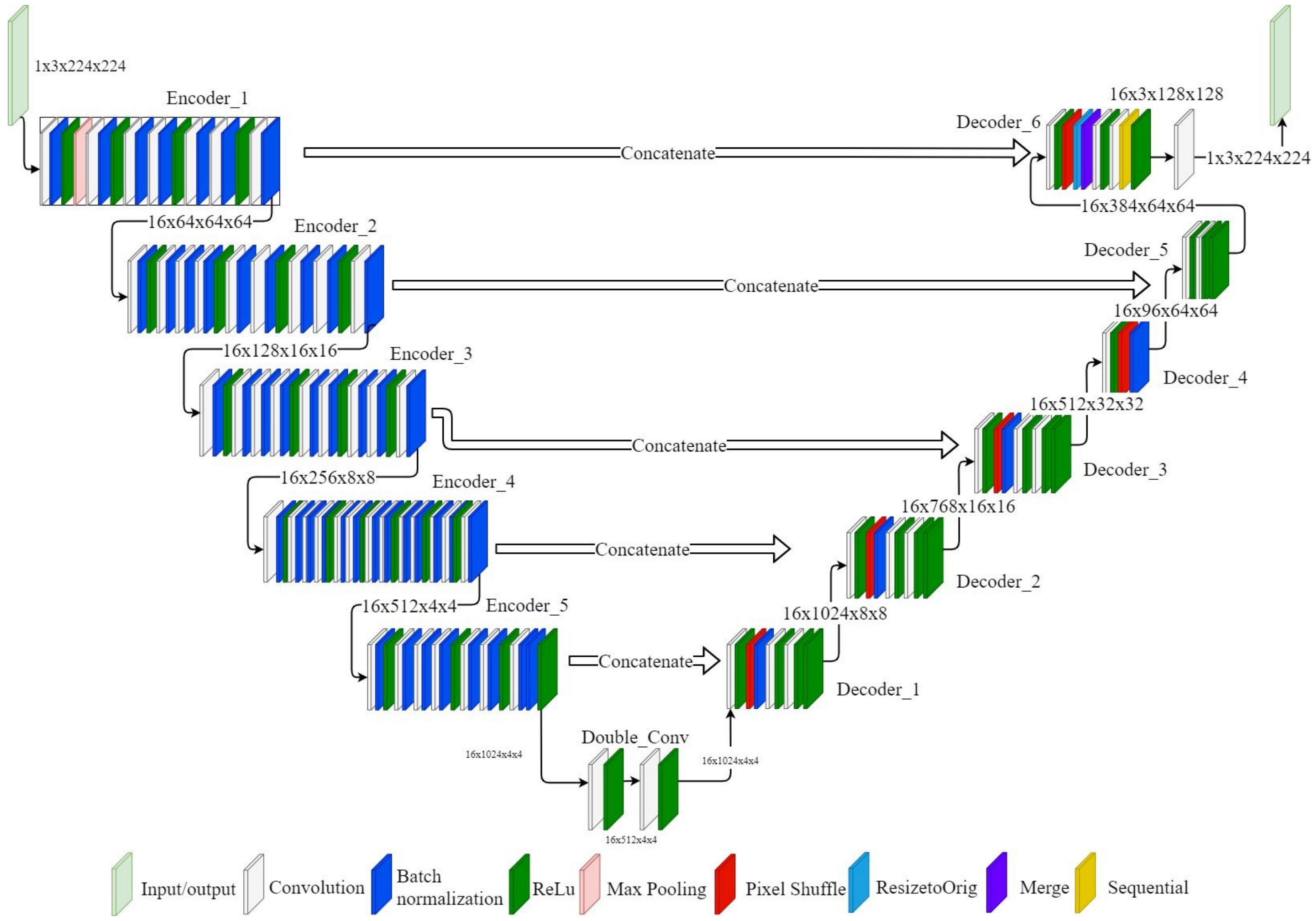
Architecture



- MinkUnet34C
- MinkUNet14C
- MinkUNet34C with attention

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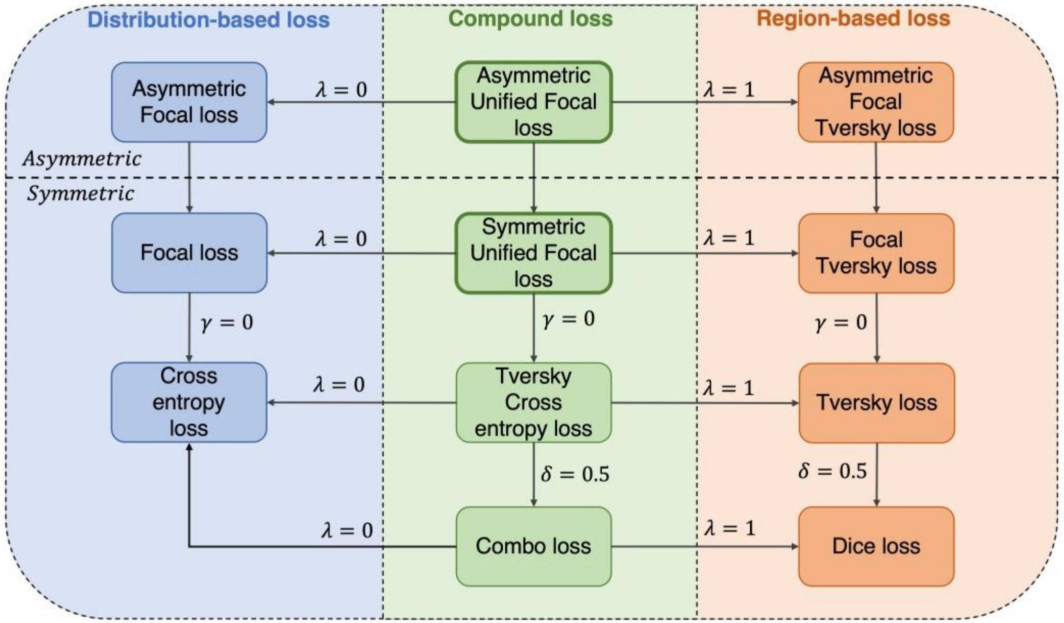
Losses



$$L_{WeightedBCE}(y, \hat{y}) = -\frac{1}{N}\sum_{i}^{N} w_1 y_i log(\hat{y}_i) + w_0(1 - y_i)log(1 - \hat{y}_i)$$

$$L_{UnifiedFocal} = \lambda L_{Focal} + (1 - \lambda)L_{Tversky}$$

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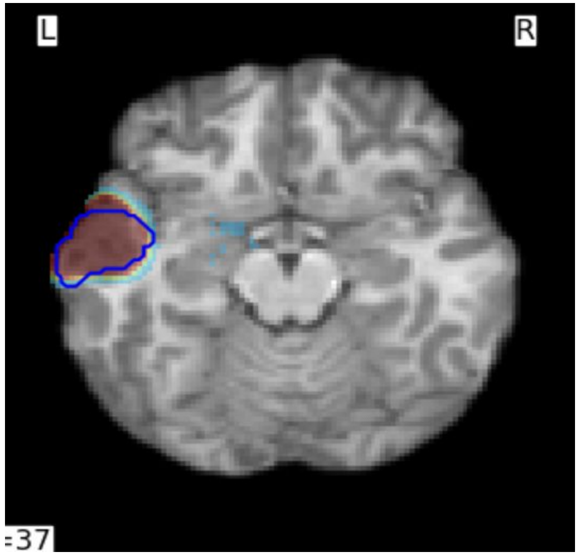
Metrics

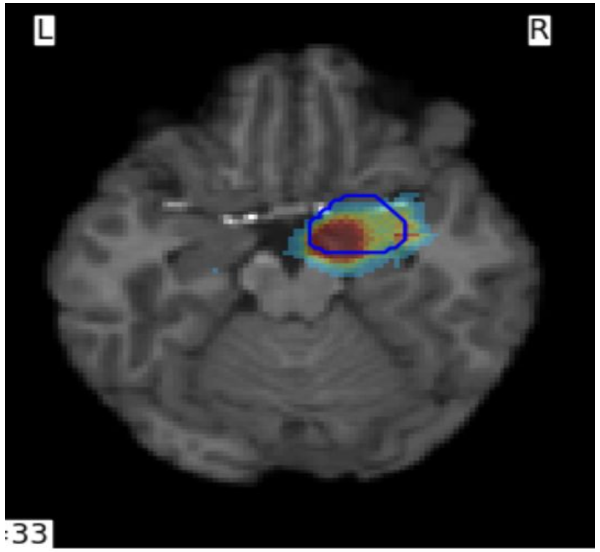
We both want to precisely segment FCD area malformation for pre-surgical planning and detect FCD for decision support system

1) object segmentation - dice
2) classification + localization - recall

dice=0.374



recall = 0.89



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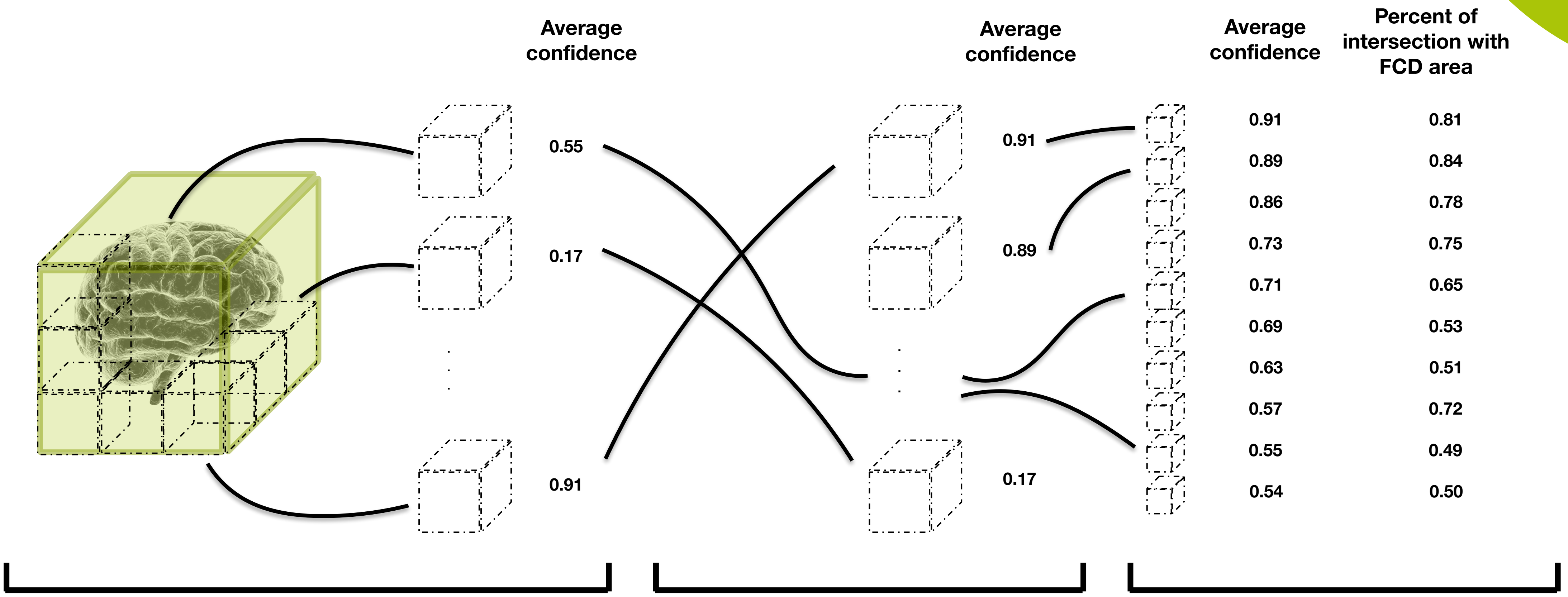
Metric

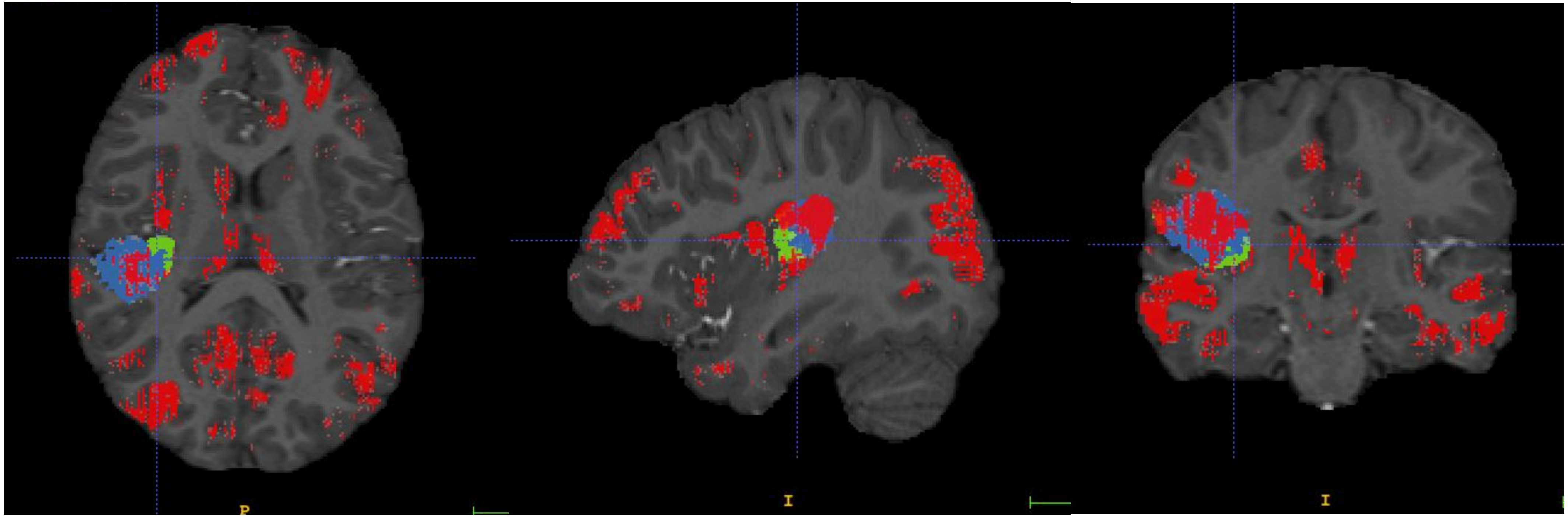


Prediction is divided into intersecting crops of defined size **C**. The average confidence is calculated for each such crop.

Crops are sorted with respect to the average confidence.

Intersection with FCD area is calculated for top **N** crops with respect to the average confidence.

Example of prediction



- Mask of FCD
- Prediction of MinkUNet14C
- Prediction of state-of-the-art model (Gill, R. S., Lee, H. M., Caldairou, B., Hong, S. J., Barba, C., Deleo, F., ... & Bernasconi, A. (2021). Multicenter validation of a deep learning detection algorithm for focal cortical dysplasia. *Neurology*, *97*(16), e1571-e1582.)

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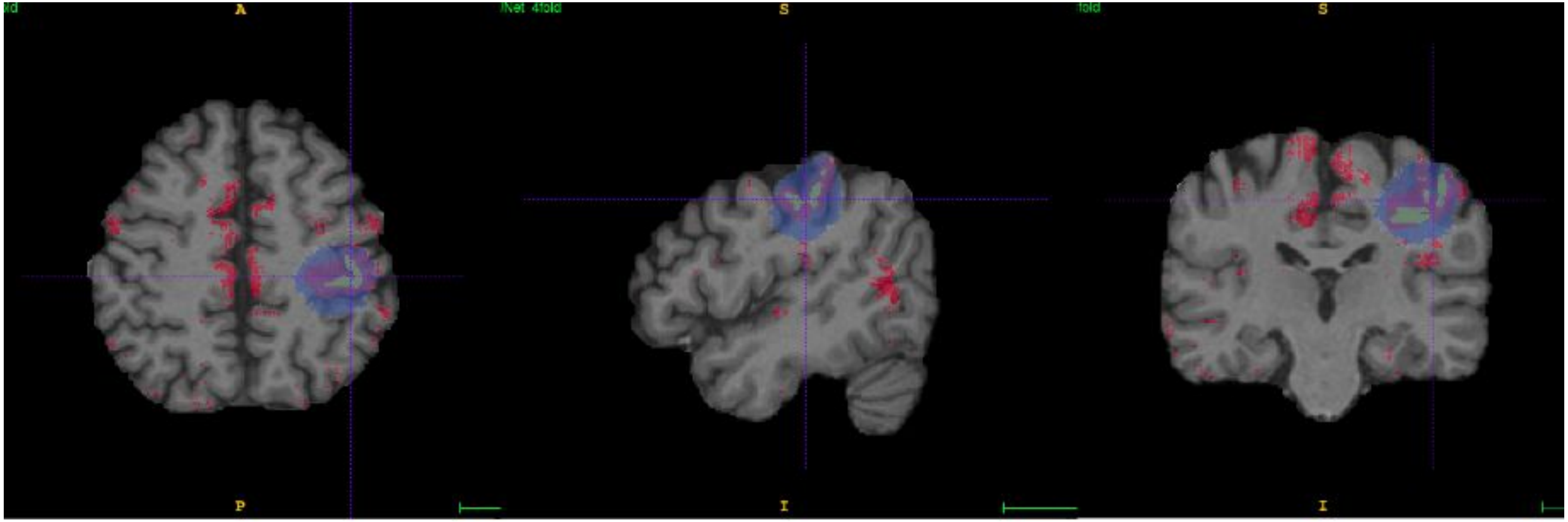
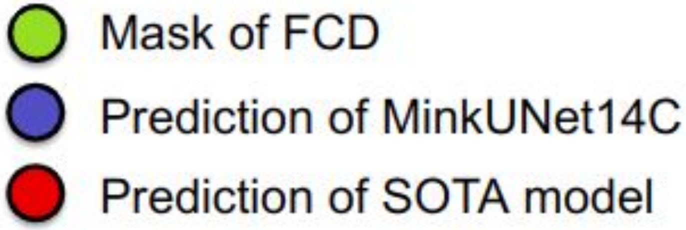
Example of prediction

- Mask of FCD
- Prediction of MinkUNet14C
- Prediction of SOTA model

Example of subject with low dice





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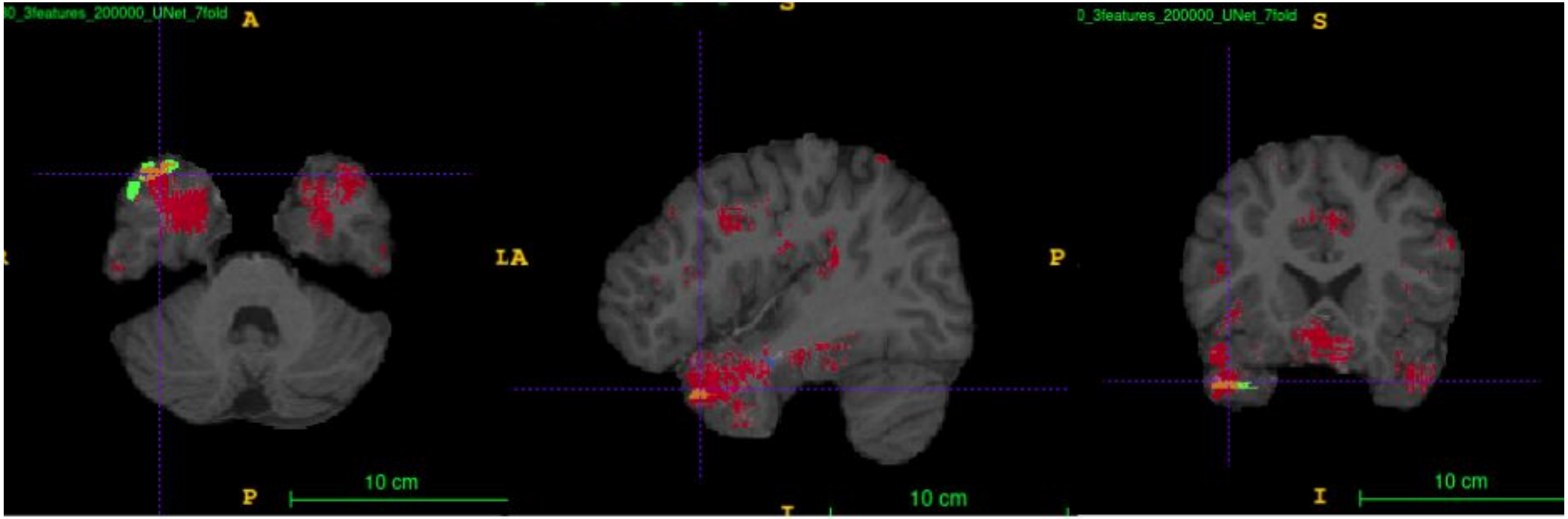
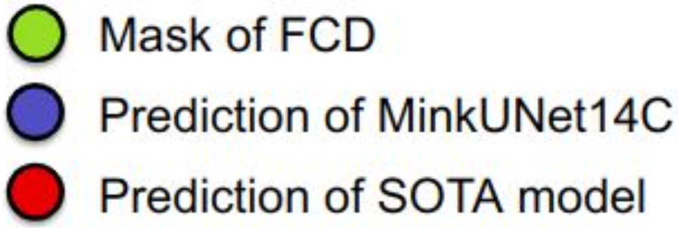
Example of failed prediction





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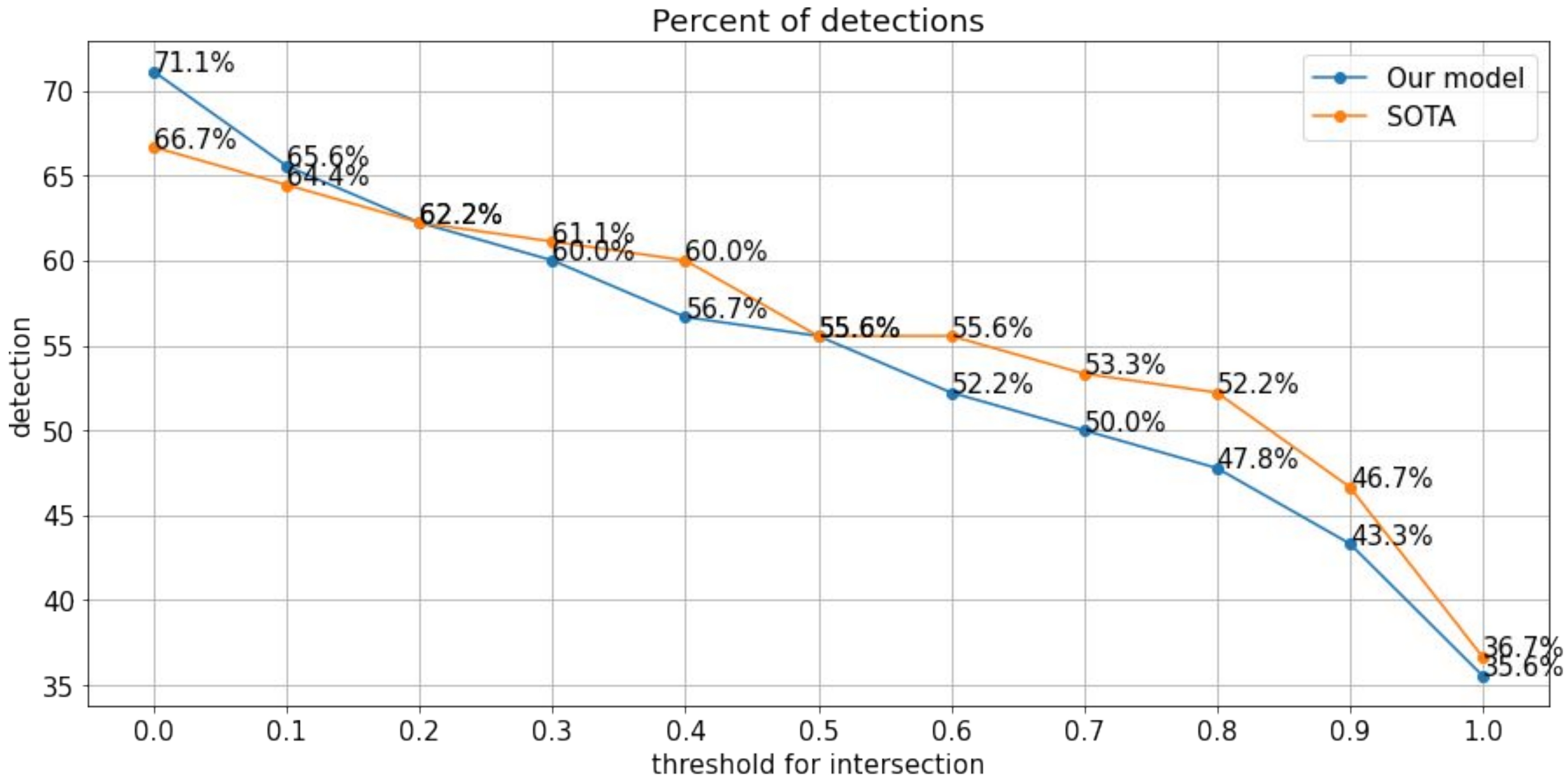
Results



- 37 out of 90 brains detected in terms of dice metric
- Recall for our model 0.51 ± 0.2
- Recall for SOTA model 0.52 ± 0.2

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Plans

- End all experiments on big dataset.
- Interpret results in terms of vital features.
- Make more precise statistical analysis of the results.
- Add new results to the draft and prepare final text.

Acknowledgements

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- Aleksei Marinets - Radiologist

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Thank you for your attention!

Additional slides

Conclusions

- Approach with sparse representation proved its consistency.
- 60% of successful predictions.
- The sets of non-detected subjects differed between proposed approach and the state-of-the-art one, suggesting that an ensemble of these models could be used to obtain more reliable predictions.
- Outcome: this model will be inserted in the pipeline of EpiDetect project.

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Scientific novelty

It has been shown for the first time that:

- **Neural networks for point clouds segmentation can be used for the MRI analysis**. Their usefulness is proved.
- **Additional features** like blurring, curvature, thickness of grey matter, concentration rate, variance and entropy were added to the pipeline.

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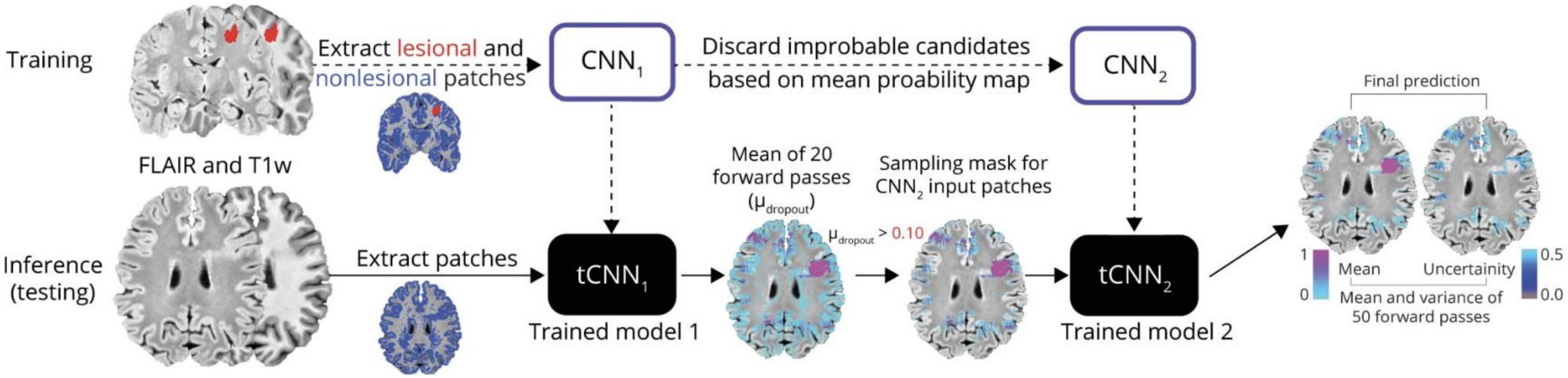
State-of-art-model



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