TE
Technology Department

HELLENIC REPUBLIC
National and Kapodistrian University of Athens
EST. 1837

# Computer-Aided deFEcts and anomalies detection, Identification and classificatioN system - CAFEIN*

## Medical Applications

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**This Project was supported by CERN KT fund for medical applications*



CERN CAFEIN

# Introduction

- **Brain disorders are one of the greatest health challenges**
  - Around 165 million Europeans are living with a brain disorder
  - It is estimated that 1 in 3 people will suffer from a neurological and/or psychiatric disorder at some point in their lives[1]

- One of the most promising areas of health innovation is the application of **machine learning in medical imaging**:[3][4][5]
  - An alternative/supportive way of quick and accurate diagnosis in order to save time and resources in the daily medical workflow
  - Early diagnosis and treatment, access to medical imaging expertise in parts of the world where access to skilled radiologists is limited

# Motivations and Research Gaps

**Project requirements based on clinical needs and environment:**

use case: the dept of Radiology of the Medical School of Athens:

**Motivations**

**Delays, efficiency, resources, accuracy**

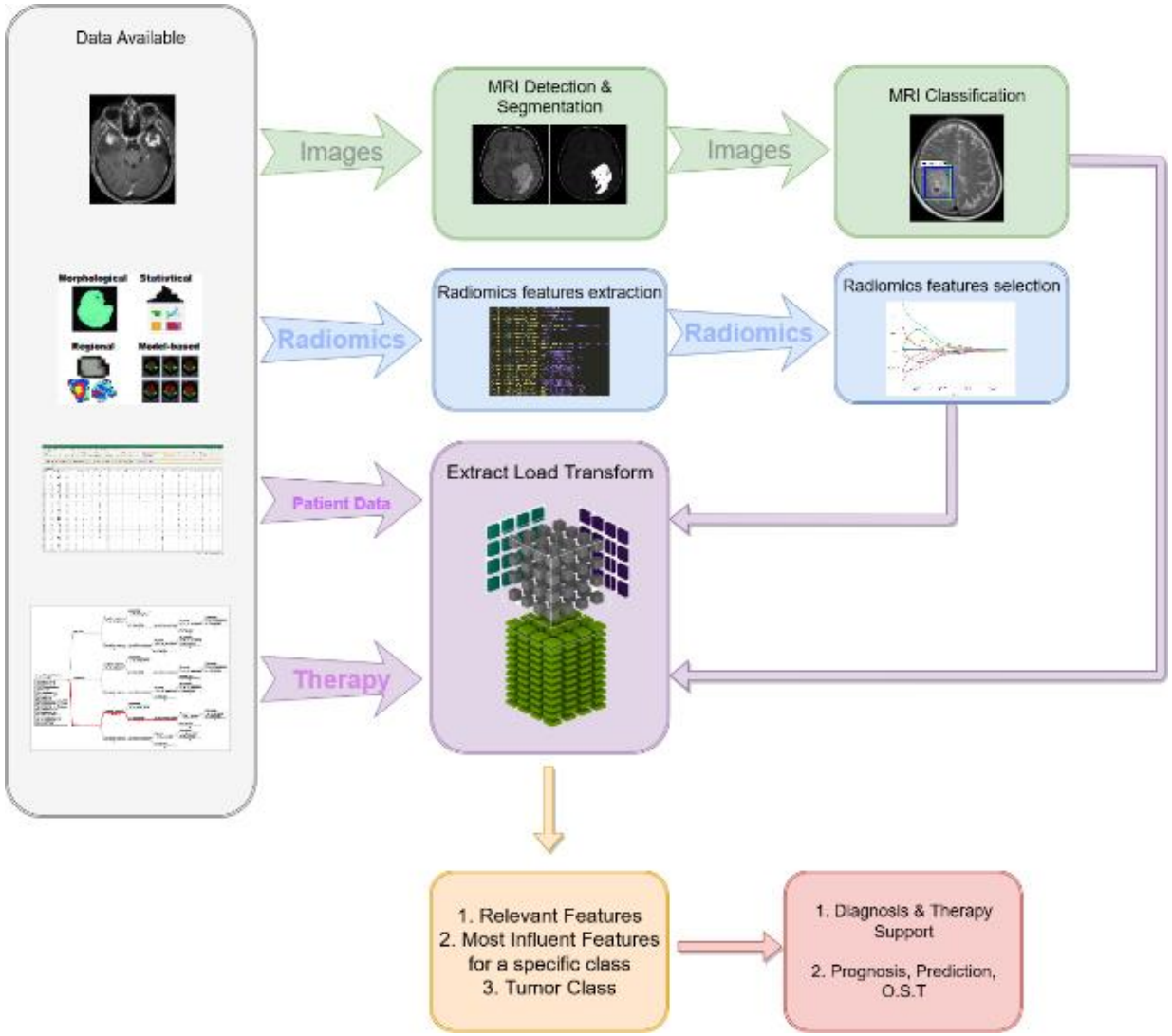
- Large number of examinations - limited experts to evaluate them
- Long examination evaluation queue
- Need for support of diagnosis - The “second opinion”
- Significant amount of heterogenous, raw and unprocessed data without a proper infrastructure to exploit them

**Research Gaps**

**Robustness, adaptability, expensive, generic**

- The available methods are not tailored to real clinical needs
- Current methods are hard to deploy in the clinical environment - Need for highly expertise support
- Mostly expensive and “black boxes”
- Hard to adapt in rapid evolving clinical environment – Static

# CAFEIN for Medical Applications Architecture

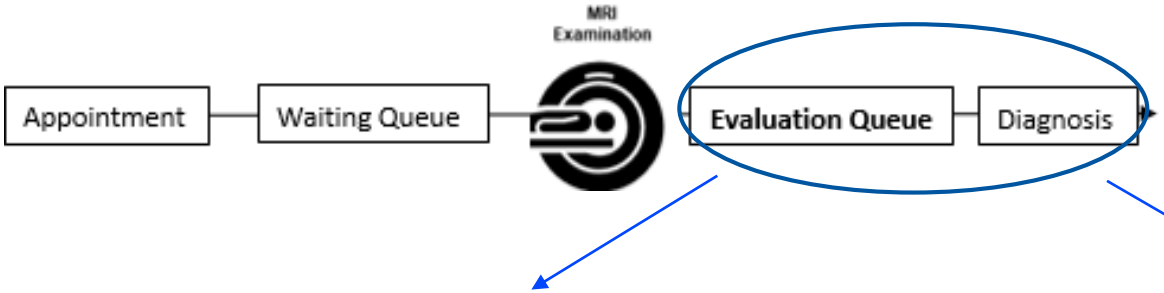



AI algorithms to extract features, patterns and develop models for segmentation, classification, risk prediction and prevention based on digital images and clinical, therapies and genetic data.

*What is new here?*

- **Automated computer software**
- **State of the art methods based on real world diverse dataset**
- **Accurate and easy to use - Being defined according to clinicians needs**
- **Integration of imaging data, radiomics and clinical data**
- **Fast and easy adjust on different clinical cases**
- **Results that will be useful in a wide range of radiology clinics with similarities with Athens**

# The “lifecycle”…




The expert should **manually**:

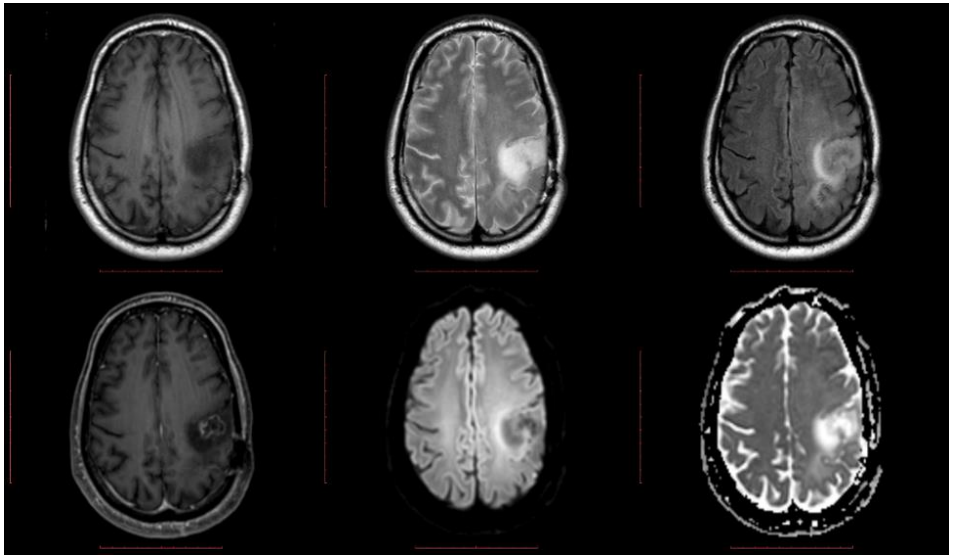
- Open the examination
- Combine different modalities
- Search for the abnormality (Detection)
- Delineate the boundaries (Segmentation)
- Try to classify it (Classification)
- Report the diagnosis

CAFEIN should **automatically**:

- Accept an examination as input
- Use different models, tools and algorithms for:
  - Detection,
  - Segmentation,
  - Classification
- Return a preliminary report to the clinician

# Data and Methods

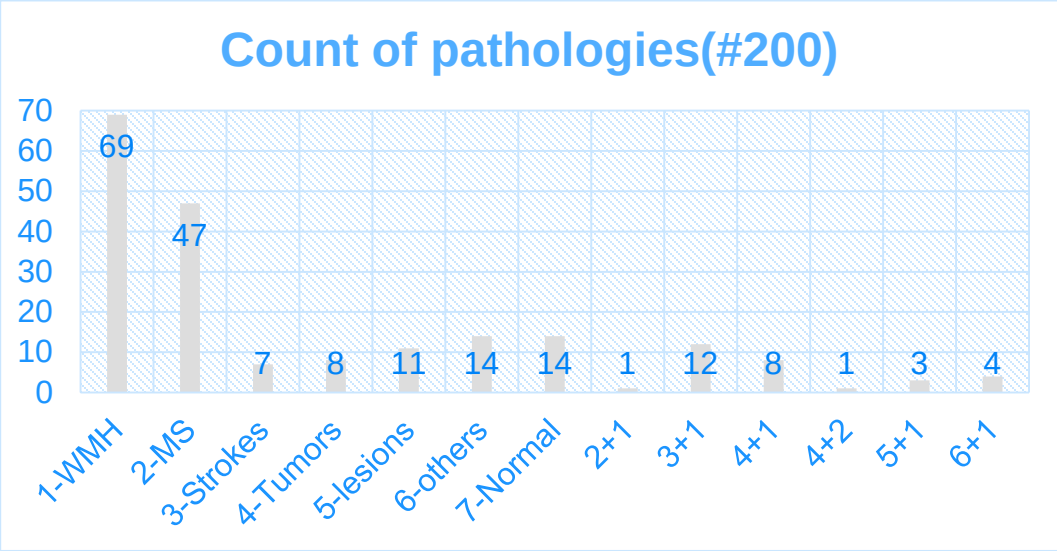
- Cases from a MRI machine of 3-Tesla from the **2nd dept of Radiology of the Medical School of Athens**
- **150 Brain MRI** examinations containing different pathologies: *Tumors, Multiply Sclerosis , White Matter Hyper-intensities, Strokes, Lesions and Normal cases*
- Up to six different MRI modalities
  - Used : **FLAIR, T2, T1ce**
- Several Image resolutions (3D or 2D)



*Six different MRI modalities (from left to right ,top to bottom): T1,T2,Flair,T1ce,Diffusion,ADC*

# Data and Methods

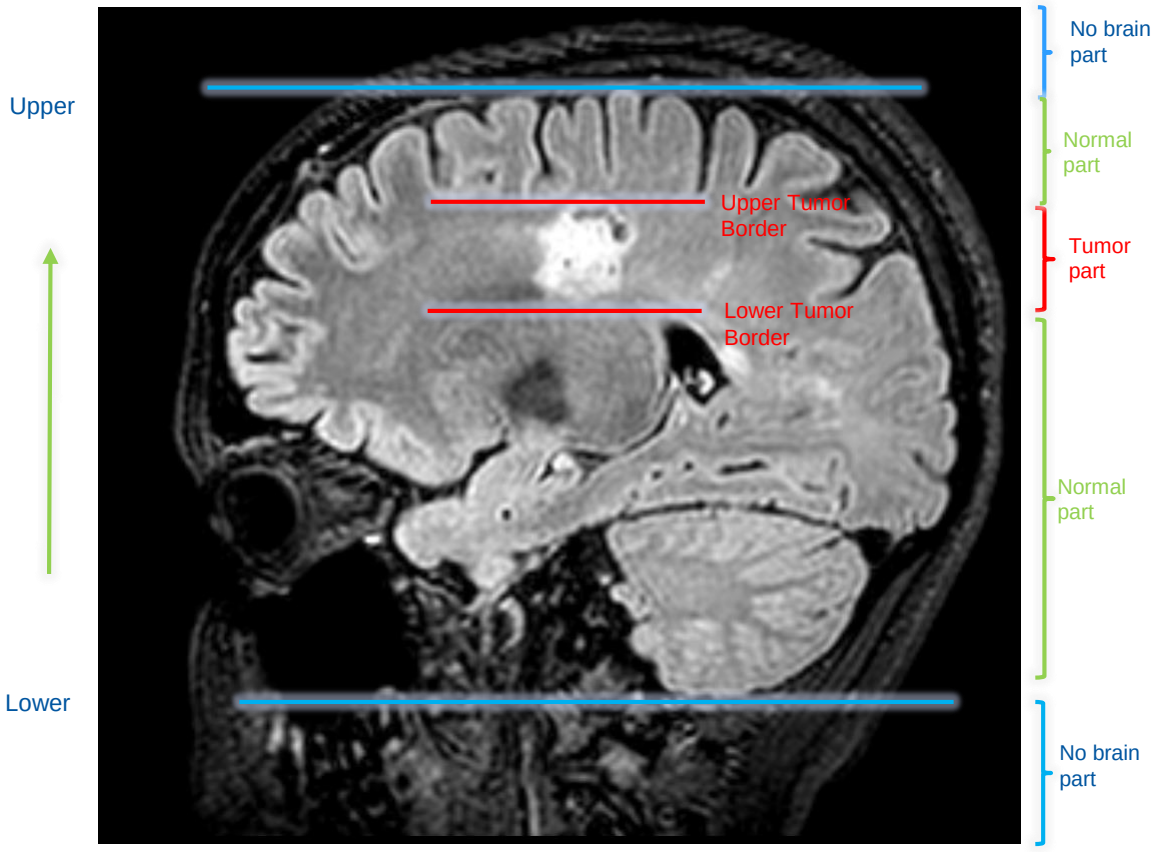
## Department workflow




| patho | Count of patho | Ratio% |
|---|---|---|
| 1-WMH | 69 | 34.5 |
| 2-MS | 47 | 23.5 |
| 3-Strokes | 7 | 3.5 |
| 4-Tumors | 8 | 4 |
| 5-lesions | 11 | 5.5 |
| 6-others | 14 | 7 |
| 7-Normal | 14 | 7 |
| 2+1 | 1 | 0.5 |
| 3+1 | 12 | 6 |
| 4+1 | 8 | 4 |
| 4+2 | 1 | 0.5 |
| 5+1 | 3 | 1.5 |
| 6+1 | 4 | 2 |
| | | |
| | | |
| | **34 working days** | |
| | | |
| | Considered cases → | 83.5% |

# Clinical application based on CAFEIN developments

- Typically examinations comes as consecutive 2D slices. However only **a small amount of them** contains useful information
- There is a need for a tool for automated and optimised **screening** of the examinations saving time and resources for the clinicians

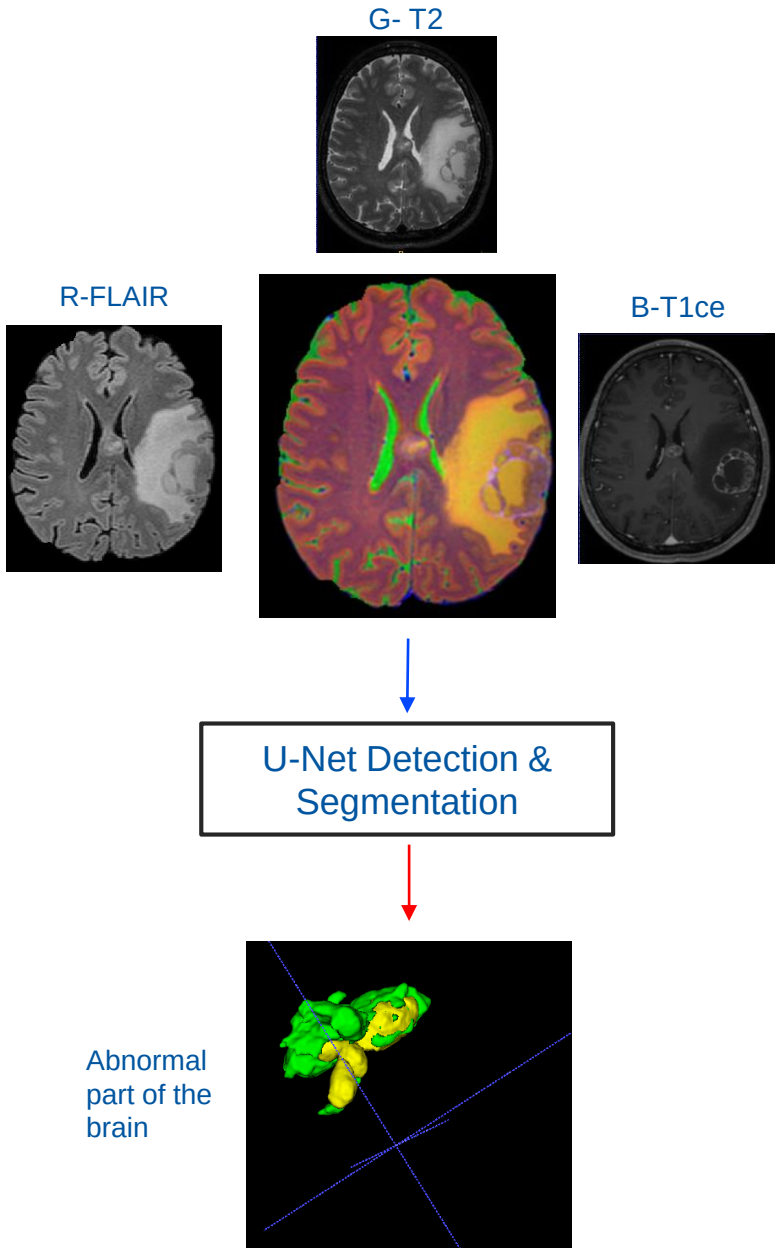


# Detection and segmentation

- 100 examinations for training
- 24 examinations for validation
  - **19036** slices for training - **4438** slices for validation
  - 3 MRI modalities Flair - T2 - T1ce as RGB slices
  - **All 4 pathologies**

Technical:

- Pre-trained InceptionV3 CNN trained on 2D “RGB” images
- Custom Preprocessing
- Custom Dice loss + Cross Entropy loss
- 100 epochs training scheme
- Adam optimizer



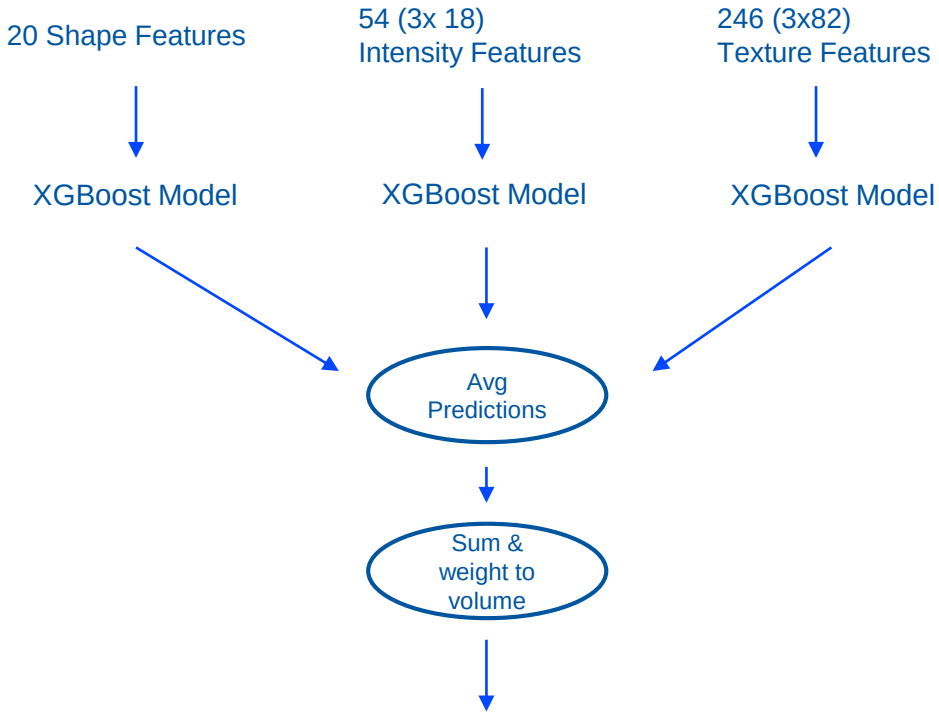
# Classification

124 examinations on a 5-fold scheme per examination

- 4507 components
- **All 4 pathologies**
  - 156 strokes
  - 159 tumors
  - 1492 MS
  - 2642 WMH
- 3 MRI modalities Flair - T2 - T1ce used

Technical:

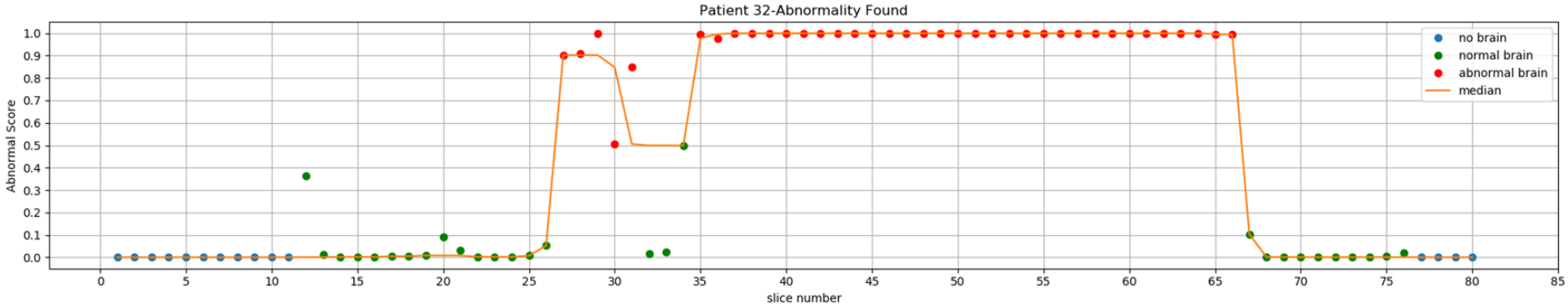
- XGBoost Model trained on component level
- Custom Preprocessing
- cross entropy loss

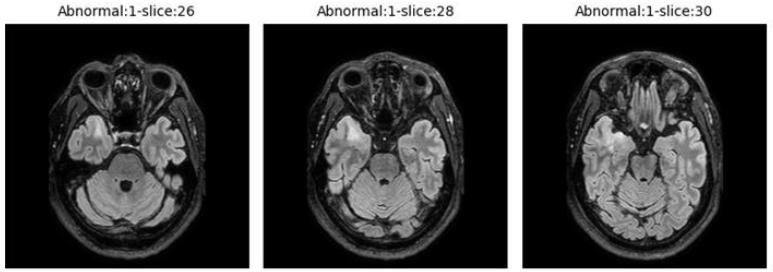


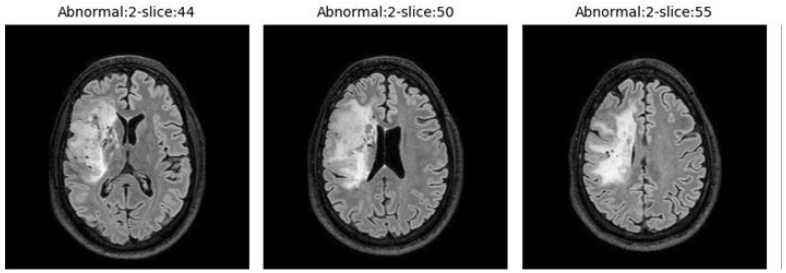

Results

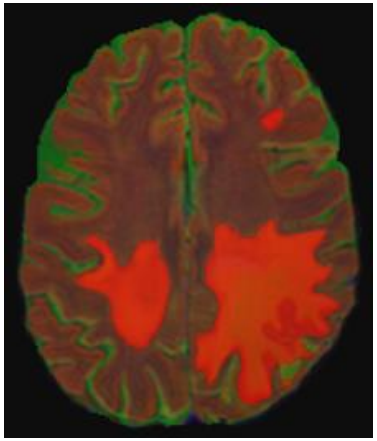
| True \ Predicted | stroke | tumor | MS | WMH |
|---|---|---|---|---|
| stroke | 26.54 | 16.80 | 16.24 | 40.42 |
| tumor | 1.63 | 63.27 | 17.40 | 17.70 |
| MS | 0.30 | 19.43 | 49.00 | 31.26 |
| WMH | 0.14 | 16.65 | 14.96 | 68.26 |

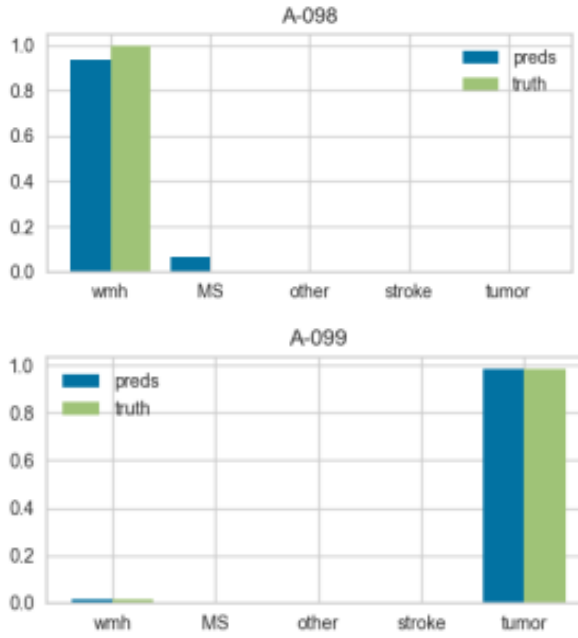
# Final Output- Screening Tool



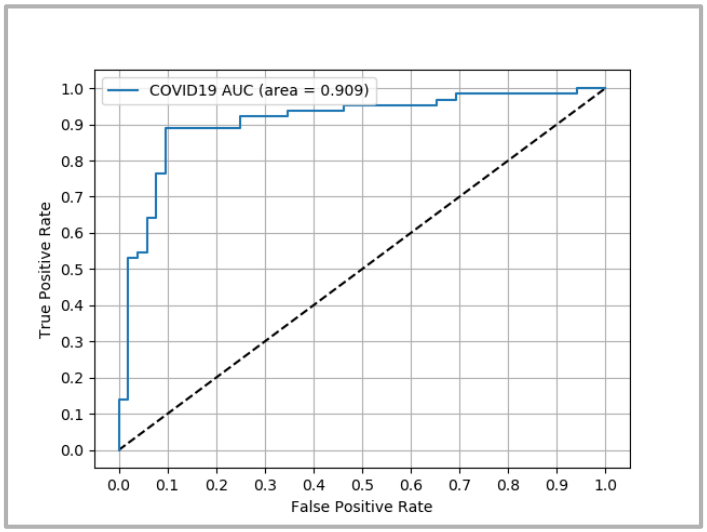



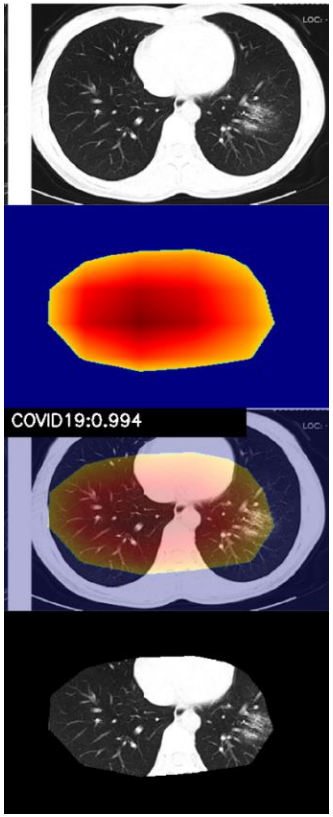


# Robustness and adaptability of the tool

## Testing on a completely different clinical case: Lung CT scans – COVID diagnosis

| | precision | recall | f1-score | test | train |
|---|---|---|---|---|---|
| Non COVID | 0.85 | 0.90 | 0.88 | 52 | 345 |
| COVID | 0.92 | 0.88 | 0.90 | 64 | 285 |
| accuracy | | | | | 0.89 |

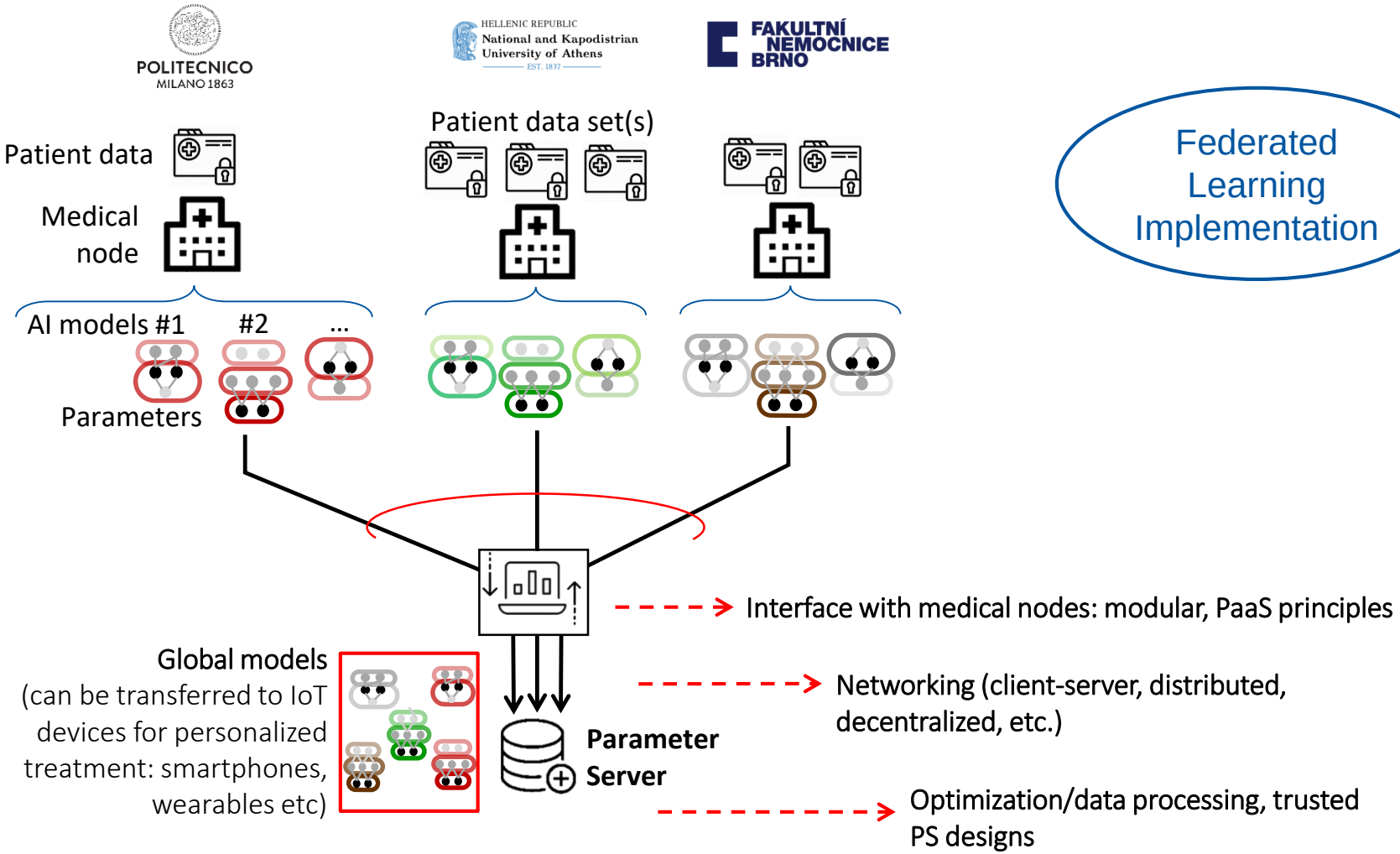



*Lung CT scans and COVID detection heat maps*

# CAFEIN Federated Learning platform test and validation

Computer-Aided Defects and Anomalies Detection, Identification and Classification system for Digital Images and Data

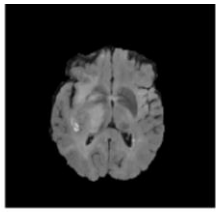
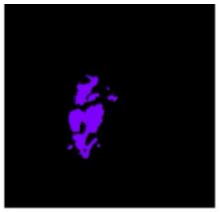
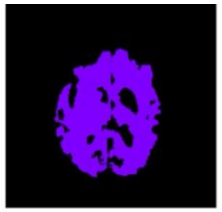
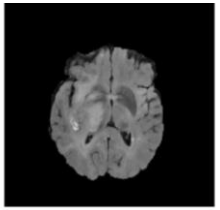
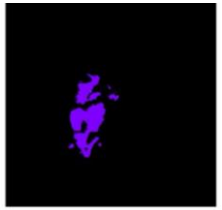
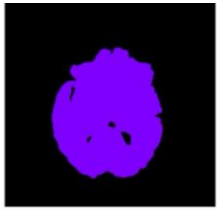
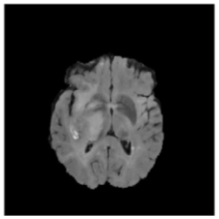
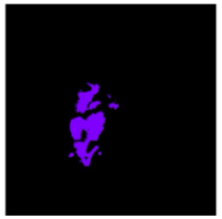


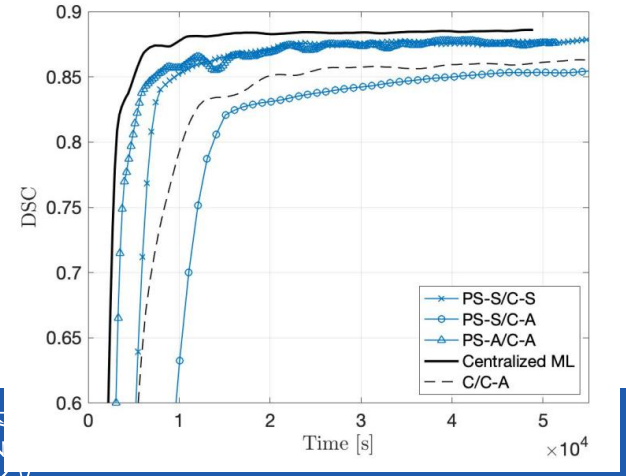
# CAFEIN Federated Learning platform test and validation

Computer-Aided Defects and Anomalies Detection, Identification and Classification system for Digital Images and Data

## Federated approach impact:

- **Robustness** of global models v. local models
- **Privacy** and **confidentiality** of data
- Communication optimization and sustainability

| | MRI | Ground Truth | Prediction |
|---|---|---|---|
| **Single node** |  |  |  |
| **FL Server** |  |  |  |
| **Centralized ML** |  |  |  |




*Nomination for the best innovation at the 2022 Geneva Health Forum*

# Multi-pathology detection & classification

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**MEDICAL APPLICATIONS**

**MULTI-INSTITUTIONAL**

HELLENIC REPUBLIC
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FAKULTNÍ NEMOCNICE BRNO

**Our tool so far:**

- based on **real clinical data** (tailored to our clinic)
- used for examinations **prioritization and screening**
- **easy** to use and interpret
- can share models between clinics while ensuring privacy

Annex…

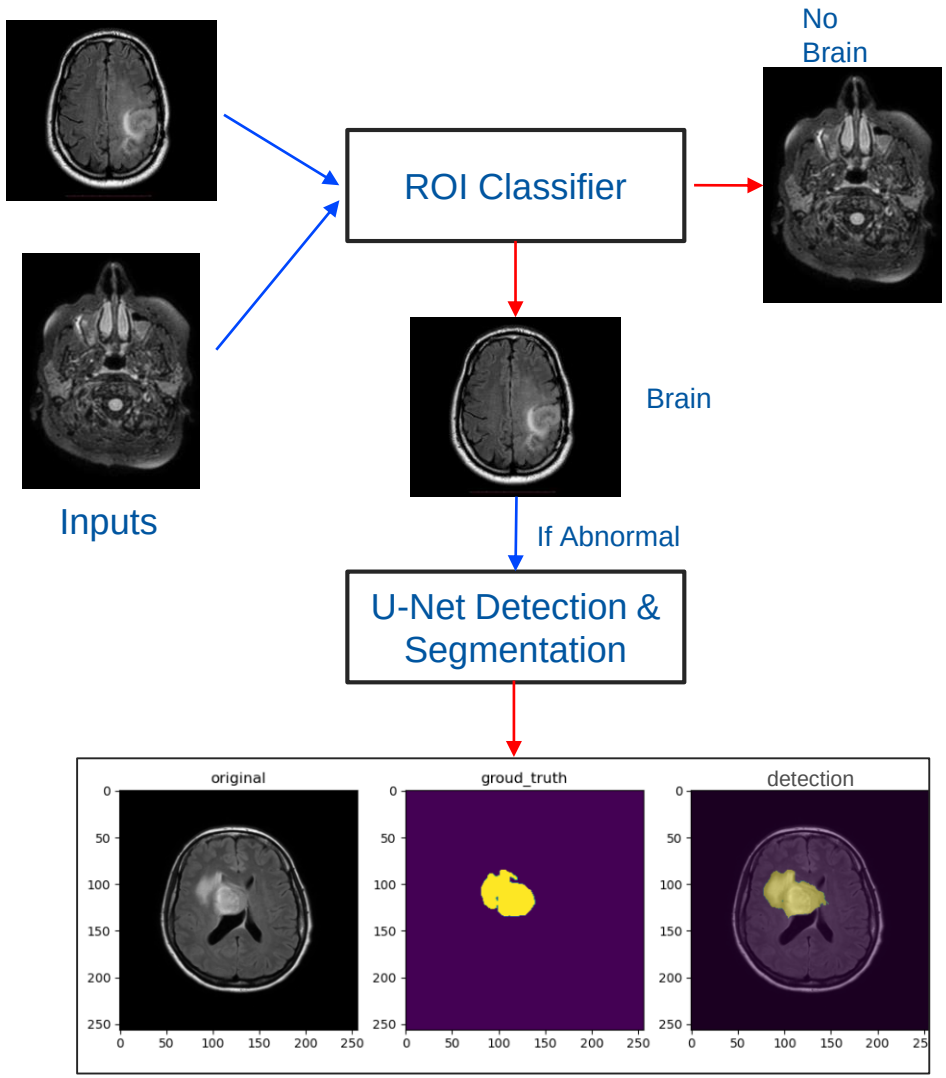
# Methodology / architecture implemented

Screening tool

- 2D Slice based - Axial - Flair

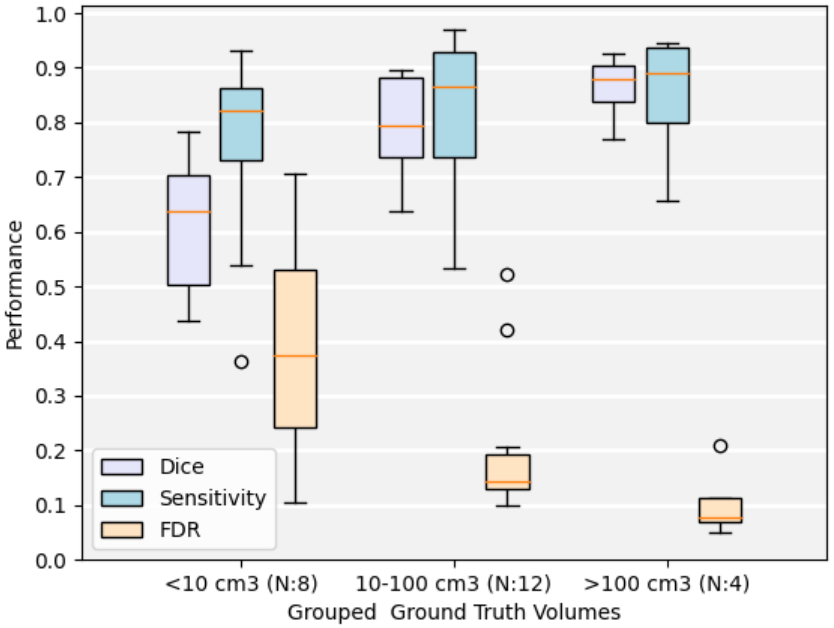
- Three Steps approach:
  1. Brain - No Brain
  2. (if Brain) Normal – Abnormal

  + if Abnormal
  - Detect & Segment

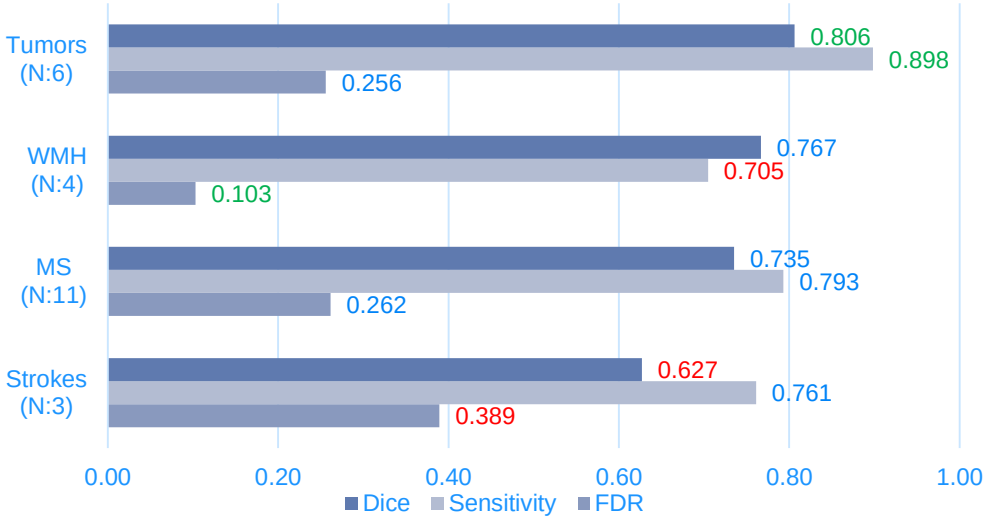


# Main metrics for the 24 validation Examinations

Per Volume




Per Pathology*




**As the main pathology defined from the diagnosis*