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Brain Tumor Detection

Computer Vision Group Project

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Use Case & Rationale

Context

We decided to exploit the power of **Transfer Learning** to develop a **supporting tool** for **early detection of brain tumor** and potentially **brain surgery planning** for surgeons and radiologists.

Technology

Using a pre-trained YOLO model for **object detection** and **instance segmentation** trained on annotated MRI scans, with the appropriate hyperparameters tuning allows us to reach satisfying results in accuracy (75-85%).

Disclaimer

Our work is intended to emulate a supporting tool, not a fully diagnostic one, the **final diagnosis** and treatment decisions should be made by **experienced healthcare professionals** who integrate the findings with **their clinical expertise**.

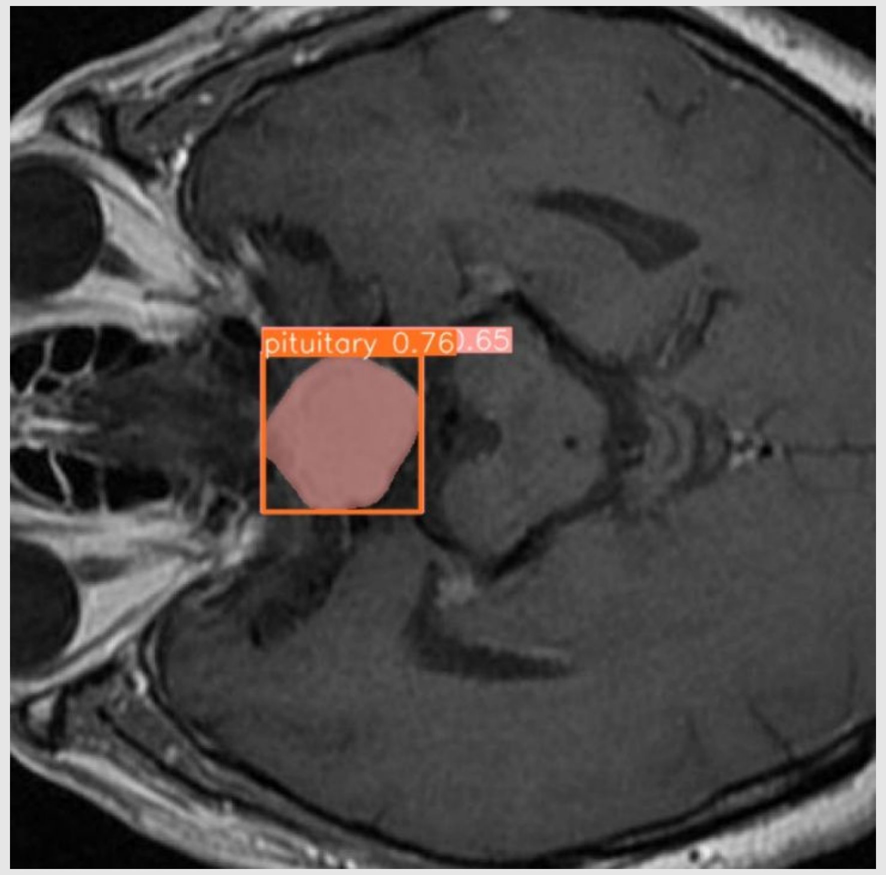
Types of Brain Tumors

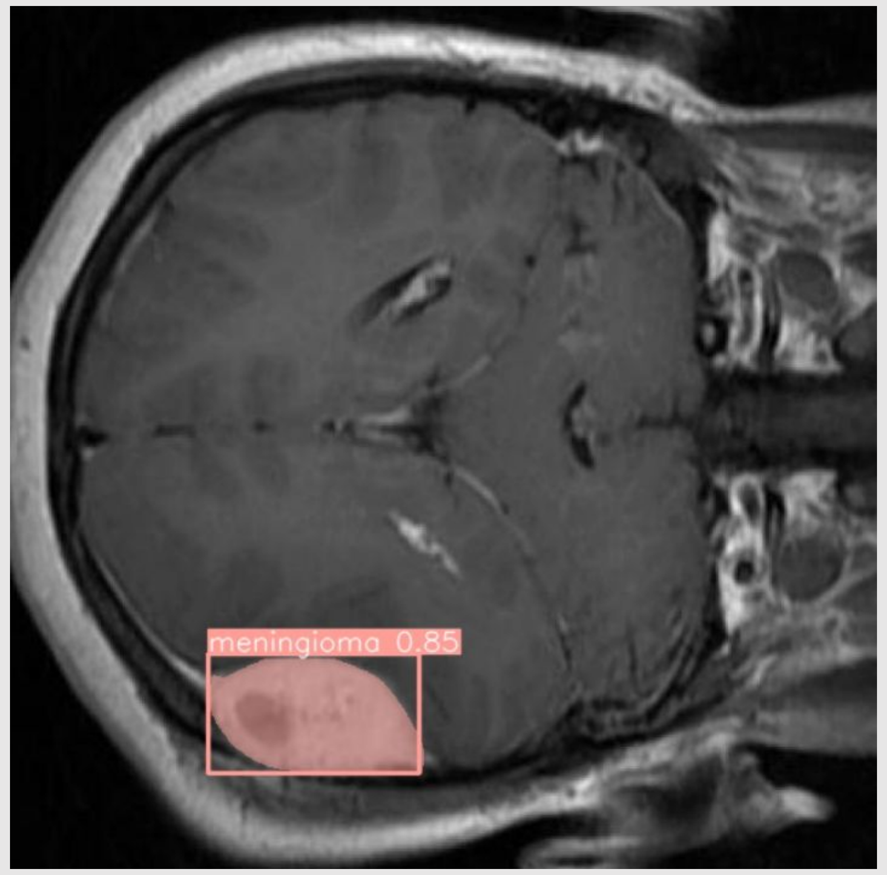
01

Pituitary

Mostly benign, grows slowly, doesn't spread to other parts of the body.

However, Pituitary gland produces hormones, thus the high need for early detection.





02

Meningioma

A primary CNS* tumor and the most common brain tumor.

Five-year survival rate of 65% for adults >40 years of age

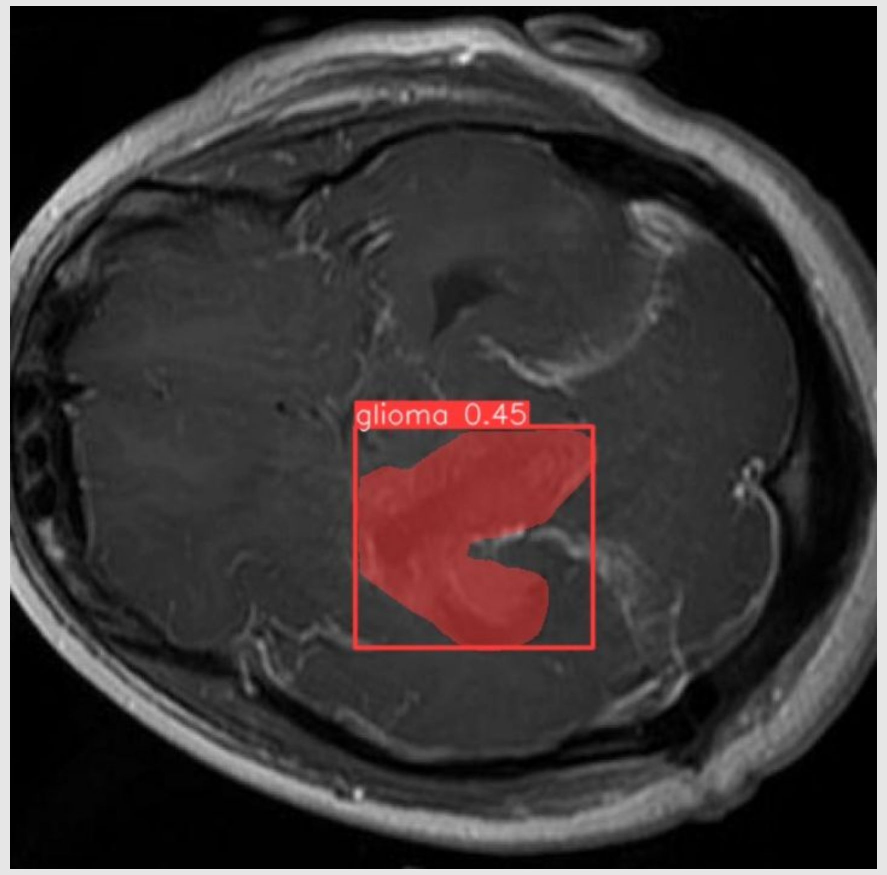
*CNS = Central Nervous System

03

Glioma

Cancerous and life-threatening tumor located in glial cells. Hard to reach and treat with surgery.

Five-year survival rate of 5%



Object Detection & Instance Segmentation

Relevance for our use case:

Object Detection

Identification & Localization

Beyond mere identification, these algorithms also specify the **exact location** of the tumor cells in the MRI scans, providing information about **boundaries**, **size**, **shape**, and **relationship** with surrounding structures.

Accuracy

This precise localization enhances the **accuracy** of **diagnosis** and subsequent treatment planning.

Early detection

These techniques provide accurate localization, **early detection**, aid in **treatment planning**, and enhance **workflow efficiency**.

Instance Segmentation

Precision

Instance segmentation provides **granular details** by distinguishing each pixel of every detected object, helping delineate the **precise boundary** of a tumor that might be missed during manual examination.

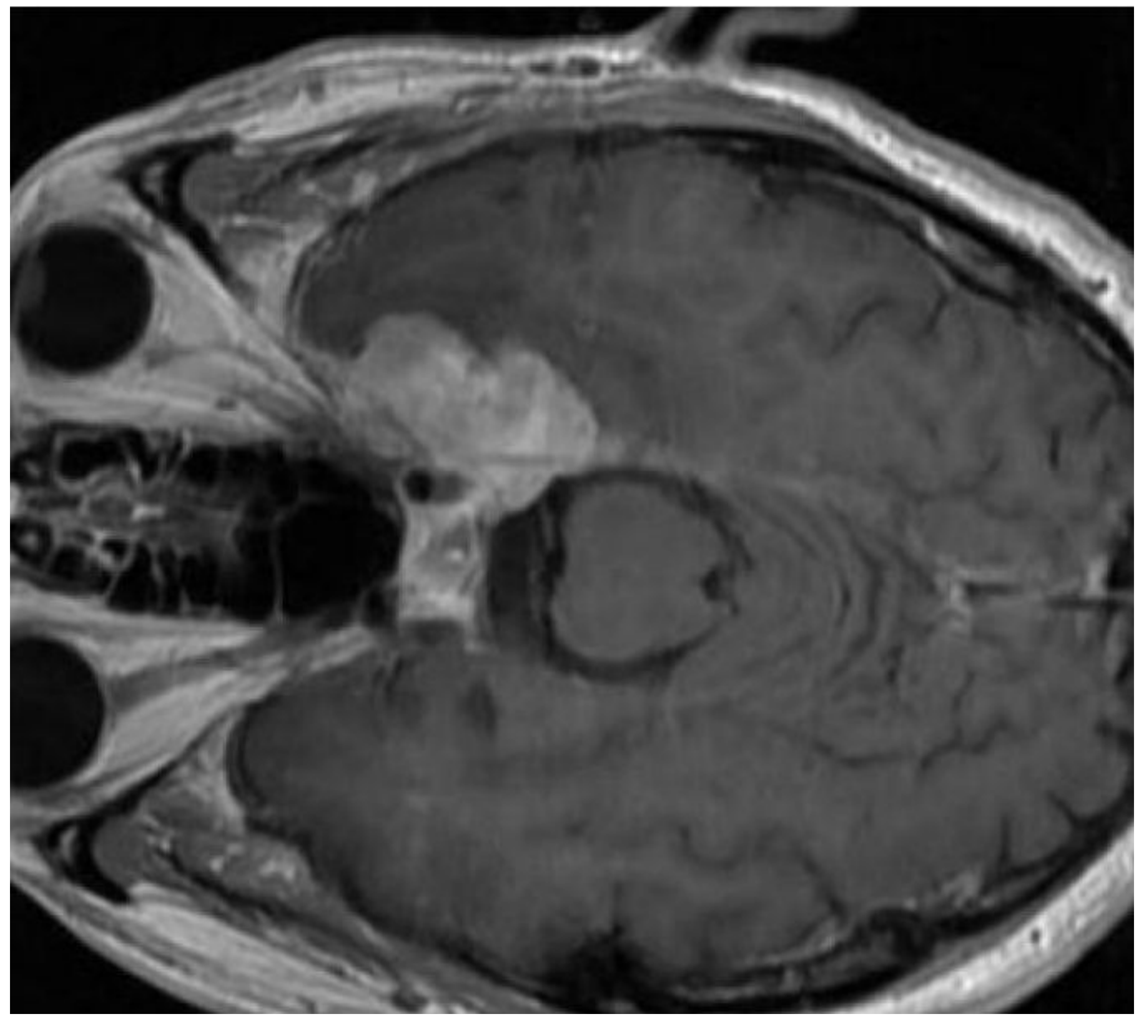
3D Model

Allows creation of three-dimensional models, useful to provide **visual representations** of tumors in relation to **surrounding structures**, assisting physicians in treatment planning.

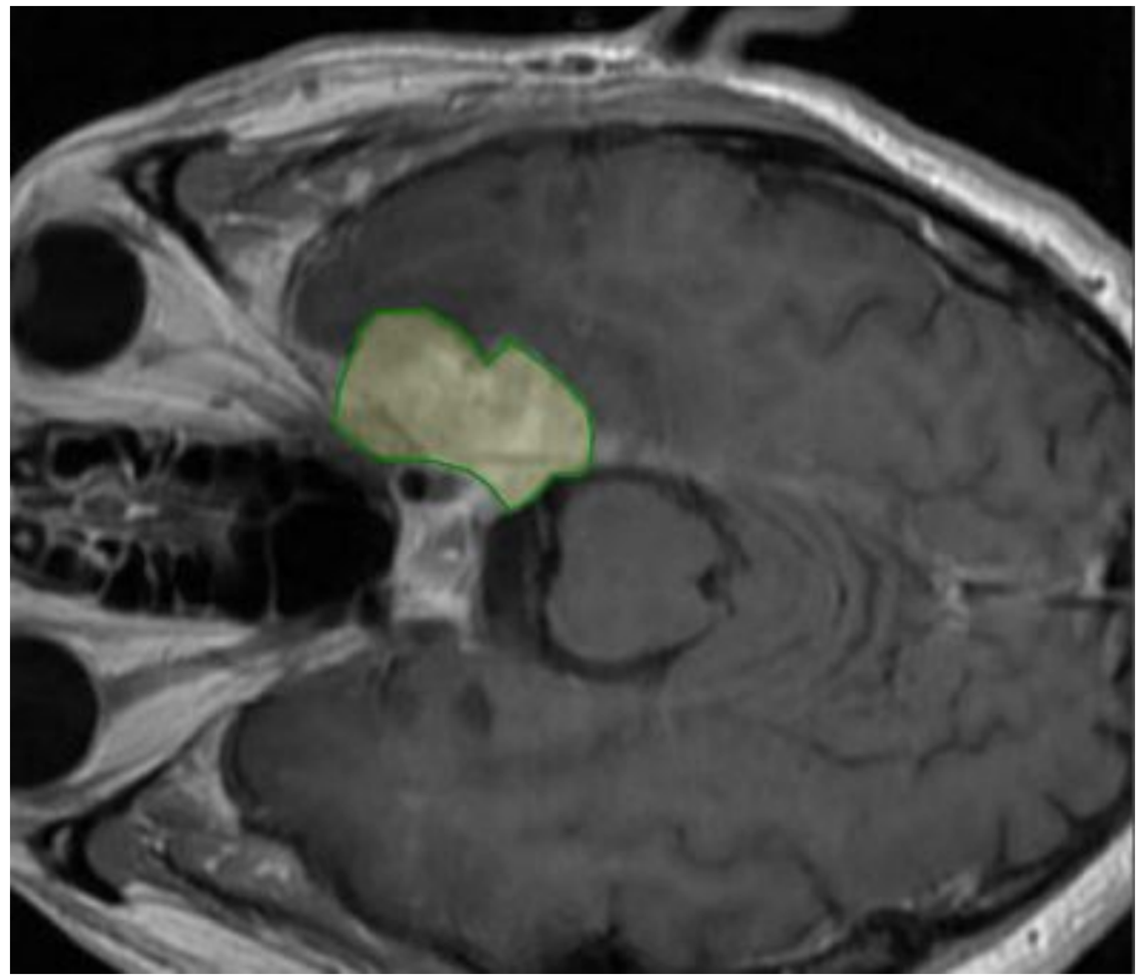
Treatment Planning

Plan **in time** of radiation therapy, where it's crucial to **target only the tumor** cells without affecting the surrounding healthy tissue.

Data Sourcing and Image Annotation



Original Image



Annotated Image

1
Dataset
The dataset we use is a publicly available dataset on Roboflow containing annotations.

2
Annotate
To demonstrate the annotation process, we annotate a few images ourselves using the tool ImgLab.

3
Download Annotations
The annotations we download from ImgLab are in COCO json format.

4
Convert Annotations
With Python, we convert the annotations into Yolo txt format.

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Hyperparameter Tuning

mAP50 metric		OPTIMIZERS						
		SDG	Adam	Adamax	AdamW	NAdam	RAdam	RMSProp
YOLO VERSION	8n	0.722	0.552	0.719	0.597	0.581	0.744	0.0473
	8s	0.792	0.571	0.698	0.576	0.548	0.643	2.58E-05
	8m	0.776	0.412	0.702	0.443	0.414	0.594	0.0497
	8l	0.804	0.4	0.6634	0.327	0.258	0.606	2.96E-06
	8x	**0.806**	0.231	0.546	0.211	0.315	0.514	0.000614

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Our Final Model

Object Detection - Instance Segmentation

Final Model

- Version: **YOLOv8x**
- Optimizer: **SGD**
- Imgsz: **640**
- Epochs: **30**
- Patience: **2**

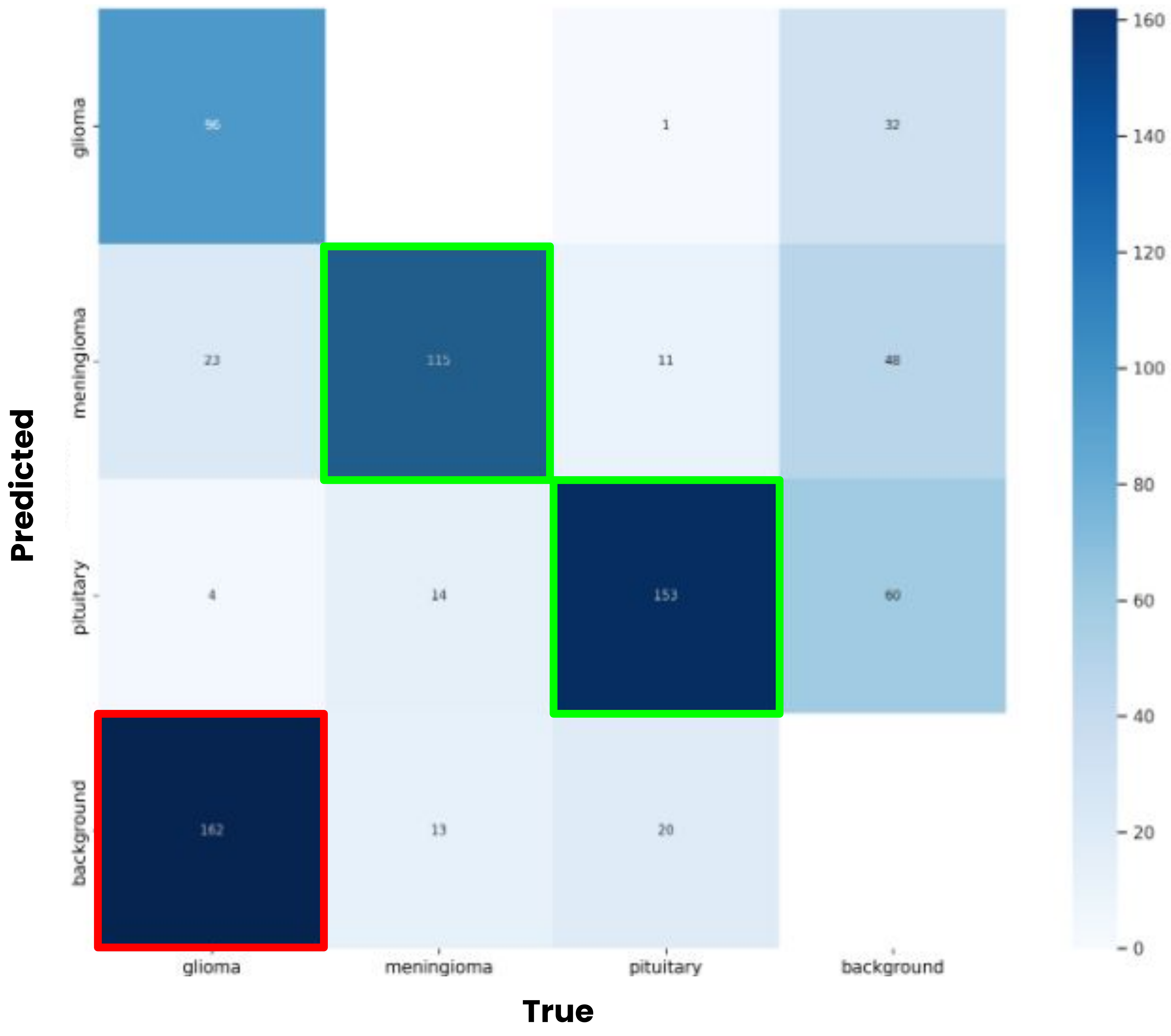
Validation Accuracy

- Pituitary: **0.863**
- Meningioma: **0.865**
- Glioma: **0.515**

Notes on performance

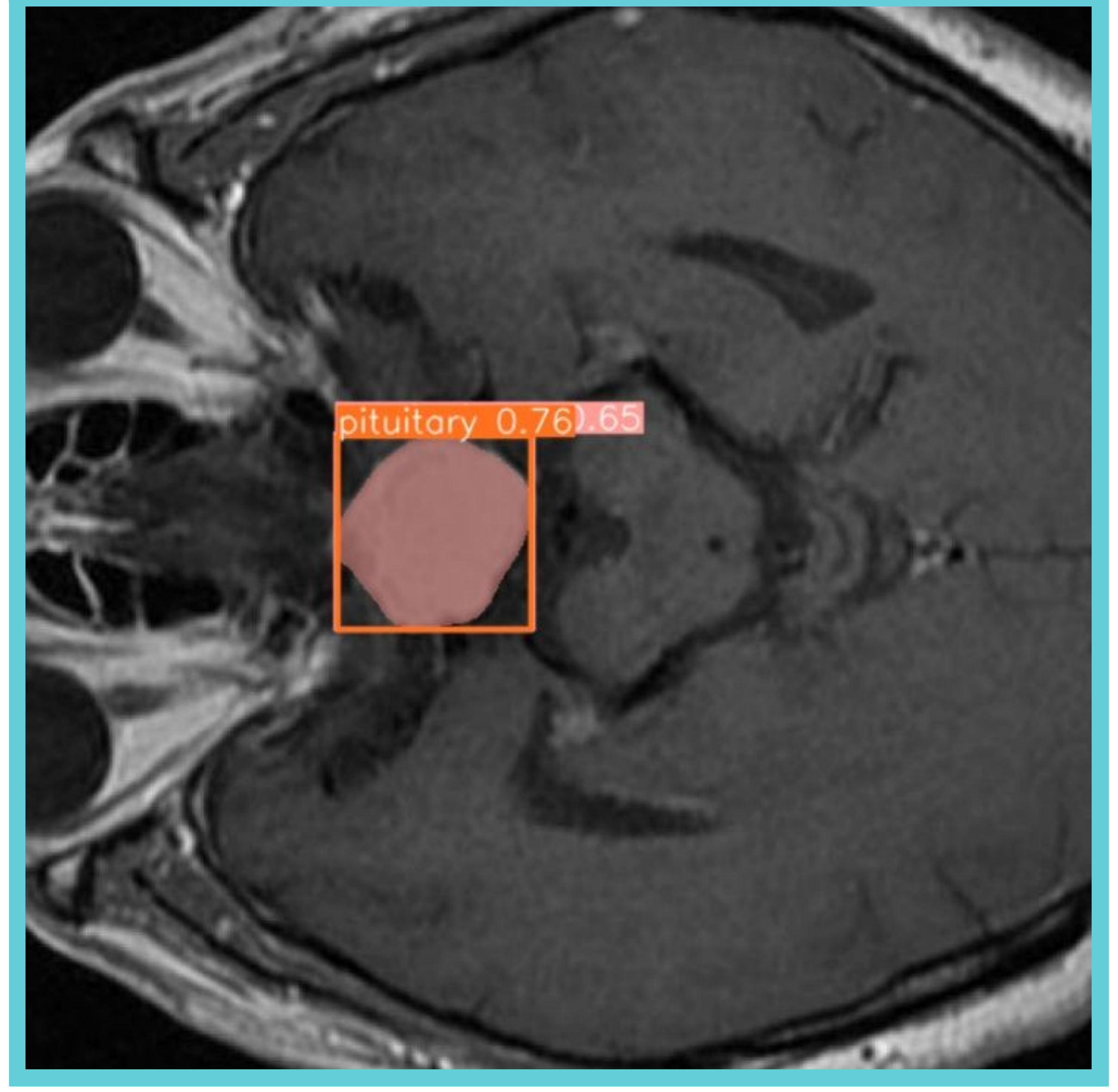
Lower performance on “glioma” class depends on the varying nature of the tumor, it should be ideally be discussed with an oncology expert.

Confusion Matrix



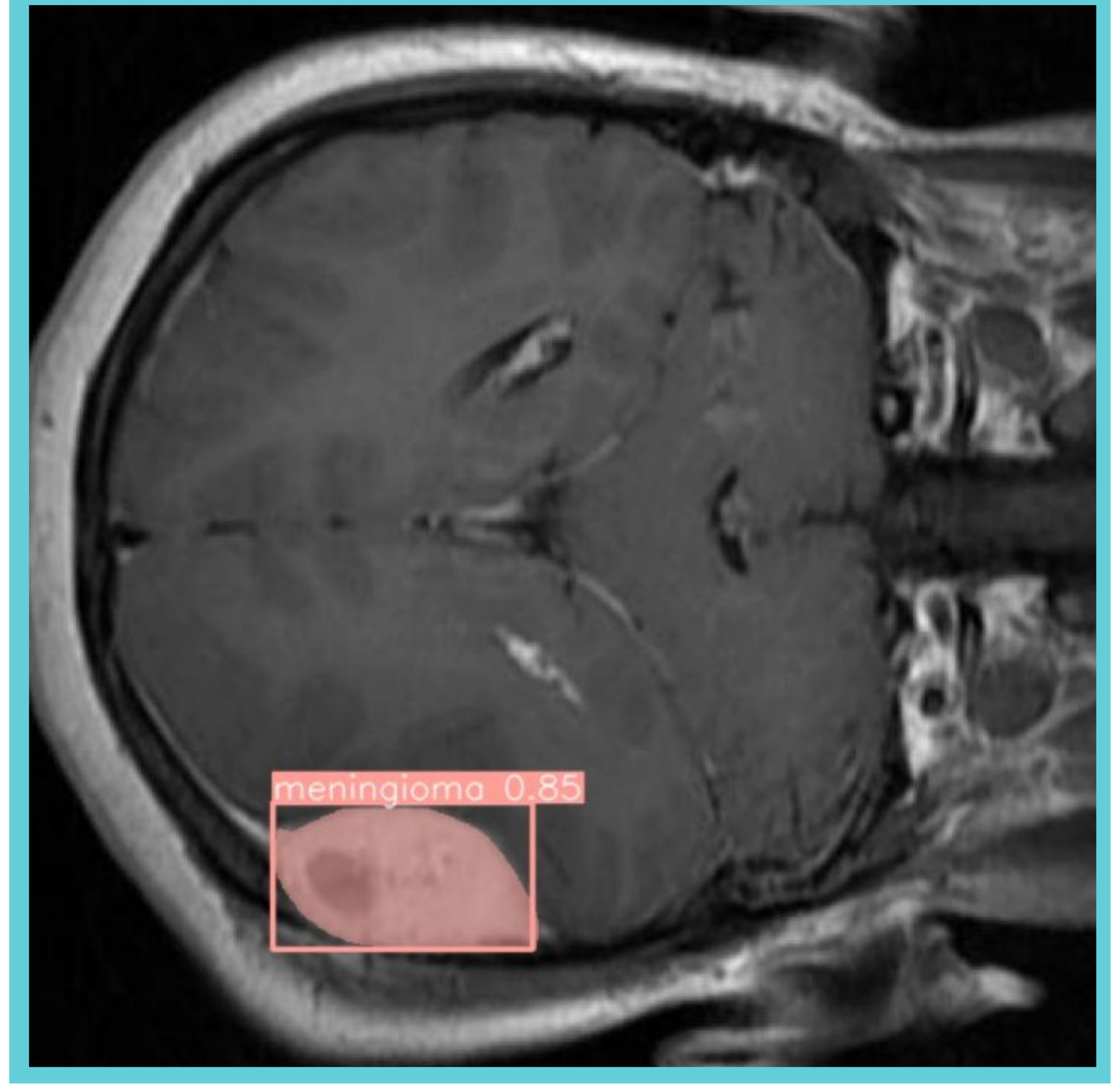
Examples of inferences on unseen data

Pituitary



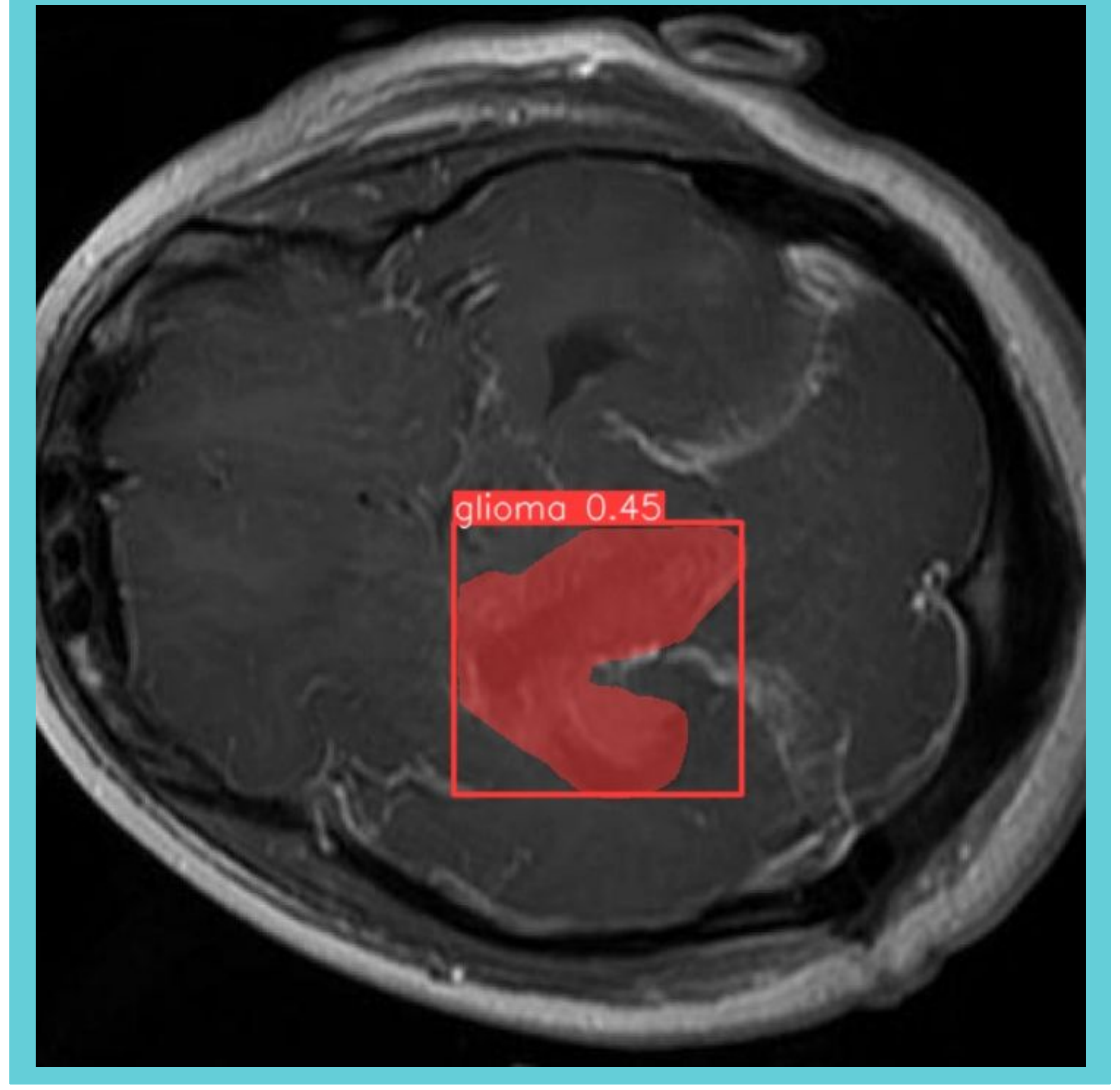
With class-specific validation accuracy of **0.863** we can see from this first image that the Pituitary tumor is correctly detected.

Meningioma



With a class-specific validation accuracy of **0.865** we can see from this first image that the Meningioma is correctly detected.

Glioma



This class proved to be the hardest to detect, with a validation accuracy of **0.515**.
We can spot a low object-detection confidence of **0.45**.

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Live Demo

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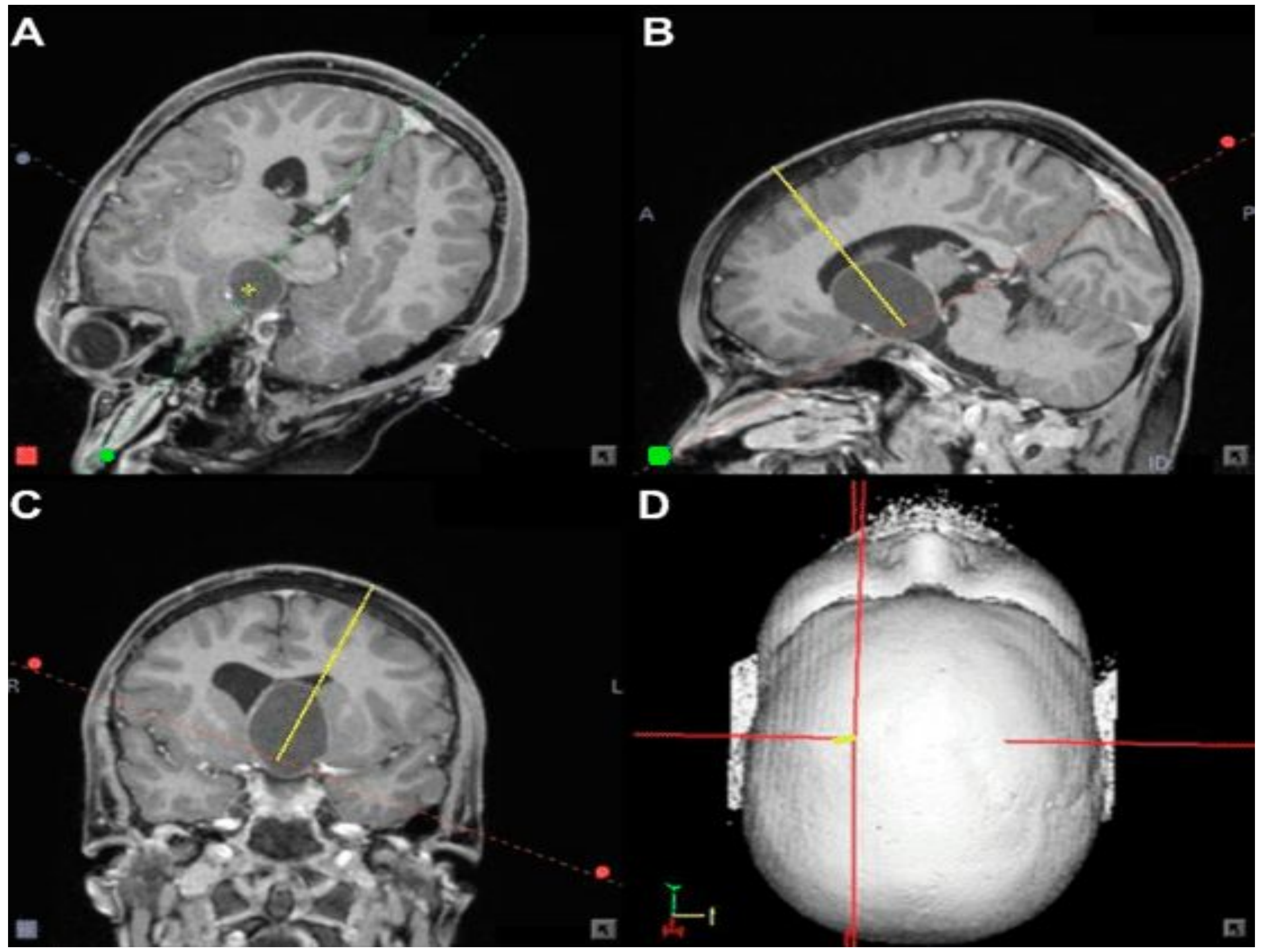
Robotic Assisted Brain Surgery



1. **Pre-operative Image Processing**
   High-resolution MRI or CT scans preprocessed through a Computer Vision Pipeline.

2. **Tumor Segmentation Model**
   The model has to be been trained to distinguish between tumor tissue and healthy tissue, effectively classifying each pixel as either being part of the tumor or not

3. **3D Reconstruction**
   Segmented Images are processed through a CV 3D Reconstruction to understand spatial relationship of the tumor with other structures.

4. **Intraoperative Guidance**
   Surgical robot uses the data from the segmented 3D model, along with the surgical plan, to precisely navigate and assist the surgery.

5. **Real-time Updates**
   Additional real-time images may be taken and analyzed by the segmentation model to enhance particular assistance situations.

Possible future improvements

Improve 3D Segmentation

Most current methods focus on 2D images or slices of 3D volumes. **Direct 3D segmentation** could potentially provide better results since it can leverage spatial information in all three dimensions, not just two.

Integration of multimodal data

Models could be trained to incorporate **multimodal medical data** such as MRI, CT, video, PET scans, to create a more comprehensive image of the brain.

Improve on real-time segmentation

Enhance the integration of these computer vision models with robotic surgical systems, **enabling real-time, precision-guided surgery.**

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Thanks for the attention!

Q&A

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