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Intracranial Aneurysm Detection using Spherical Representations



Youssef Assis¹, Liang Liao^{1,2,3}, Fabien Pierre¹, René Anxionnat^{2,3}, Erwan Kerrien¹

¹ University of Lorraine, CNRS, INRIA, LORIA, F-54000 Nancy, France

² Department of Diagnostic and Therapeutic Neuroradiology, University of Lorraine, Nancy, France

³ IADI, INSERM U1254, University of Lorraine, Nancy, France



Context & Contributions

- **Context:** Detection of unruptured Intracranial aneurysms is a difficult problem.
- **Goal:** - Automate aneurysm detection.
- Assist radiologists in their clinical routine.
- **Contributions:** - Efficient data sampling strategy.
- 3D adaptation of the YOLO [4] architecture.
- More adapted evaluation metrics.

Introduction

- **Intracranial aneurysms:** local dilatations of cerebral blood vessels (Figure 1, red arrows).
- Extremely difficult detection problem:
 - **Data scarcity:** - Small and private datasets.
- 0 to 5 aneurysms per patient.
 - **Class imbalance:** very small structures ($\approx 10/1M$ voxels).
 - **Data annotation:** difficult and time-consuming.

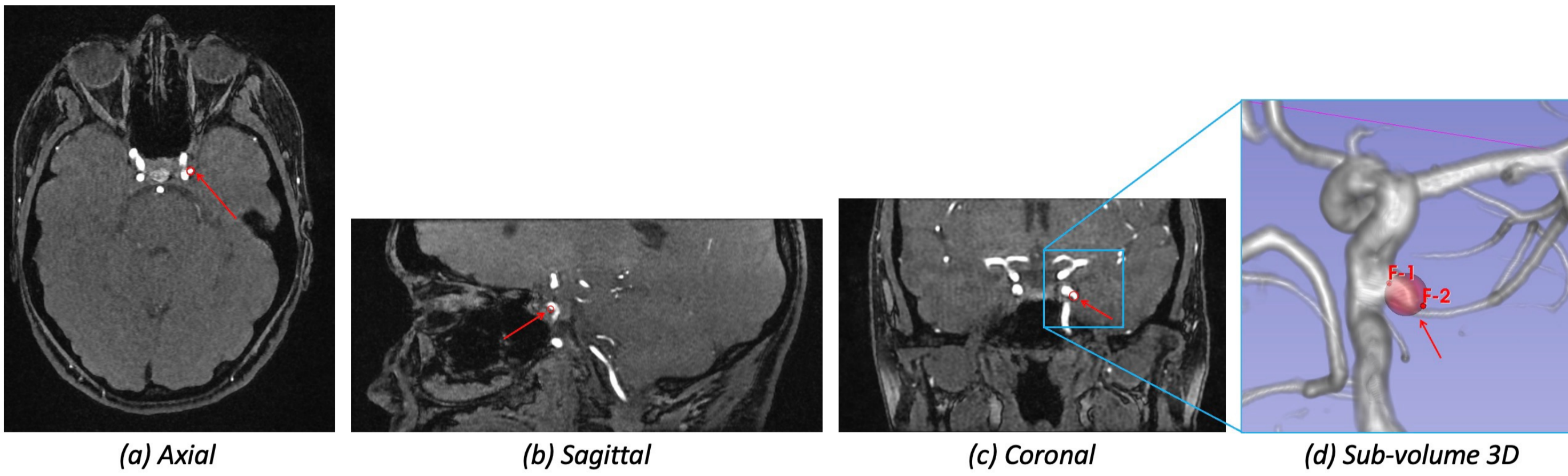


Figure 1: MRA (a,b,c) cut planes; (d) VR view (aneurysm size 3.80mm)

Method

1. Datasets: TOF-MRA images

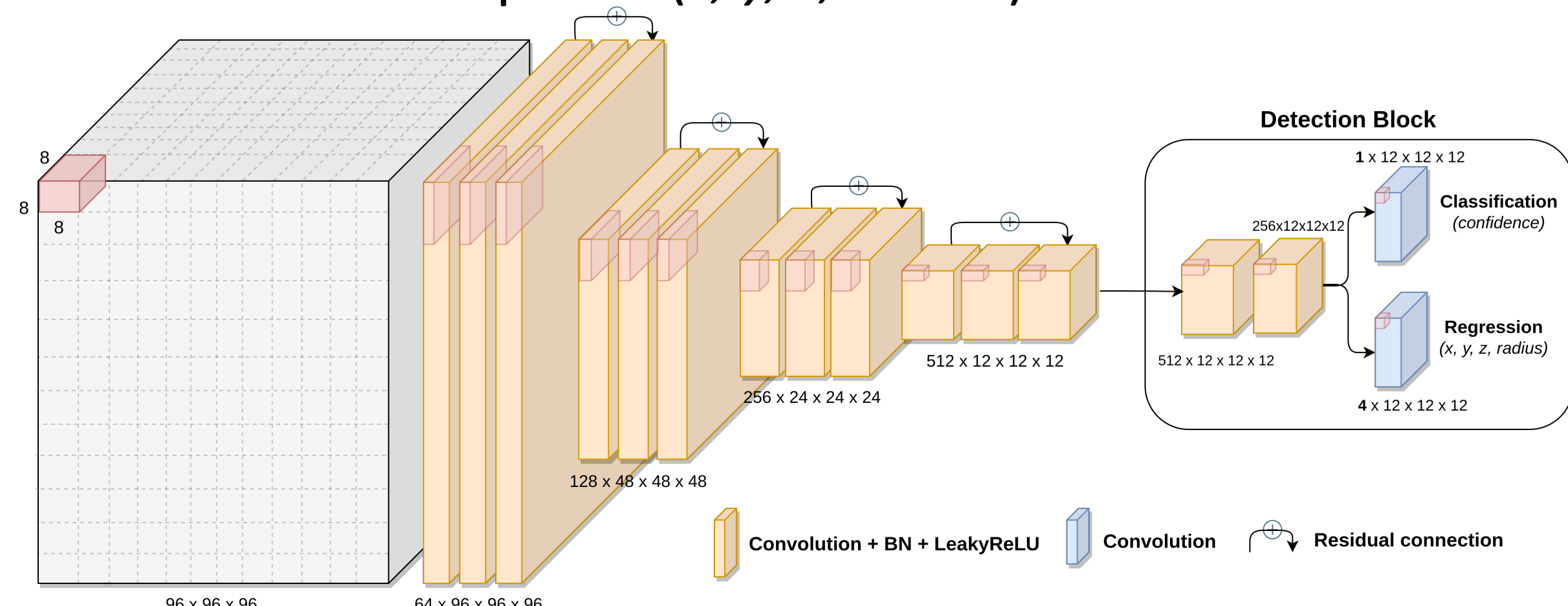
	# Subjects	# Aneurysms	Mean size
CHRU Nancy	132	206	3.97mm
CHUV Lausanne [1]	270	164	3.74mm

2. Data Sampling Strategy:

- Data annotation:**
 - Approximate and fast: 2 points \rightarrow Sphere (Figure 1).
- Small patch-based approach:**
 - 96 x 96 x 96 voxels.
 - Non-intersecting \rightarrow independent patches.
- Data selection and synthesis:**
 - Negative patches (without aneurysm): Selection 40 patches per patient; Mostly centered on blood vessels.
 - Positive patches (with aneurysm): Synthesis 50 duplicates and deformation by random distortion.

3. Deep Neural Network Architecture:

- 3D anchor-free adaptation of the YOLO [4] architecture.
- Detection \rightarrow Sphere ($x, y, z, radius$) + confidence score.



4. Evaluation:

- Based on Intersection-over-Union metric (TP = IoU > 10%).
- Average Precision (AP), Sensitivity, False positives per case.

Experimental Study

1. Preliminary study: CHRU Nancy

- **Ablation study confirms our data sampling strategy:**
 - Data selection and synthesis.
 - Spherical representation \gg Box representation.
 - Anchor-free \gg Anchor-based.
- Results (5-Fold cross validation):
 - Average Precision: 81.22%.
 - Sensitivity: 81.55% associated with 0.57 FP/case.

2. Validation with public dataset: CHUV Lausanne [1]

- 5-Fold cross validation.
- Very competitive results.
- Reduced training and inference time.

	Average Precision (%)	Sensitivity (%)	FP/case	Training Time
nnDetection [2]	73.68	84.76	0.67	29 hours
nnUnet [3]	72.46	71.95	0.13	5 days
Ours	75.80	84.76	0.57	24 hours

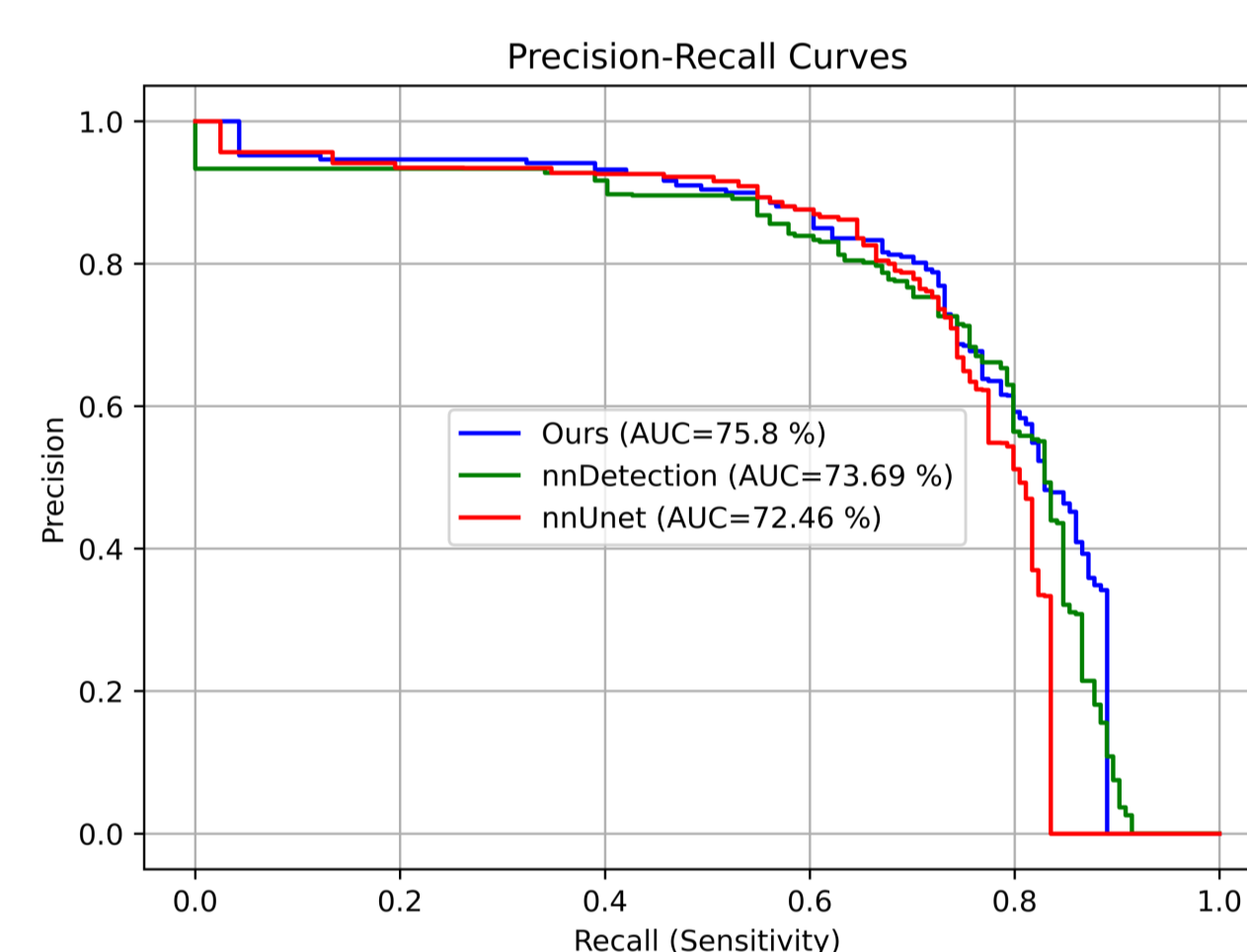


Figure 3: Precision-Sensitivity curves

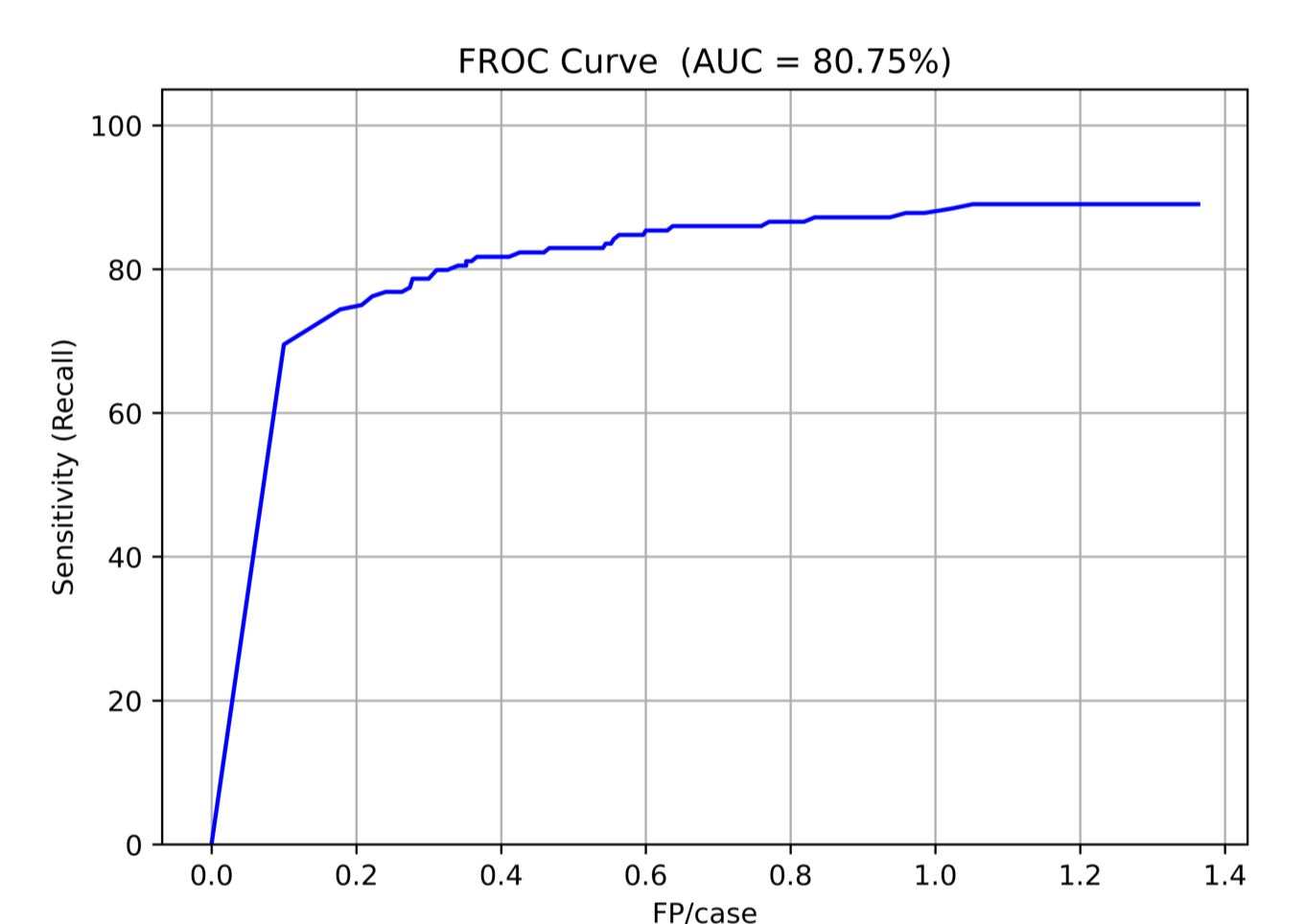


Figure 4: FROC curve of our method

Visual Results

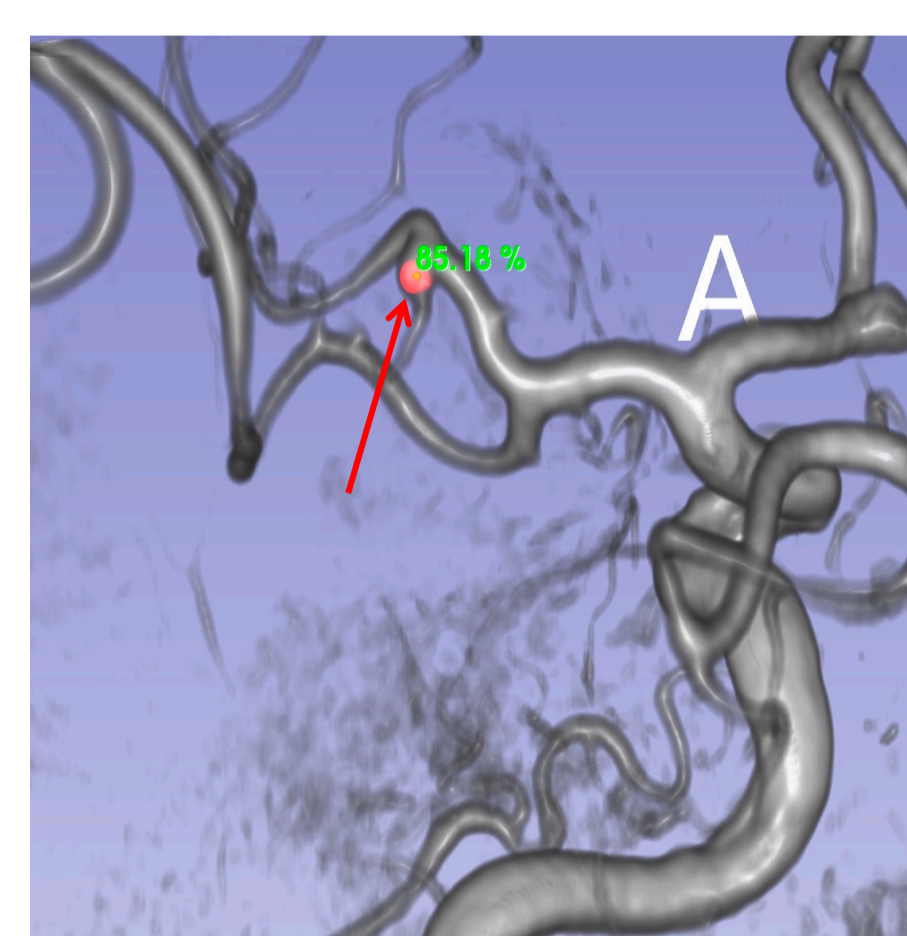


Figure 5: Branching of small arteries can be mistaken for an aneurysm (false positive)

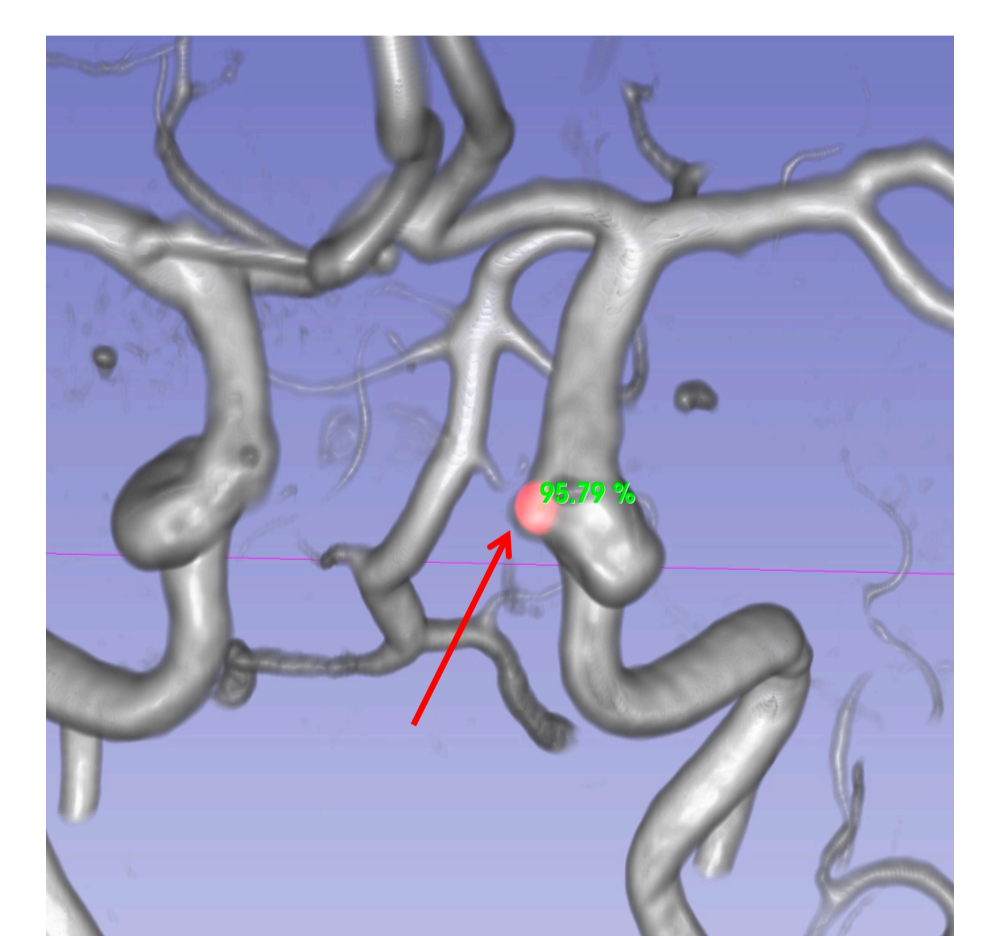


Figure 6: A detected aneurysm that was overlooked during the annotation phase (Expert sensitivity < 100%)

Conclusion & Perspectives

- Combination of an efficient data sampling strategy with a 3D YOLO architecture for aneurysm detection.
- Can be easily adapted for small object detection problems.
- **Perspectives:** combine and improve the performance with recent training techniques from 2D object detection.

References

- [1] Di Noto et al. Towards automated brain aneurysm detection in TOF-MRA: open data, weak labels, and anatomical knowledge, Neuroinformatics, 2022.
- [2] Baumgartner et al. nnDetection: a self-configuring method for medical object detection. MICCAI, 2021.
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- [4] Redmon et al. Yolov3: An incremental improvement, arxiv preprint, 2018.