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Intracranial Aneurysm Detection using Spherical Representations



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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.

Experimental Study

- 1. Preliminary study: CHRU Nancy
 - Ablation study confirms our data sampling strategy:
 - Data selection and synthesis.
 - Spherical representation >> Box representation.
 - Anchor-free >> Anchor-based.
 - Results (5-Fold cross validation):
 - Average Precision: 81.22%.

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 (≈10/1M voxels).
 - Data annotation: difficult and time-consuming.

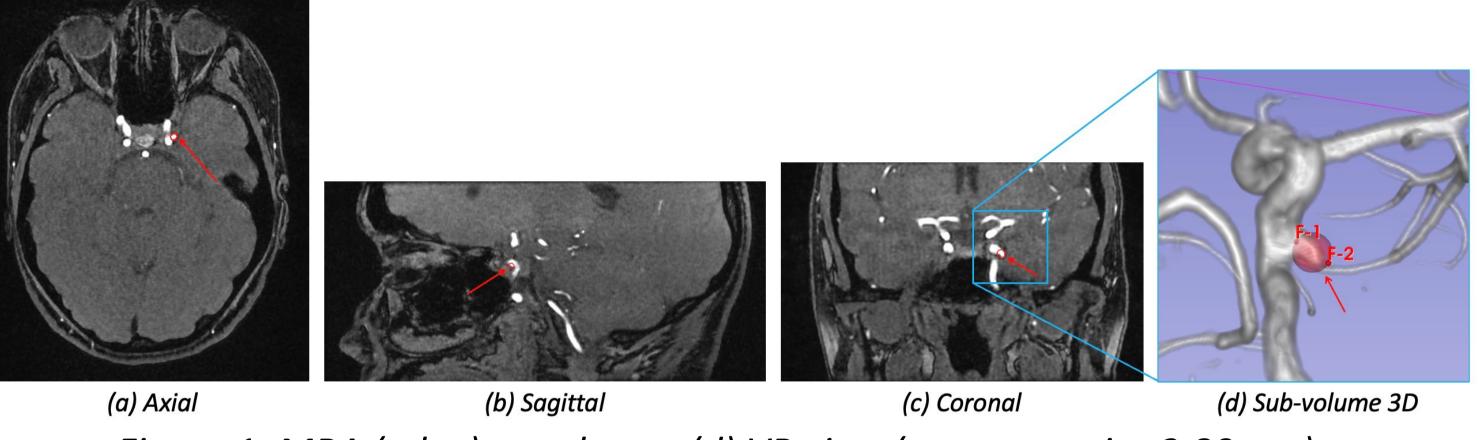
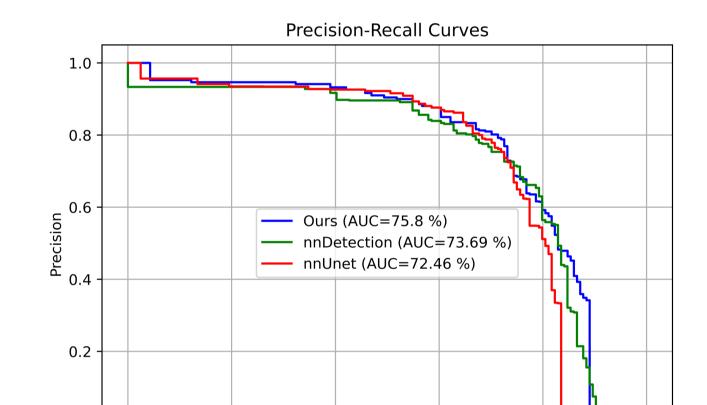
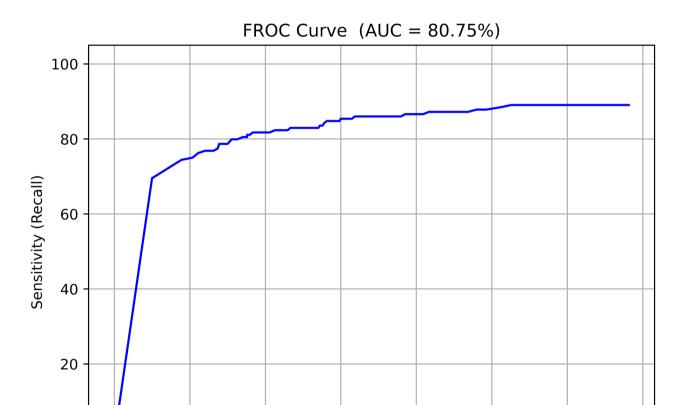


Figure 1: MRA (a,b,c) cut planes; (d) VR view (aneurysm size 3.80mm)

- 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





Method

1. Datasets: TOF-MRA images

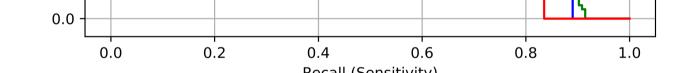
	# Subjects	# Aneurysms	Mean size
CHRU Nancy	132	206	3.97mm
CHUV Lausanne [1]	270	164	3.74mm

- 2. Data Sampling Strategy:
 - a) Data annotation:
 - Approximate and fast: 2 points \rightarrow Sphere (Figure 1).
 - b) Small patch-based approach:
 - 96 x 96 x 96 voxels.
 - Non-intersecting \rightarrow independent patches.

c) 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:



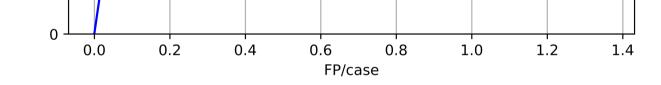
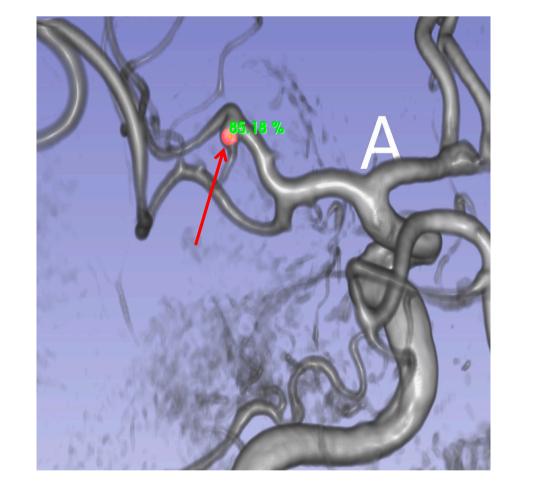


Figure 3: Precision-Sensitivity curves

Figure 4: FROC curve of our method

Visual Results



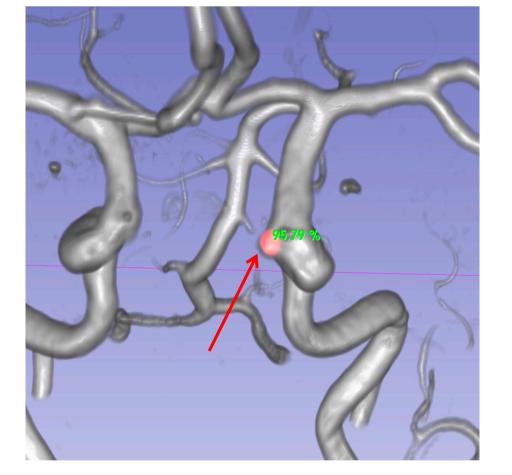
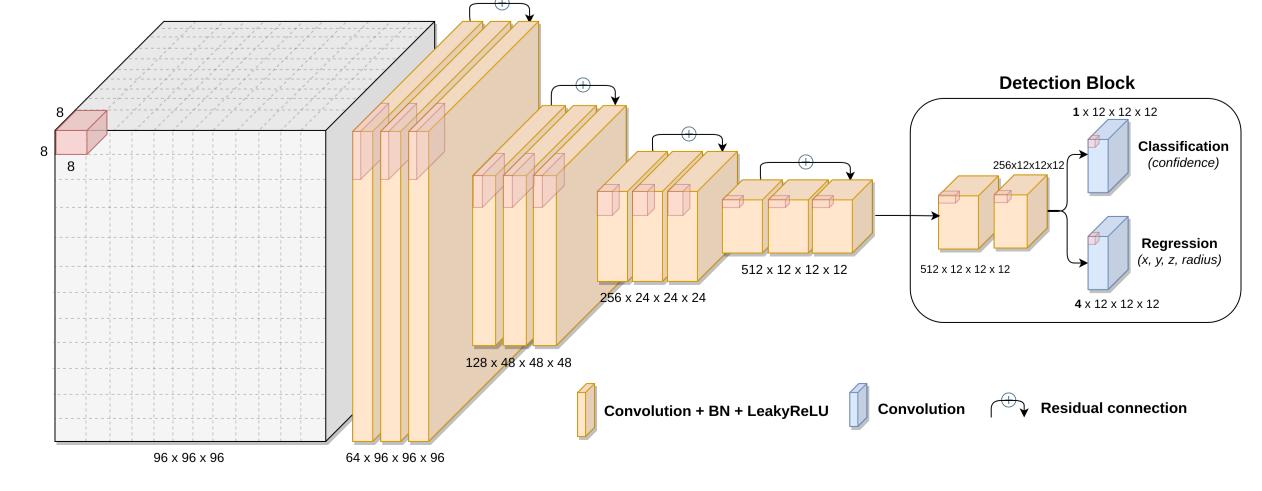


Figure 5: Branching of small arteries can be mistaken for an aneurysm (false positive)

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.
- 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.

- Can be easily adapted for small object detection problems.
- **Perspectives:** combine and improve the performance with recent training techniques from 2D object detection.

References

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- [4] Redmon et al. Yolov3: An incremental improvement, arxiv preprint, 2018.