Aneurysm Pose Estimation with Deep Learning

Youssef Assis[1], Liang Liao[1,2,3], Fabien Pierre[1], René Anxionnat[2,3], Erwan Kerrien[1]

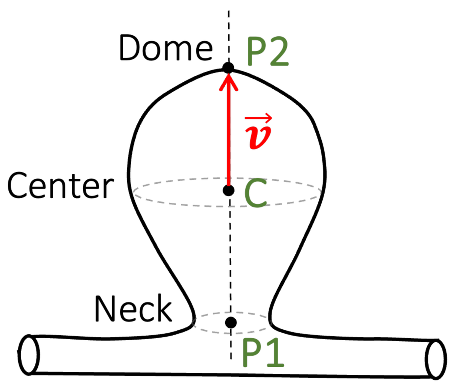
[1] Université de Lorraine, CNRS, Inria, LORIA, F-54000 Nancy, France
[2] CHRU-Nancy, Department of Diagnostic and Therapeutic Interventional Neuroradiology, Nancy, France
[3] Université de Lorraine, Inserm, IADI, F-54000 Nancy, France

Context & Contributions

- **Context**
  - Challenging clinical problem: unruptured brain aneurysm detection and assessment from TOF-MRA data.
  - Need for automated and appropriate visualization of candidate aneurysms.
- **Contributions**
  - End-to-end CNN for pose estimation and object detection tasks.
  - Efficient data sampling strategy.
  - Evaluation metrics tailored to the problem.

Introduction

- **Brain aneurysms:**
  - Local dilatations of cerebral blood vessels.
  - Mostly ball-shaped objects.
- **Objectives:** Reformatted plane → Automated view
  - Analyze connection to parent vessel.
  - Similar to the DSA projection used for coiling.



- **Challenges:**
  - **Data scarcity:**
    - Small and private datasets.
    - 0 to 4 aneurysms per patient.
  - **Class imbalance:** very small structures (≈10/1M voxels).
  - **Data annotation:** difficult and time-consuming.

Method

- **Datasets:** 402 subjects

TOF-MRA	# Subjects	# Aneurysms	Mean size (mm)
In-house	132	206	3.97 ± 2.32
CHUV [1] (public)	270	164	3.74 ± 2.17

- **Data Strategy**
  - **Data annotation:**
    - Approximate and fast: 2 points (P1, P2) → Sphere.
  - **Small patch-based approach:**
    - $96 \times 96 \times 96$ $voxels$ $(38.4 \times 38.4 \times 38.4\ mm)$.
    - Non-intersecting patches → independent.
  - **Data selection and synthesis:**
    - Negative patches (aneurysm-free): Selection
      - 40 patches per patient, randomly selected.
      - Mostly centered on blood vessels.
    - Positive patches (with aneurysm): Synthesis
      - 50 duplicates and deformation by random distortion.
- **Neural Network Architecture**
  - End-to-end 3D anchor-free CNN, inspired by 2D *YOLO [2]*.
  - **Pose Estimation:**
    - **Localization:** Center coordinates $\boldsymbol{C} = (C_x, C_y, C_z) = (\mathrm{P1} + \mathrm{P2})/2$.
    - **Orientation:** Size and orientation $\vec{\boldsymbol{v}} = (V_x, V_y, V_z) = (\mathrm{P2} - \mathrm{P1})/2$.
  - **Object Detection:**
    - **Spheres**: center $\boldsymbol{C}$, radius = $|\vec{\boldsymbol{v}}|$.

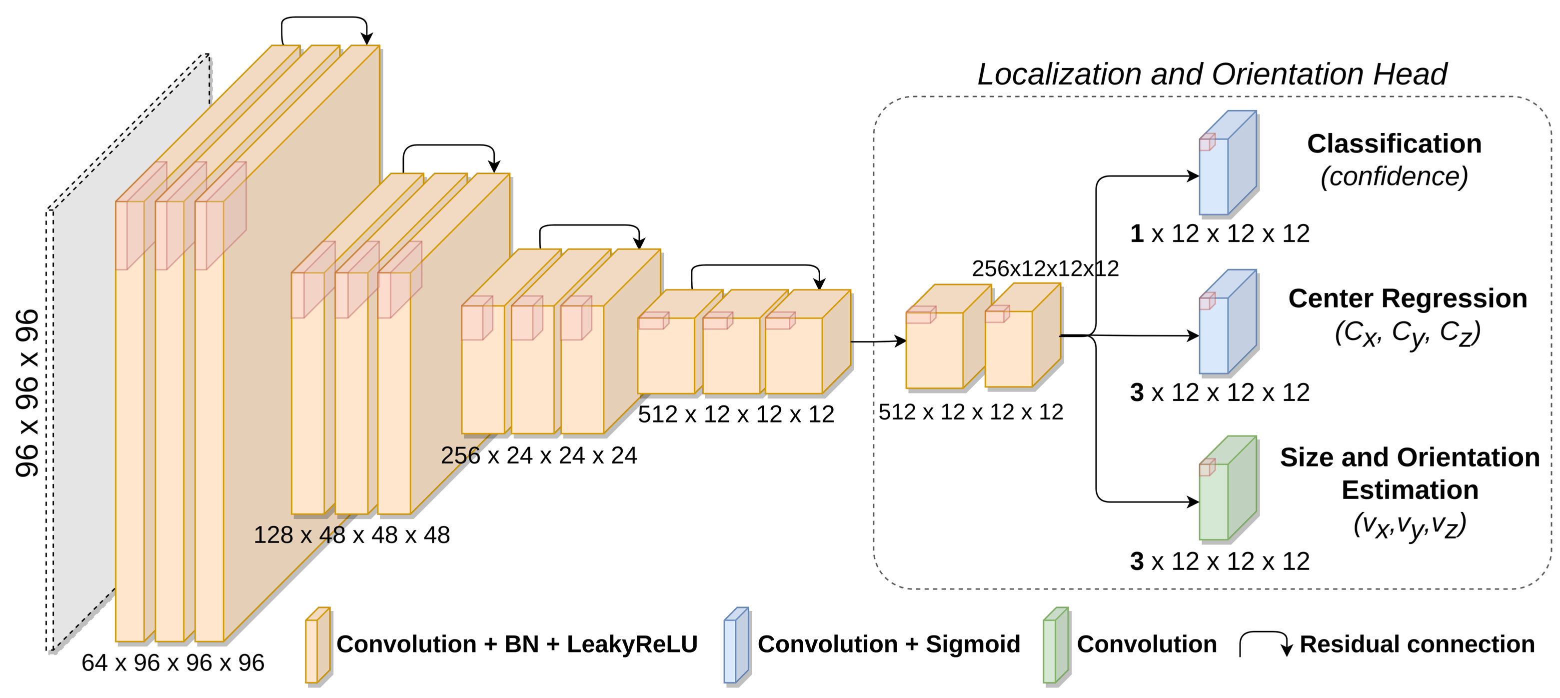


Figure 1: Our proposed aneurysm pose estimation architecture.

Experimental Study

- **Evaluation:** 5-fold cross-validation
  - Positive detection (TP):
    - Spheres (GT vs Prediction): $\mathrm{IoU} > 10\%$.
- **Pose Estimation:** no SOTA to compare with
  - **Datasets**: In-house and CHUV.
  - **Localization:** Euclidian distance *to GT center (mm)*
  - **Orientation:** Cosine similarity *to GT orientation (acos)*

	Localization (mm)		Orientation (°)	
	Median	Range	Median	Range
In-house	0.49	0.05 - 1.74	11.91	0.21 - 68.35
CHUV [1]	0.48	0.05 - 1.43	12.27	1.05 - 68.30

- **Object Detection:** Spheres ($\boldsymbol{C}$, radius)
  - **Dataset**: *CHUV* [1].
  - Compared with two fully automated SOTA baselines.

	Average Precision (%)	Sensitivity (%)	FP/case
nnDetection [3]	73.68 ± 6.38	84.76 ± 4.72	0.67 ± 0.12
nnUNet [4]	72.46 ± 4.74	71.95 ± 9.11	0.13 ± 0.06
Ours	76.60 ± 5.24	82.93 ± 5.92	0.44 ± 0.04

Qualitative Results

GT annotation (P1, P2) vs Predictions (Pred1, Pred2).

$$\mathrm{Pred}\{1,2\} = \boldsymbol{C} \pm \vec{\boldsymbol{v}}$$

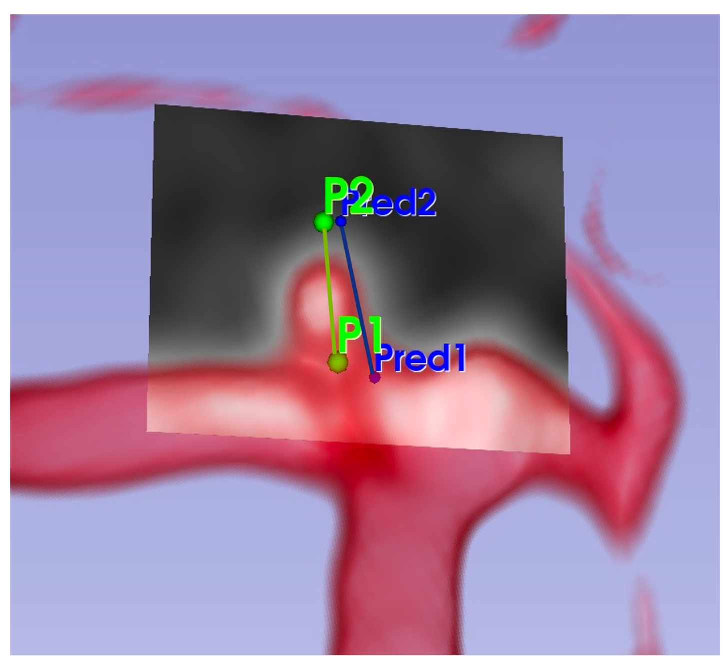


Figure 2: Detection of a very small 1.97 mm aneurysm (Error: 0.82 mm; 8.20°).

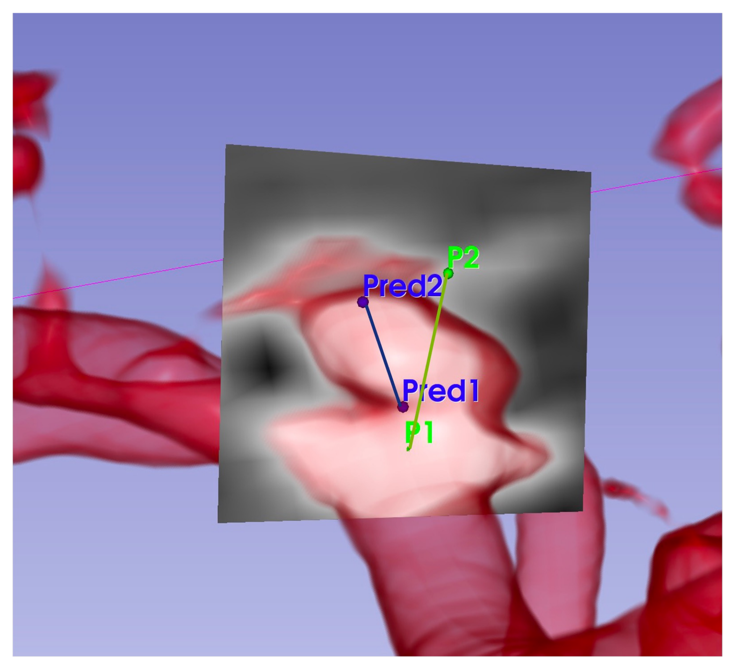


Figure 3: Large orientation error of 41.54° for a complex-shaped 3.52 mm aneurysm.

Conclusion & Perspectives

- **Conclusion**
  - The pose estimation architecture has shown promising results.
  - Can also be applied to classical object detection tasks.
  - Orientation errors are primarily due to annotation uncertainty for small and complex-shaped aneurysms.
- **Perspectives**
  - Develop a clinical definition for aneurysm orientation.
  - Conduct evaluations in clinical settings.
- Code and annotations are publicly available at: https://gitlab.inria.fr/yassis/DeepAnePose.

References

1. Di Noto et al. Towards automated brain aneurysm detection in TOF-MRA: open data, weak labels, and anatomical knowledge, Neuroinformatics, 2022.
2. Redmon et al. Yolov3: An incremental improvement, arxiv preprint, 2018.
3. Baumgartner et al. nnDetection: a self-configuring method for medical object detection. MICCAI, 2021.
4. Isensee et al. nnu-net: a self-configuring method for deep learning-based biomedical image segmentation. Nature methods, 2021.