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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.
  - 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 (>10/1M voxels).
  - **Data annotation:** Difficult and time-consuming.

Method

1. **Datasets:** TOF-MRA images

<table>
<thead>
<tr>
<th></th>
<th># Subjects</th>
<th># Aneurysms</th>
<th>Mean size</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHRU Nancy</td>
<td>132</td>
<td>206</td>
<td>3.97mm</td>
</tr>
<tr>
<td>CHUV Lausanne [1]</td>
<td>270</td>
<td>164</td>
<td>3.74mm</td>
</tr>
</tbody>
</table>

2. **Data Sampling Strategy:**
   a) **Data annotation:**
      Approximate and fast: 2 points \(ightarrow\) 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:**
   - 3D anchor-free adaptation of the YOLO [4] architecture.
   - Detection \(ightarrow\) 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 \(\rightarrow\) Box representation.
     - Anchor-free \(\rightarrow\) 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.

<table>
<thead>
<tr>
<th></th>
<th>Average Precision (%)</th>
<th>Sensitivity (%)</th>
<th>FP/case</th>
<th>Training Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>nnDetection [2]</td>
<td>73.68</td>
<td>84.76</td>
<td>0.67</td>
<td>29 hours</td>
</tr>
<tr>
<td>nnUnet [3]</td>
<td>72.46</td>
<td>71.95</td>
<td>0.13</td>
<td>5 days</td>
</tr>
<tr>
<td>Ours</td>
<td>75.80</td>
<td>84.76</td>
<td>0.57</td>
<td>24 hours</td>
</tr>
</tbody>
</table>

Visual Results

- **Figure 3:** Precision-Sensitivity curves
- **Figure 4:** FROC curve of our method
- **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