Single-View X-ray Depth Recovery
Towards a Novel Concept for Image-Guided Interventions
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Overview and Motivation

• X-ray imaging is widely used for guiding minimally-invasive surgeries
• Physicians work at the limit of their perceptual and cognitive abilities [1]
• Correct depth prediction is still hampered due to its projective nature [2]
• Estimated depth of interventional imaging is highly desirable

Methodology:

• Our framework starts with a pre-operative Computed Tomography volume.
• From this, simulated X-ray images together with their corresponding depth maps are rendered.
• For each set of M similar X-ray source configurations, we learn a dictionary and produce a corresponding Depth Atlas.
• These two will be used as prior information for the depth prediction during intervention.

1. Cluster Estimation (C-arm Pose Estimation)

\[
\text{Cluster } i = \arg \min_{i} \sum_{k=1}^{n} \sum_{j=1}^{M} \left( d_{ijk} - D_{ijk} \right)^2 + \lambda \left( \| w_{i} \|_{2} \right)
\]

2. Depth Prediction using LCKSVD algorithm [7]

\[
p_{\text{rec}}(x) = \arg \max_{p} \left( \sum_{k=1}^{n} \sum_{j=1}^{M} \left( d_{ijk} - D_{ijk} \right)^2 \right)
\]

3. Depth Recovery (Prior + Post-processing)


Evaluation: Mean Square Error (MSE), Normalized Cross Correlation (NCC), and Relative Error (RE) are reported.

Experiments & Results:

Table 1: Cluster estimation validation

<table>
<thead>
<tr>
<th>Experiment</th>
<th>MSE</th>
<th>NCC</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.04</td>
<td>0.98</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>2.27</td>
<td>0.96</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>2.40</td>
<td>0.95</td>
<td>1.4</td>
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</tbody>
</table>

Table 2: The average classification accuracy

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Abdomen</th>
<th>Thorax</th>
<th>Abdomen</th>
<th>Thorax</th>
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</thead>
<tbody>
<tr>
<td>Depth</td>
<td>0.97</td>
<td>0.95</td>
<td>0.98</td>
<td>0.96</td>
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<tr>
<td>Evaluation Metrics</td>
<td>11.3</td>
<td>11.5</td>
<td>11.7</td>
<td>11.9</td>
</tr>
</tbody>
</table>

Conclusion:

• We have presented novel concept for Single-View Depth Estimation
• We have achieved around 4.40% ± 2.04 and 11.47% ± 2.27 MSE on abdomen and thorax datasets respectively
• One focus of our future work to use deep learning together with conditional random field (CRF) to get more accurate and smoother depth map [8]
• Importantly, transfer the proposed method to real interventional X-ray images.

References: