Automatic localization and identification of vertebrae in spine CT scans by combining Deep Learning with morphological image processing techniques

Ana Jiménez-Pastor¹, Angel Alberich-Bayarri¹,², Belén Fos-Guarinos¹, Fabio García-Castro¹, Luis Martí-Bonmatí¹,³

¹ QUIBIM S.L., Valencia, Spain
² La Fe Health Research Institute, Valencia, Spain
³ La Fe Radiology Department, Valencia, Spain

anajimenez@quibim.com
Outline

- Introduction
- Purpose
- Materials
- Methods
  - Spine Centerline Detection
  - Vertebra Centroid Localization
- Results
- Conclusions
The correct **detection** and **identification** of vertebrae is essential for correct **diagnosis** and pathologies’ **follow up**
Nowadays, this localization is done **manually** or by landmarks by the specialists, **hindering** their workflow.
Main challenges on the automation of vertebrae localization in CT scans

Arbitrary field-of-view

Vertebrae similarity along the spine

Image artifacts due to metal implants
Purpose

Develop an algorithm for the **automatic** vertebrae localization and identification on arbitrary field-of-view scans

- Pipelines for the **automatic characterization** of vertebrae bone microarchitecture
- Help radiologists to perform diagnosis in a **shorter period of time**
Dataset

230 CT scans retrospectively collected:
- Arbitrary field-of-view
- Healthy and pathological cases
Methodology

Spine localization

Vertebral localization

Morphological image processing techniques

Deep Learning techniques
Methods

Methodology

Spine localization

Morphological image processing techniques

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Methods

Spine centerline detection

Original Image → Thresholding $\geq 250$HU → Dilation → NOT operation → Background removal → Small objects removal
Methods

Spine centerline detection

Spinal cannal detection → Translation to spine centerline → Outlier detection and curve fitting
Methodology

Vertebral localization

Deep Learning techniques

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Convolutional Neural Networks - Transfer learning
Convolutional Neural Networks - Transfer learning

SPECIFIC CLASSIFIER

FEATURE EXTRACTION

CLASSIFICATION
Vertebra centroid localization
### Region classifier dataset

<table>
<thead>
<tr>
<th>Region</th>
<th>Example Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic Superior</td>
<td><img src="image1" alt="Thoracic Superior example images" /> <img src="image2" alt="Thoracic Superior example images" /> <img src="image3" alt="Thoracic Superior example images" /></td>
</tr>
<tr>
<td>Thoracic Inferior</td>
<td><img src="image4" alt="Thoracic Inferior example images" /> <img src="image5" alt="Thoracic Inferior example images" /> <img src="image6" alt="Thoracic Inferior example images" /></td>
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<tr>
<td>Lumbar</td>
<td><img src="image7" alt="Lumbar example images" /> <img src="image8" alt="Lumbar example images" /> <img src="image9" alt="Lumbar example images" /></td>
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<tr>
<td>Sacrum</td>
<td><img src="image10" alt="Sacrum example images" /> <img src="image11" alt="Sacrum example images" /> <img src="image12" alt="Sacrum example images" /></td>
</tr>
</tbody>
</table>

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Vertebra centroid localization

Spine centerline detection
Vertebra – Non vertebra classifier dataset
Vertebra centroid localization

Vertebra position → Centroid calculation → Vertebra identification
Regions and spine centerline detection

Thoracic Superior
Thoracic Inferior
Lumbar
Sacrum
Vertebra detection
Centroid calculation
Vertebra identification
**Localization error (mm):** Distance between the predicted vertebra centroid and the real one

- **X < 2 mm**
- **Y < 8 mm**
- **Z < 3.5 mm**
Identification rate (%): Percentage of correctly identified vertebrae

> 87%
### DECISION FORESTS (ECR 2017)

<table>
<thead>
<tr>
<th>REGION</th>
<th>MEDIAN</th>
<th>MEAN</th>
<th>STD</th>
<th>ID. RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>10.335</td>
<td>13.734</td>
<td>10.318</td>
<td>77.99%</td>
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<tr>
<td>Thoracic</td>
<td>10.172</td>
<td>13.045</td>
<td>9.478</td>
<td>79.56%</td>
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<tr>
<td>Lumbar</td>
<td>10.710</td>
<td>15.112</td>
<td>11.716</td>
<td>74.84%</td>
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</table>

### CONVOLUTIONAL NEURAL NETWORKS

<table>
<thead>
<tr>
<th>REGION</th>
<th>MEDIAN</th>
<th>MEAN</th>
<th>STD</th>
<th>ID. RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>4.913</td>
<td>7.982</td>
<td>8.734</td>
<td>90.43%</td>
</tr>
<tr>
<td>Thoracic</td>
<td>4.123</td>
<td>7.368</td>
<td>8.695</td>
<td>89.20%</td>
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<tr>
<td>Lumbar</td>
<td>6.420</td>
<td>9.210</td>
<td>8.696</td>
<td>92.90%</td>
</tr>
</tbody>
</table>

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Conclusions

- A methodology has been developed which provides the **lowest error** on the automatic vertebrae detection and identification on CT scans.

- The localization can be addressed on **arbitrary field-of-view** scans.

- This **improves** the **radiological workflow** in spine evaluation through CT and allows the creation of **automatic pipelines** for the calculation of vertebrae **bone microarchitecture** characteristics.
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Katherine Wilisch Ramírez - Marketing Manager

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Isabel Montero Valle – Team Coordinator
Encarna Sánchez Bernabé - Chief Operating Officer
Daniel Iordanov López - Assistant to Business Development

Ángel Alberich Bayarri, PhD.
GIBI Scientific-Technical Director
QUIBIM CEO & Founder

Luis Martí Bonmatí MD, PhD.
GIBI Principal Investigator
QUIBIM Founder
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