A Robust Technique for Detecting Abdominal Aortic Calcification Using Dual Energy X-ray Absorptiometry

By
Karima M Elmasri

(1st year PhD student at Cardiff University - School of Engineering)

Under the Supervision of:

Dr. Yulia Hicks, Dr. Chris Yang; Dr. Xianfang Sun
and
Prof. Wil Evans
Outline

• **Introduction**
• Background
  • Detection of Abdominal Aortic Calcification
• Objectives
• Methods
  • Modelling of Spine and Aortic Walls
• Results
  • Active Shape Model ASM Results
  • Combine shape and appearance
  • Appearance Model Results
• Conclusion
Cardiovascular Disease (CVD)

According to the British Heart Foundation*

- Cardiovascular (heart and circulatory) disease causes more than a quarter of all deaths in the UK.
- Coronary Heart Disease (CHD) is the biggest killer.
- Nearly one in six men and one in ten women die from coronary heart disease.
- Stroke causes more than 40,000 deaths in the UK each year.

* BHF Headline Statistics, British Heart Foundation, 2015
Cardiovascular Disease (CVD)

• The most common cause of cardiovascular disease is a condition called atherosclerosis.
• Atherosclerosis is a thickening of the walls of arteries due to plaque deposition.
• The presence of atherosclerosis is one of the main triggering factors for cardiovascular diseases.
• Abdominal Aortic Calcification (AAC) is a manifestation of atherosclerosis, and a predictor of subsequent vascular associated morbidity and mortality.
• Many patients at high risk of cardiovascular disease are also at high risk of fracture due to osteoporosis.
• Introduction
• **Background**
  • Detection of Abdominal Aortic Calcification
• Objectives
• Methods
  • Modelling of Spine and Aortic Walls
• Results
  • Active Shape Model ASM Results
  • Combine shape and appearance
  • Appearance Model Results
• Conclusion
Detection of AAC

- Abdominal radiography
- Abdominal Computed Tomography (CT)
- Dual Energy X-ray Absorptiometry (DXA)
  - DXA is used to measure bone mineral density for the diagnosis and monitoring of osteoporosis at skeletal sites such as spine and hip.
  - Lateral spine imaging – sometimes called Instant Vertebral Assessment (IVA) – is often done as part of DXA investigation.
  - On IVA images AAC is typically seen as a linear stripping in the anterior and posterior walls of the aorta.
- IVA as part of DXA offers a diagnostic that can be used to assess osteoporosis and cardiovascular disease.
Background

IVA is usually performed in single energy (SE) mode.
Problems with single energy (SE) IVA Images

- Variations in soft tissue composition within the X-ray beam.
- Artefacts due to metal or clothing.
- Beam hardening
- Combined effect is to make it very difficult to distinguish the calcified aorta from surrounding soft tissue.
• Introduction
• Background
  • Detection of Abdominal Aortic Calcification
• Objectives
• Methods
  • Modelling of Spine and Aortic Walls
• Results
  • Active Shape Model ASM Results
  • Combine shape and appearance
  • Appearance Model Results
• Conclusion
Objectives

• To develop a technique for the automatic detection of AAC in IVA images.
  • Segmentation of aorta based on its position relative to the lumbar spine.

• To develop a method of quantifying AAC.
  • Optimization for robustness, accuracy, and speed.
Outline

• Introduction
• Background
  • Detection of Abdominal Aortic Calcification
• Objectives
• **Methods**
  • Modelling of Spine and Aortic Walls
• Results
  • Active Shape Model ASM Results
  • Combine shape and appearance
  • Appearance Model Results
• Conclusion
Methods

- Active Shape Models (ASM) and Active Appearance Models (AAM) used to segment the lumbar spine (L1 to L4) and the aortic walls.

- ASM segmentation algorithm identifies the location and shape of structures in a target image.
  - Good at dealing with noisy data.

- AAM identifies the texture of the objects extracted by shape model.
  - Generates new image corresponding to the object of interest.

- The models are based on the use of prior knowledge of what is expected in the image.

- This approach has been used with conventional lateral radiographs of the abdomen but this project extends it to IVA images acquired during DXA.
Modelling of Spine and Aortic Walls

Method developed using a training set of 14 IVA images in which a calcified aorta can be seen clearly.

IVA Images → Pre-Processing: Histogram Equalization → Land Marks → Alignment → ASM & AAM
Labelling the shapes – Manual Process

Identify by eye 6 points in each vertebra and 20 points on the anterior and posterior aortic walls – “Landmark Points”

Aligning the training set

- Scaling and translation of the landmark point to the origin of a new image matrix

ASM & AAM

- Principal Component Analysis (PCA)
- Shape Variation
- Texture Variation
- Shape & Texture Variations
• Introduction
• Background
  • Detection of Abdominal Aortic Calcification
• Objectives
• Methods
  • Modelling of Spine and Aortic Walls
• **Results**
  • Active Shape Model ASM Results
  • Combine shape and appearance
  • Appearance Model Results
• Conclusion
### Shape Variation – Results

<table>
<thead>
<tr>
<th>Mode</th>
<th>Variation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>87</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>1.3</td>
</tr>
</tbody>
</table>
First five modes of shape variation

Mode 1

Mode 2

Mode 3

Mode 4

Mode 5
Active Shape Model ASM - Results

Search using ASM

ASM to Search an Image

• Initial position estimation

• Find the best fit data

• Model parameters adjustment

• Apply global constraints to keep model consistent.
Search using ASM of IVA images, given a poor starting point
Combine shape and appearance

Original Texture

Texture made by combine shape and appearance models
Model intensities result - AAM

Real and model intensities

Model intensities

Real intensities
Outline

- Introduction
- Background
  - Detection of Abdominal Aortic Calcification
- Objectives
- Methods
  - Modelling of Spine and Aortic Walls
- Results
  - Active Shape Model ASM Results
  - Combine shape and appearance
  - Appearance Model Results
- Conclusion
Conclusion

• It is possible to identify the location of the aorta based on the position of the lumbar spine using ASM and AAM.
  • The process takes only seconds.

• The searching process in both ASM and AAM can be improved by increasing the number of images in the training set.
  • The model can be tested on any other IVA image.

• A method to quantify the severity of aortic calcification in the segmented IVA images will be developed.
Thank You

Questions