A Semi-Automatic Methodology for Segmentation of the Coronary Artery Tree from Angiography

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Summary

- Introduction
- Definitions
- Motivation
- Problem Statement
- Objective
- Methodology
- Challenges
- Some Results
- Vessel Resemblance Function
- Next Steps
Medical diagnostics using images has a considerable importance in many areas of medicine.
Definitions

- Coronary arteries are the set of arteries that deliver blood to the heart muscle.

- Angiographies are images acquired from an X-Ray apparatus for vessels analysis.

- Coronary artery disease (CAD) can be identified from angiography analysis.

- Stenosis is the narrowing in any artery.
Motivation

- Statistics show that vessels diseases are one of the biggest reasons for mortality in the world.

- Between 3.6% and 6% of the world population is suffering of any kind of aneurism and/or stenosis.
Motivation

- Stenosis example.
Motivation

- Traditional methods for stenosis analysis are based on the doctor’s personal experience and visual evaluation.

- A computational approach for stenosis analysis has many advantages.

- An important step for the stenosis analysis is the blood vessels detection.
Problem Statement

Given a digital angiography from an X-Ray CathLab apparatus, the problem is to extract the cardiac coronary tree with the maximum branches as possible.

Challenges on this approach:
- Complex nature of vessels tree
- Imperfection on the images (noise)
- Brightness and contrast non-uniforms
Objective

- To develop an approach for a Semi-Automatic Segmentation of the cardiac coronary artery tree from angiographies
The artery identification is based on a threshold applied to ROI around a seed point. This seed point is given by the doctor with a mouse click.
Methodology

- In the circle area, all the pixels intensities are evaluated to find a good local threshold to identify which ones belong to the coronary

- After that, it is possible to compute the artery diameter

- In both artery identified ends, the diameter is computed and its mean point is the center of new circles
Methodology
Methodology

- The process continues until the circle radius is smaller than a minimum specified.

- Connected components is used to avoid non-vessel points being seen as vessels points.
Challenges

- Circle radius – Depends on the image resolution, artery diameter, algorithm for thresholding, image quality

- Algorithms for thresholding (Niblack, otsu, sauvola, etc)

- Images with different brightness and contrast depending on the patient weight
Some Results

Niblack and 0.01 of std.
Radius = Diameter
Some Results

*Niblack and 0.01 of std.*

*Radius = Diameter*
Some Results

Niblack and 0.01 of std.
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Some Results

Demo Movie
This approach gives a vessel resemblance value for each pixel in the image.

- It works with feature image.
- It works with different scales.
Hessian Matrix $H$

$$G = \{(u, v, z) \mid z = g(u, v)\}$$

$$H(x) = \begin{bmatrix} g_{uu}(x) & g_{uv}(x) \\ g_{vu}(x) & g_{vv}(x) \end{bmatrix}$$

$$g_{ab}(x; \sigma) = \sigma^2 h_{ab}(x; \sigma) \ast g(x)$$
Eigenvalues of Hessian

- Strongest Eigenvalue gives the strength of the 3D surface

- The artery is a dark region against a brighter background – First derivative increases which means a positive value for the first eigenvalue

- All we need is to sort these eigenvalues and get the strongest positive ones as possible artery points.

\[ |\lambda_1| \geq |\lambda_2| \]
Resemblance function

\[ V(x; \sigma) = \begin{cases} 
0 & \text{if } \lambda_1 < 0, \\
\exp(-\frac{R_B^2}{2\beta_1^2}) \left[ 1 - \exp\left(-\frac{S^2}{2\beta_2^2}\right) \right] & \text{otherwise}
\end{cases} \]

\[ R_B = \frac{|\lambda_2|}{|\lambda_1|} \quad S = \sqrt{\lambda_1^2 + \lambda_2^2} \]
\( \beta_1 = 1.0, \beta_2 = 8.0 \) and \( \sigma \) between 2 and 4
Next Steps

- To combine these approaches as a possible solution to avoid branch missing.

- Which global method to use?
  - Scaling Variations?
  - Mathematical Morphology?
  - Differential Geometry?
Some References


Questions