Tortuosity measurements



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Outline

Introduction

Tortuosity measurements

measurements

- Arc Length Over Chord Length Ratio
- tc/tsc over Arch length/Chord Length
- Mean direction Angle Change
- Inflection Count Metric
- Proposed method of the article

Summary



Introduction



Page 3

Based on article:

- A Novel Method for the Automatic Grading of Retinal Vessel Tortuosity
- Enrico Grisan, Marco Foracchia, and Alfredo Ruggeri
- IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 27, NO. 3, MARCH 2008

Requirements:

 For an automatic measurement a segmentation and thinning algorithm is needed

Arc Length Over Chord Length Ratio (implemented)

- Chord Length:
 - Distance of end points (L_x)
- Arc Length:
 - The real length of the curve (L_c)
- Measurement:
 - The tortuosity is the ratio of the 2 lengths
- Problems:
 - A curved, but not tortuous vessel can have a high value too
 - Highly depends on amplitude, and low dependency on frequency



Measures Involving Curvature (implemented)

Definitions:

- s(l) is the curved line
- tc is absolute curvature
- tsc is squared curvature

Measurements:

 The ratio of tc/tsc and the arc/chord length

$$s(l) = [x(l), y(l)] : D \subset \mathbb{R} \to \mathbb{R}^2$$

10

$$\kappa(l) = \frac{\frac{dx}{dl}\frac{d^2y}{dl^2} - \frac{d^2x}{dl}\frac{dy}{dl}}{\left(\left(\frac{dx}{dl}\right)^2 + \left(\frac{dy}{dl}\right)^2\right)^{3/2}},$$

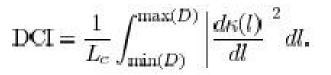
$$tc = \int_{\min(D)}^{\max(D)} |\kappa(l)| \, dl$$
$$tsc = \int_{\min(D)}^{\max(D)} |\kappa(l)|^2 \, dl.$$



Derivative of Curvature (implemented)

Measurement:

 Integral of the squared derivative of curvature





Mean direction Angle Change (not implemented yet)

Definitions:

- d_i: coordinates of the ith samplepoint
- v_{i+n} (V_{i-n}): A vector from the ith sample point to the "i +n"th ("i-n"th) sample point

$$v_{i+n} = a_{i+n} - a_i$$
$$v_{i-n} = d_{i-n} - d_i$$
$$\theta(i) = \arccos(v_{i+n} \cdot v_{i-n})$$

120

$$MAC = \frac{1}{N-2 \cdot n} \sum_{i=1}^{n} \theta(i)$$

Inflection Count Metric (implemented)



Page 8

Measurement:

 Arc length over chord length value multiplied by the "number of inflection points +1"

Proposed method of the article (not implemented yet)

Measurement:

 They segment the curved line into n segments with constant curveture (using an unknown algorithm) and summarize them using the equationto the right.

$$\tau(s) = \frac{n-1}{n} \frac{1}{L_c} \sum_{i=1}^n \left[\frac{L_{c_{s_i}}}{L_{\chi_{s_i}}} - 1 \right].$$





Summary

- No ground-truth for tests
- Raster images generate not existing curvature changes
- No solution for bifurcations and vessel crossings