Accurate and robust fully-automatic QCA: Method and numerical validation

Abstract

The Quantitative Coronary Angiography (QCA) is a methodology used to evaluate the arterial diseases and, in particular, the degree of stenosis. In this paper we propose AQCA, a fully automatic method for vessel segmentation based on graph cut theory. Vesseness, geodesic paths and a new multi-scale edginess map are used to compute a globally optimal artery segmentation. We evaluate the method performance in a rigorous numerical way on two datasets. Moreover, the method can discriminate between arteries and catheter with an accuracy of 96.4%.

1. Automatic Vessel Segmentation

Graph-cuts Energy Minimization Framework [3]

\[ E(\alpha, k, \theta, z) = U(\alpha, k, \theta, z) + V(\alpha, z) \]

2. Centerline extraction

Segmentation ➔ Distance transform ➔ Non-maximum suppression ➔ Ridge transversal

3. Caliber estimation

\[ \sigma^2 \log_G(x, y; \sigma) \]

Minimum at \( \sigma = w/2 \)

4. Catheter detection

Feature Extraction

Position \( x \), Curvature \( K(x) \), Angular direction \( \alpha(x) \), Caliber \( C(x) \)

Bayesian Classifier

\[ p(x|c) \]
\[ p(\log(e + K(x))|c) \]
\[ p(\alpha(x)|c) \]
\[ p(C(x)|c) \]

5. Results

Absolute and signed caliber error in DS2 (in mm)

<table>
<thead>
<tr>
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<th>( \Delta D )</th>
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<tbody>
<tr>
<td>IO</td>
<td>0.18±0.24 -0.001±0.3</td>
</tr>
<tr>
<td>GC</td>
<td>0.84±0.74 0.096±1.12</td>
</tr>
<tr>
<td>AQCA</td>
<td>0.49±0.55 -0.1±0.73</td>
</tr>
</tbody>
</table>

Catheter detection %

| Sensitivity | 70.9 |
| Precision | 90.1 |
| Accuracy | 96.4 |

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