Flowchart of the proposed segmentation

Early Portal Late
Registration of three phase images using RBF [12] (Maximum a posterior probability method)

Rough extraction of liver and spleen [1] (Region Growing)

Extraction of abdominal aorta, portal and splenic veins (Region Growing)

Spatial standardization of shape and position of pancreas

Rough extraction of pancreas [1] (Modified morphological process)

Fine segmentation of pancreas [1] (Modification based on spatial standardization)

Result of segmentation

Experiments - Materials:
Size: 512 x 512 x (101 - 615) [read]
Spacing: 0.5 - 1.0 mm [read]
Number of cases: 34

Criterion for performance evaluation

\[ J.I. = \frac{\#(A \cap B)}{\#(A) + \#(B) - \#(A \cap B)} \]

Spatial standardization
- A: pancreas in a reference image
- B: pancreas in a floating image

Segmentation
- A: true region
- B: result of segmentation

< Performance of spatial standardization >

Table 1: Jaccard index of the standardization process

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Our previous</th>
<th>Proposed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>0.12 ± 0.08</td>
<td>0.13 ± 0.10</td>
<td>0.24 ± 0.09</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.29</td>
<td>0.32</td>
<td>0.45</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.00</td>
<td>0.03</td>
<td>0.10</td>
</tr>
</tbody>
</table>

< Performance of rough extraction of pancreas >

Table 2: Performance of the rough extraction process

<table>
<thead>
<tr>
<th></th>
<th>Our previous</th>
<th>Proposed</th>
</tr>
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<tbody>
<tr>
<td>J.I.</td>
<td>0.41 ± 0.22</td>
<td>0.52 ± 0.14</td>
</tr>
<tr>
<td>(Max: 0.67, Min: 0.00)</td>
<td>(Max: 0.71, Min: 0.20)</td>
<td></td>
</tr>
<tr>
<td>FPR</td>
<td>0.33 ± 0.34</td>
<td>0.33 ± 0.35</td>
</tr>
<tr>
<td>FNR</td>
<td>0.48 ± 0.27</td>
<td>0.37 ± 0.12</td>
</tr>
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< Performance of rough extraction of pancreas >

Failure case

Table: Performance of the rough extraction process

<table>
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<tr>
<td>Rough</td>
<td>0.71</td>
<td>0.07</td>
<td>0.24</td>
</tr>
<tr>
<td>Fine</td>
<td>0.77</td>
<td>0.57</td>
<td>0.23</td>
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< Final results >

Table 3: Performance of the final results

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<td>FPR</td>
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Radial Basis Function (RBF) based standardization

- Landmark point:
  - Point where portal vein contacts liver
  - Point where splenic vein contact with spleen
  - Function point of portal and splenic veins

Total 24 point

< RBF based mapping >

\[ x \approx A \times + T + WD \]

Reference Floating

Gapping overlap

Probabilistic Atlas

Step 1

< MAP based segmentation >

\[ n = \arg \max \left( \frac{p(v|n, p(n))}{p(v|n, p(n))} \right) \]

- Label of organ
- Feature vector
- A priori probability of organ
- Probabilistic atlas
- Conditional density function
- Extraction regions

Parameter estimation: modified EM algorithm

< Abdominal aorta, portal and splenic veins >

< MAP based segmentation >

\[ n = \arg \max \left( \frac{p(v|n, p(n))}{p(v|n, p(n))} \right) \]

- Feature vector
- Features for liver and spleen seg.
- Three phase CT values

< Portal and splenic veins >

< Abdominal aorta >

2D Region Growing

Terminal condition
\[ R_x > 0.95 \]

Portal phase

< Portal and splenic veins >

3D Region Growing

Terminal condition
\[ D_x > 3000 \] (result)

- 20 points on the body surface
- Total 24 point

Spatial standardization of shape and position of pancreas

Radial Basis Function (RBF) based standardization

- Landmark point:
  - Point where portal vein contacts liver
  - Point where splenic vein contact with spleen
  - Function point of portal and splenic veins

Total 24 point

< RBF based mapping >

\[ x \approx A \times + T + WD \]

A: Affine matrix, T: Translation vector, W: Weight matrix
B: Radial Basis Function matrix, P': Landmark

J.I. = 0.71, FPR = 0.07, FNR = 0.24

Success case

Table: Performance of the rough extraction process

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Proposed standardization is effective in extraction of pancreas from 3D CT images.

False positive

False negative

Wilcoxon test \[ p < 0.01 \]

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Future plan

I. FN near the boundary of pancreas were caused by poor spatial standardization

II. FP regions in stomach wall and intestine stemmed from low separability of feature

III. Moreover

We plan to evaluate the performance using unknown and large dataset, which will be followed by improvement

References

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