Heart Ventricle Separation in Low-Dose CT Scans

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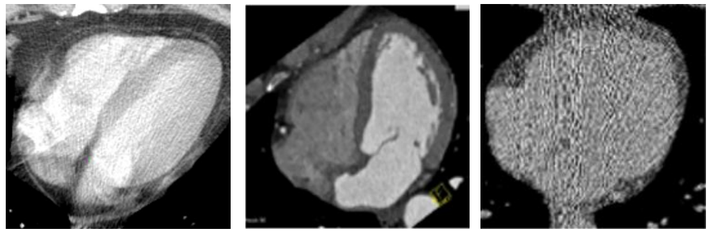
Introduction

Motivation

Cardiovascular disease is a leading cause of death in developed countries. Interventricular septum, the surface separating ventricles from one another, is an indicator of heart health. Abnormal position or geometry of septum reflects potential heart disease, e.g. progressively loss of convexity of septum can indicate ventricular volume overload which may lead to heart failure. To diagnose heart disease, contrast agent is usually injected into patient's body to obtain contrast-enhanced images, but it can have adverse effects on patients, and may cause death. Low-dose CT, which is used in lung cancer screening, produces lower radiation than standard-dose CT, and does not require contrast agent. Identifying the septum in low-dose CT can bring extra benefits to patients to monitor heart health without risks.

Challenges

- High noise level
- No clear boundary between tissue and blood



(a) (b) (c)

Fig. 1 Comparison of heart area in
(a) Standard-Dose CT (b) Contrast CT (c) Low-Dose CT

Workflow

Atlas Construction: annotate the interventricular septum in one image

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Registration: find the mapping between heart areas of atlas and test image

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Label Propagation: transform the manual annotation from atlas to test image

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Surface Fitting: third order polynomial surface to fit the labelled points

↓

Get the surface that separates ventricles

Fig. 2 Workflow of proposed method

Atlas-Based Segmentation

Step1 Atlas Construction

Atlas is the image with manually annotated septum

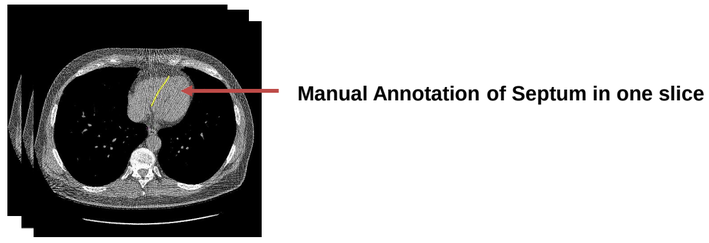
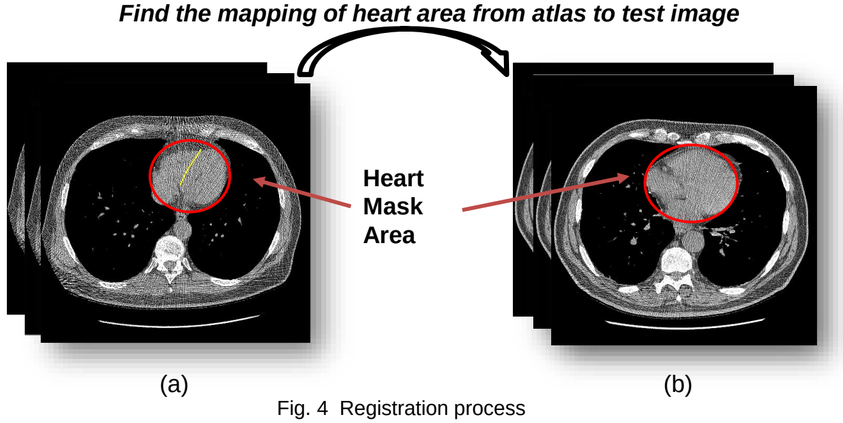


Fig. 3 Illustration of atlas

Step2 Registration

Find the mapping of heart area from atlas to test image

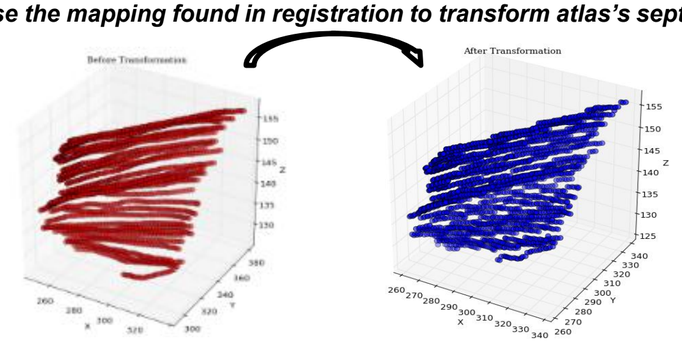


(a) (b)

Fig. 4 Registration process
(a) Atlas (b) Test image

Step3 Label Propagation

Use the mapping found in registration to transform atlas's septum

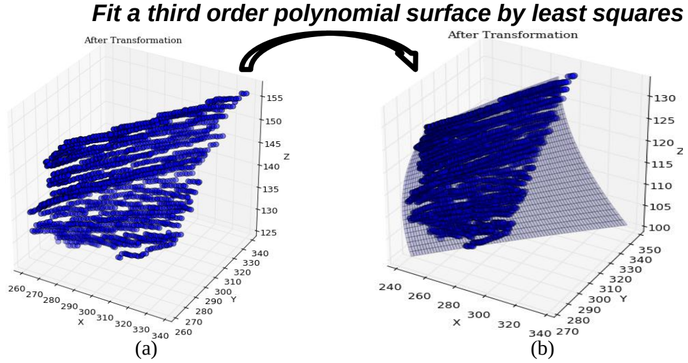


(a) (b)

Fig. 5 Label Propagation process
(a) Septum annotation in atlas (b) Transformed annotation in test image

Step4 Surface Fitting

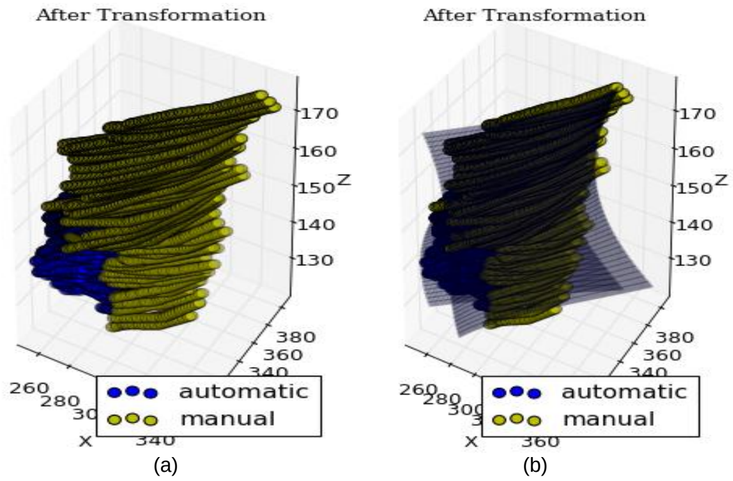
Fit a third order polynomial surface by least squares



(a) (b)

Fig. 6 Segmentation
(a) without surface fitting (b) with surface fitting

Results



(a) (b)

Fig. 7 Segmentation Visualization
(a) Before surface fitting (b) After surface fitting

Metric: Average Distance (AD)

Definition:

Two point sets $A = \{a_1, a_2, ..., a_{N_a}\}, B = \{b_1, b_2, ..., b_{N_b}\}$

$$d(a, B) = min_{b \in B} ||a - b||$$

$$AD = \frac{\Sigma_{a \in A} d(a, B) + \Sigma_{b \in B} d(b, A)}{N_a + B_b}$$

Table 1 Partial test cases results

Case Number	AD between point sets (voxel)	AD between fitted surfaces (voxel)
W0002	18.121	24.4
W0007	8.095	10.30
W0009	8.790	11.073

References

[1] I. Işgum, M. Staring, A. Rutten, M. Prokop, M. Viergever, B. van Ginneken, "Multi-atlas-based segmentation with local decision fusion—Application to cardiac and aortic segmentation in CT scans", *IEEE Trans. Med. Imag.*, vol. 28, no. 7, pp. 1000-1010, 2009.

[2] S. Klein, M. Staring, K. Murphy, M. A. Viergever, J. P. W. Pluim, "elastix: A toolbox for intensity-based medical image registration", *IEEE Trans. Med. Imag.*, vol. 29, no. 1, pp. 196-205, Jan. 2010.

[3] Slide of Fitting Curves and Surfaces by Least Squares . Available at: http://www.d.umn.edu/~mduan/stat3411/ch4_2.pdf

[4] ELCAP Public Lung Image Database. Available at: http://www.via.cornell.edu/databases/lungdb.html