Registration of 2D Deformable Model to 2D CT Image

HT050623N, Li Hao

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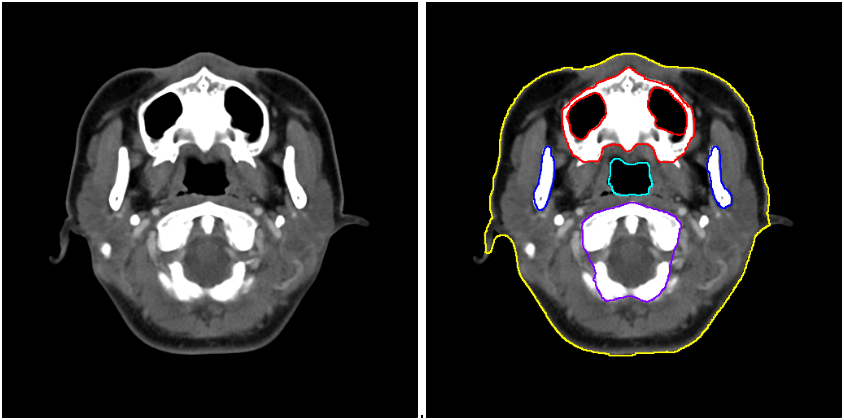
Part I

Problem Formulation

Inputs

- Let M denote the 2D model image
- Let $C = \{C_i\}$ denote the contours of anatomies in the model image.
- Let S denote a function related to shape information. $S(p_t)$ is the curvature of C_i at point p_t.

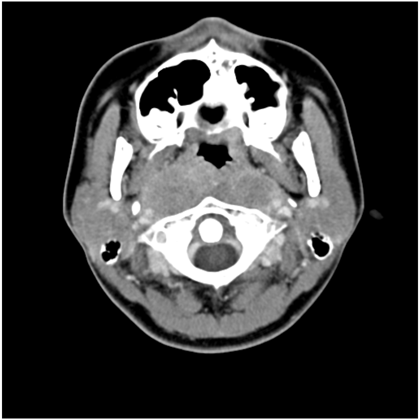
Example: Input Model

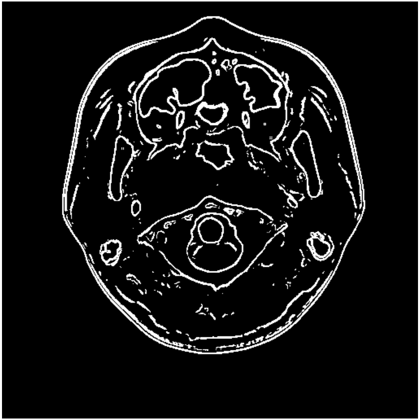


Inputs(cont.)

- Let T denote the target 2D CT image to be registered to.
- Let E_T denote the set of edge points of T

Example: Target & Edge





Output

The output is:

- the contours of corresponding anatomies in the target image.

Problem Definition

Define the following:

- Let $D = \{D_i\}$ denote a set of deformation functions, i.e. Di moves a point $p_t \in C_i$ to a new location $D_i(p_t)$.
- Let f be a correspondence function from C(contour model) to E_t(target edge points), that is, $f(p_t) \in E_t$.
- Let T denote a 2D affine transformation of C.

Problem Definition(Cont.)

The problem can be defined as:

- find the affine transformation T, correspondence f, and for each $C_i \in C$, find the deformation D_i that minimize the edge point error E_p:

$$E_p = \sum_i \sum_{p_t \in C_i} \| D(T(p_t)) - f(p_t) \|$$

and the shape difference E_S:

$$E_B = \sum_i \sum_{p_t \in C_i} \| S(D(T(p_t))) - S(p_t) \|$$

Performance Measure

Let $A = \{A_i\}$ denote the actual contours, $C' = \{C'_i\}$ denote the extracted contours. The performance measure can be defined as:

$$E_p = \sum_i \sum_{q_t \in A_i} \| q_t - f'(p_t) \|$$

where $f'(q_t)$ is the closest point in C'_i to q_t.

Part II

Algorithm

Outline of Algorithm

1. Global Transformation
2. Nearest Connected Components
3. Dual-GVFSnake

Global Transformation Using ICP

Firstly, find the global transformation:

- Get the boundary of the target image.
- Using the boundary of the model, and boundary of the target as parameters, run ICP.
- Get the global affine transformation T.

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Nearest Connected Components

Note that:

- Most of the edges in the target image are distinct.
- For each anatomy, intensities of pixels on it do not differ too much.

Therefore, we can:

- Compute all connected components in the edge image.

Nearest Connected Components(Cont.)

For each contour C_i,

- 1.Compute the intensity information inside/outside that contour. If the intensity distribution of one side of the contour is uniform, then keep this information as a feature.
- 2.Compute the Nearest Components from $T(C_i)$, i.e. for each component $Comp_j$

$$d_j = \sum_{p_t \in Comp_j} \| p_t - g(p_t) \|$$

  where $g(p_t)$ is the closest point in $T(C_i)$ to q_t. If d_j is less than a threshold d_T, keep $Comp_j$ as one of the nearest component.
- 3.Delete the points in $Comp_j$ that do not have the feature of C_i.

Dual-GVFSnake

For each contour $T(C_i)$,

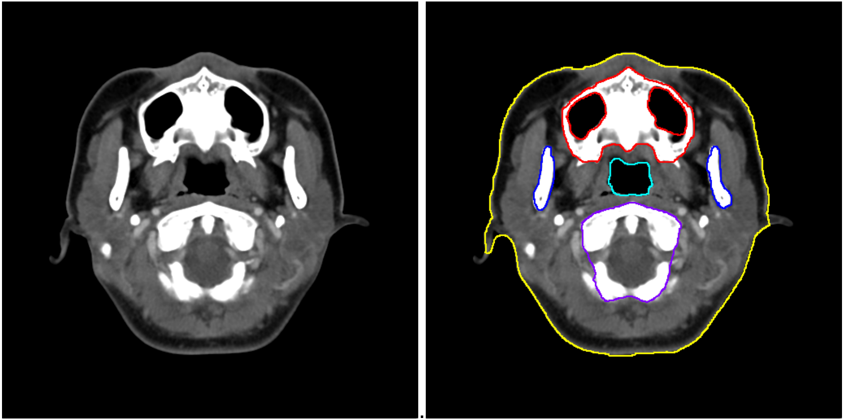
- 1. Run *GVFSnake* on the image created by filtered nearest connected components. Get G_i.
- 2. Using G_i as the initialization, run *GVFSnake* on the target image. (Refinement)

Step 2 generate the final result C_i'.

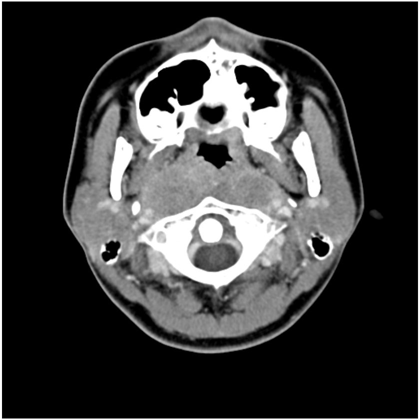
Part III

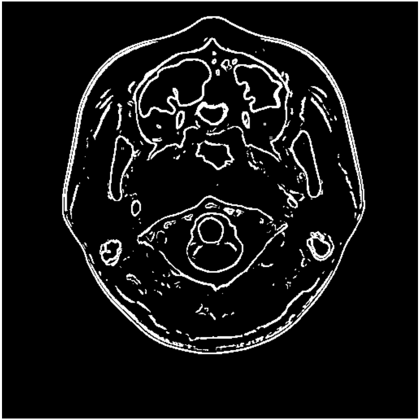
Tests & Discussion

Test 1, Input Model

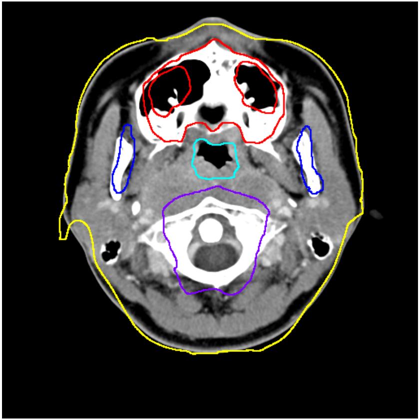


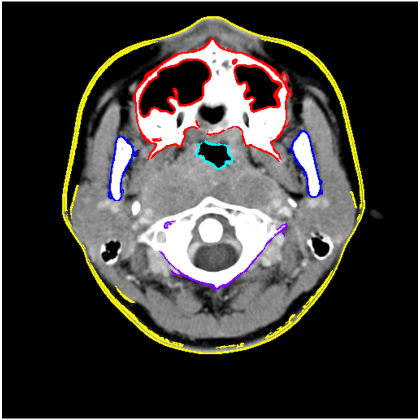
Test 1: Target & Edge





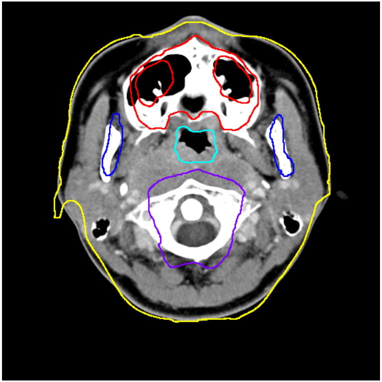
Test 1: Global & Comp

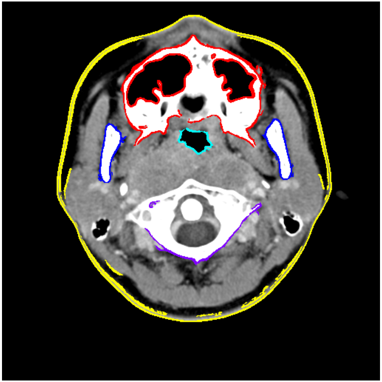




Test 1

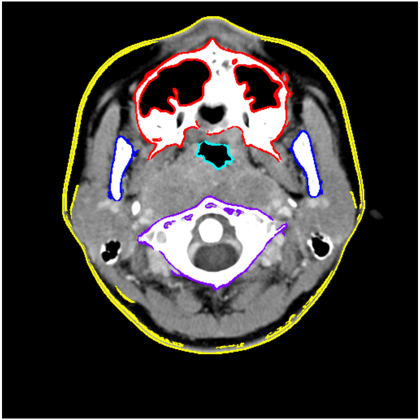
Note that the nearest component of the spine is not well found, because of the significant deformation. If we use this intermediate result, the final result would not get correct.



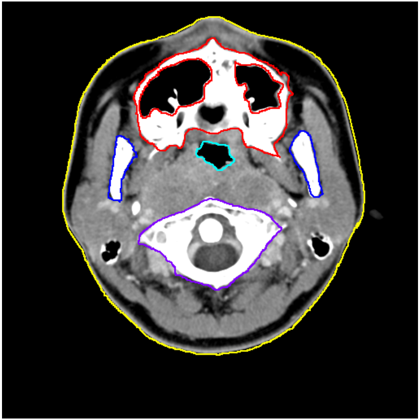


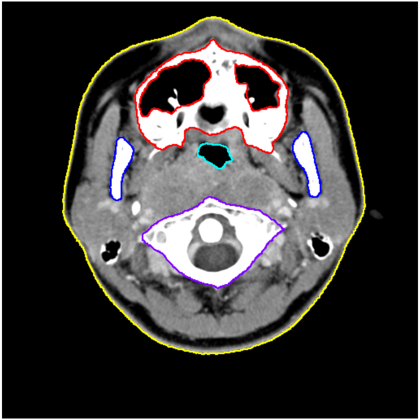
Test 1

The solution is: run snake before computing nearest components!

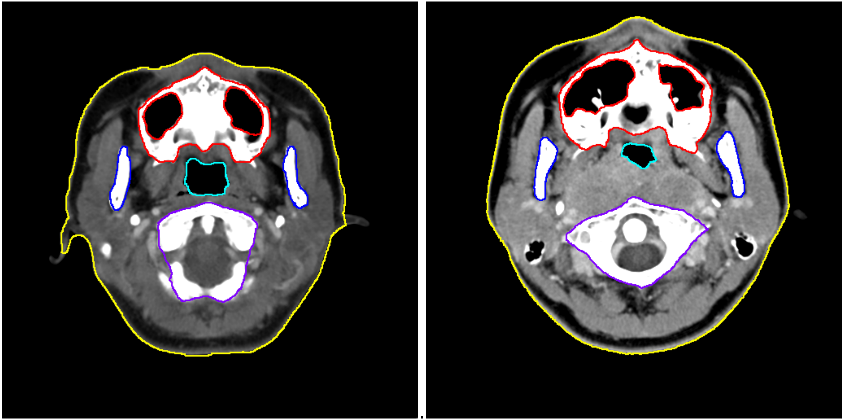


Test 1: Dual-GVFSnake



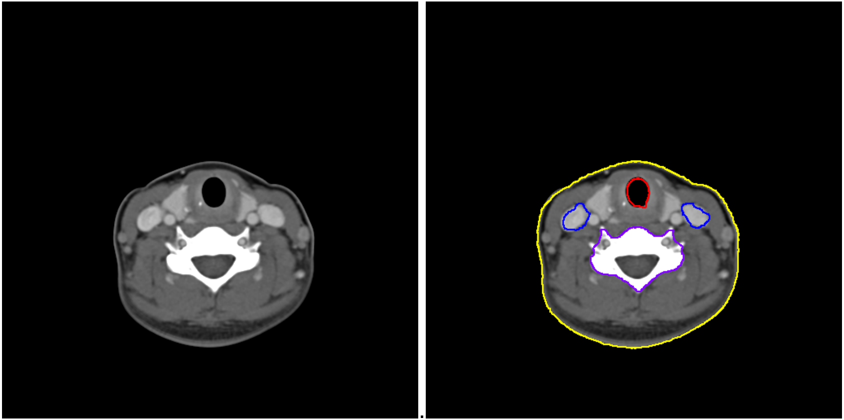


Test 1: Model & Result

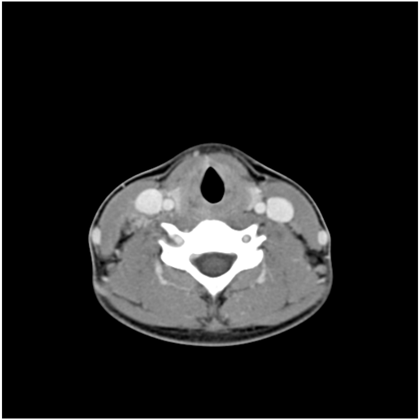


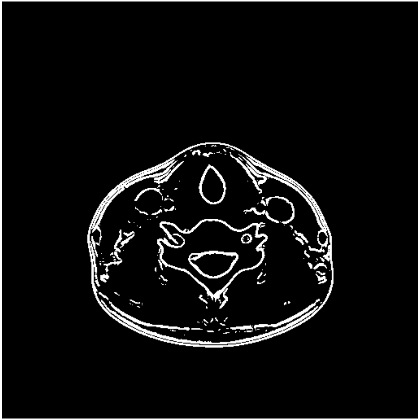
$$E_p \longrightarrow 0$$

Test 2, Input Model

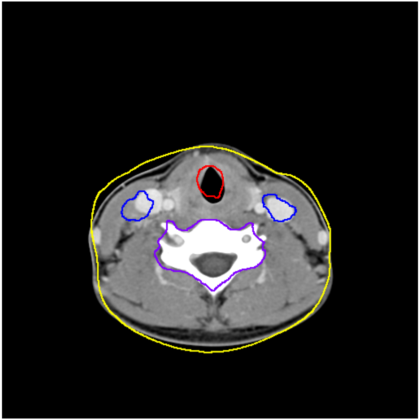


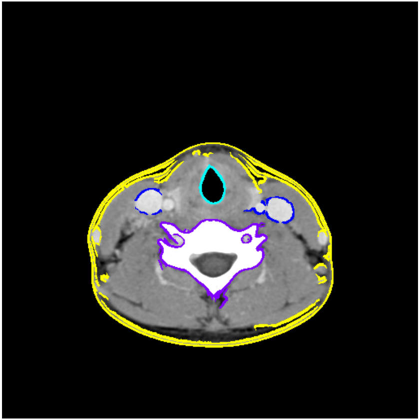
Test 2: Target & Edge



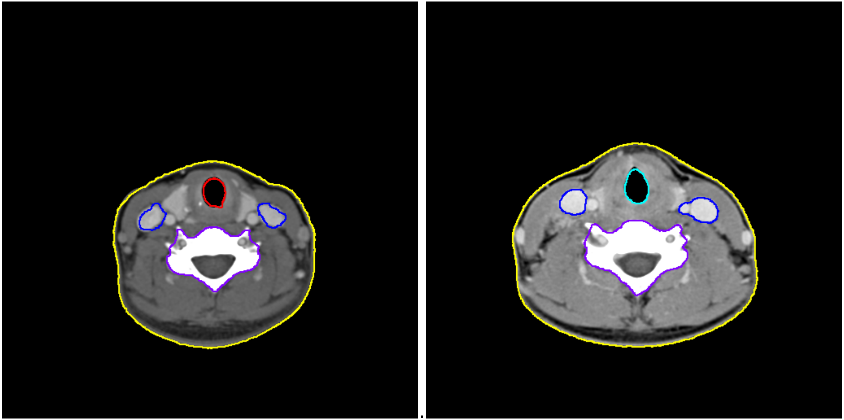


Test 2: Global & Nearest Components

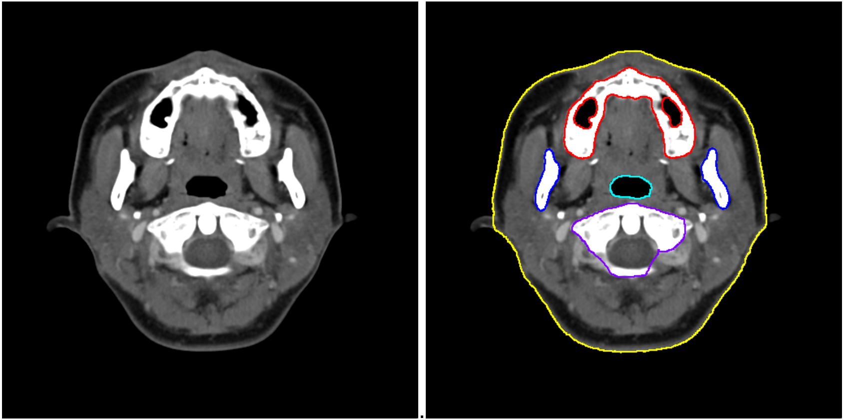




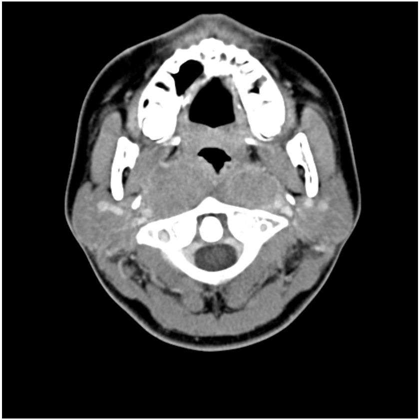
Test 2: Model & Result

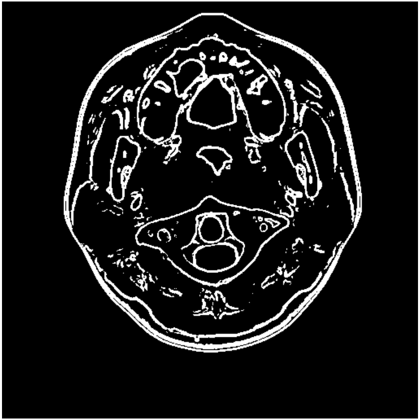


Test 3, Input Model

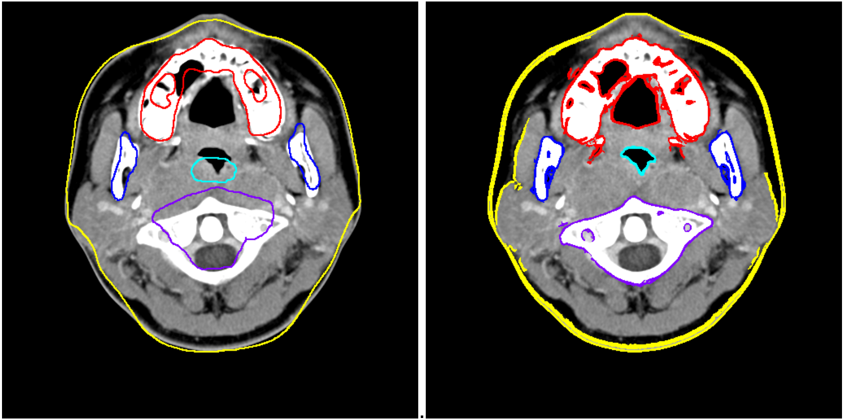


Test 3: Target & Edge

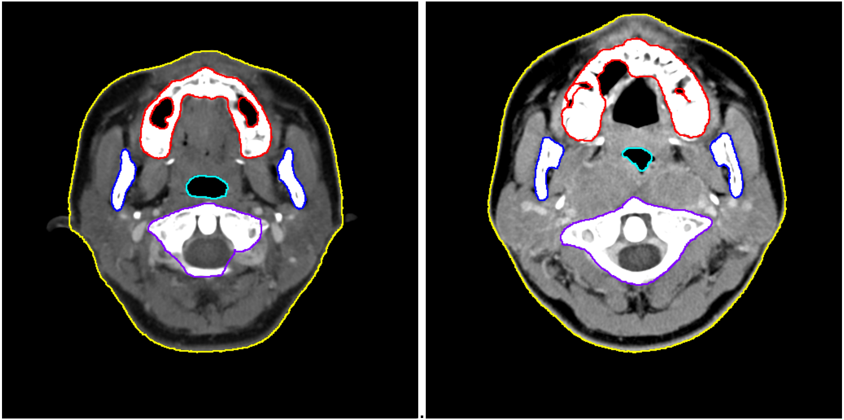




Test 3: Global & Nearest Components



Test 3: Model & Result



Reference

- F.Ding, W. K. Leow, S.-C. Wang, *Segmentation of 3D CT Volume Images Using a Single 2D Atlas*, CVBIA, 2005.
- Chengyang Xu, Jerry L.Prince, *Snake, Shapes, and Gradient Vector Flow*, IEEE Transactions on Image Processing, 1998.