Multiple hypothesis tracking based extraction of airway trees from CT data

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MULTIPLE HYPOTHESIS TRACKING BASED EXTRACTION OF AIRWAY TREES FROM CT DATA

Using statistical ranking of template-matched hypotheses

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Abstract

Segmentation of airway trees from CT scans of lungs has important clinical applications, in relation to the diagnosis of chronic obstructive pulmonary disease (COPD). Here we present a method based on multiple hypothesis tracking (MHT) and template matching, originally devised for vessel segmentation, to extract airway trees. Individual tubular templates are constructed and ranked using scores assigned based on the image data. Several such regularly spaced hypotheses are used in constructing a hypothesis tree, which is then traversed to obtain improved segmentation results.

Introduction

COPD is a leading cause of mortality worldwide, characterised by:
- Destruction of the lung tissue (emphysema)
- Morphological changes to the airways

Objective: Develop segmentation methods, with improved specificity and sensitivity, to study morphological changes of airway trees from CT.

Existing methods:
- Airway tree segmentation is a challenging problem
- Most methods try to strike a balance between specificity and sensitivity
- Room for improvement on both fronts
- Single hypothesis / greedy algorithms
  - Immediate decisions
- Only the best hypothesis is propagated
  - Semi-automatic
  - Highly local solutions

Philosophy:

- Delay decisions. Use more data. Benefit from hindsight.
- Only the best hypothesis is propagated
- Account for branching
- Semi-automatic
- Highly local solutions

MHT-based methods

Idea: Defefer decision at current step to a future step. Meanwhile, maintain all hypotheses.

Multiple hypothesis tracking (MHT)

- Philosophy: Delay decisions. Use more data. Benefit from hindsight.
  - Widely used in multi-target tracking [5]
  - Deferred decision based on more data
  - Several hypotheses are maintained
  - Search depth controls the size of tree
  - Trade-off between optimality, tractability

A tracking perspective to segmentation

Prediction by regularly spaced guesses
- Image data is used to update the guesses

Figure 1: Coronal, sagittal and axial views from a CT, along with a reference segmentation.

Figure 2: Coronal view of the probability image after classification. Darker regions correspond to high probability, and hence likely airway regions.

Figure 3: Overview of tracking between two steps.

Figure 4: MHT tree, of search depth = 2. The decision at T_0 is made based on all the data up to T_2. Tracking back the best global hypothesis depicted in blue. Figure 5: 3D tubular template of radius r, with center at x, along the direction d. Intensity profile (σ) at a cross-section is shown on right.

Figure 6: Generation of local hypotheses. 1. Each hypothesis inherits parameters from previous step, uses a predetermined increment in direction and position to progress to the next step.

Figure 7: Illustration of scores and thresholds in org. and ranking based MHT methods.

Figure 8: Each step, all hypotheses are considered for clustering. As an example here, two clusters are formed and the best hypothesis within each is propagated as a new branch.

Figure 9: Contourlines of test set results overlaid with reference.

Figure 10: Performance comparison of the modified MHT (org-MHT) method with the original MHT (org-MHT), region growing on intensity (rg-int) and region growing on probability (rg-prob).

Error distance:

\[ d_{err} = \sum_{i=0}^{n} \min_{j=0}^{n} | C_{org} - C_{ref} | \]

\[ C_{org}, C_{ref} \text{ are centroids of reference, output segmentations, with } n \text{ points respectively, } d_{err} \text{ is Euclidean distance} \]

References


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