Multiple hypothesis tracking based extraction of airway trees from CT data
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METHODOLOGY TRACKING BASED EXTRACTION OF AIRWAY TREES FROM CT DATA

Using statistical ranking of template-matched hypotheses

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Abstract

Segmentation of airway tree 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. Idealized 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:

\* Distortion of the lung tissues (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
\* Inconsistent decisions

\* Only the best hypothesis is propagated
\* Sensitivity to noise

\* Highly local solutions

MHT-based methods

Idea: Defy 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 view 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 5: 3D tubular template of radius \( r \), with center \( x_0 \), along the direction \( d \). Intensity profile \( p \) at a crosssection is shown on right.

Template matching-based MHT

Method based on [1], proposed for tracking small vessels:

\* Designed to track small tubular structures
\* Uses a scale-dependent score threshold
\* Semi-automatic

Model

\* Probability images obtained from trained KNN classifier \((K = 21)\), airways \((p = 1)\)
\* Method in [1] is modified, while retaining the image model:

\[ \text{image} \oplus \text{contrast template} \land \text{mean} \land \text{noise}, \text{or} \]

\[ E_{op} = \langle |T(x, x_0, y)\rangle \rangle \](1)

\* Template function \((T)\) used to map probability variations to a profile function \((p)\)

\[ T(x_0, x, y) = \frac{\gamma}{\sqrt{D(x_0, x, y)^2 + \epsilon}} \]

\[(2)\]

\( d_{ij} \) is minimum squared distance between \( x_i \) and \( x_j \) along \( d \) through \( x_k \) with \( y = h \)

Constructing the hypothesis tree

\* Fixed number of guesses are generated
\* Guesses are 3D templates based on parameters from previous step
\* Corresponds to the “prediction” step.

Predictions are “updated” by solving the weighted minimization problem:

\[ \min_{x, x_0, y} (\langle W(x, x_0, y) \rangle + \sum_{n} (T(x, x_0, y) - \sum_{i \neq n} T(x, x_0, y)) - 1) \]

\[ \text{score} = \frac{\text{contrast}}{\text{ideal contrast}} \]

(3)

Score from the estimated contrast.

Hypothesis tree is constructed to search for the best global hypothesis

Each path through the hypothesis tree has an average global score