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. 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

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
- - Instance-based decisions
- - Only the best hypothesis is propagated
- - Sensitive to noise
- - Highly local solutions

MHT-based methods

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

Method based on [1], [2], proposing 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:

\[
\text{image} = \text{contrast} \times \text{template} \times \text{mean} + \text{noise}, \quad \text{or}
\]

\[
E_{\text{noise}} = \min T(x, x_0, v) \quad (3)
\]

- Template function (T) used to map probability variations to a profile function (P)

\[
T(x, x_0, v) = \frac{1}{\sigma^2} \left( \frac{d^2}{\text{d}(x, x_0, v)} \right)^2 + \gamma
\]

\[
d^2 = \min \text{squared distance between } x \text{ and line along } v \text{ through } x_0 \text{ with } y = \hat{y}
\]

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:

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

Hypothesis tree is constructed to search for the best global hypothesis
- Each path through the hypothesis tree has an average global score

Error distance:

The Centerlines of reference, output segmentations with C_{\text{ref}}, C_{\text{op}}, C_{\text{mean}} points respectively, error distance:

\[
d_{\text{E}} = \sqrt{\sum_{i=1}^{n} (d_i - C_{\text{mean}})^2}
\]

\[
C_{\text{ref} / \text{op} / \text{mean}} \text{ are centerlines of reference, output segmentations, respectively.}
\]

Discussion

- Ranking-based MHT method shows an improvement in performance.
- Fully automatic tree extraction method
- It does not outperform region-growing on probability images

Conclusions

- MHT allows for improved tracking decisions, as tracking solutions are not local.
- Method in [1] has been modelled to extract airway trees.
- Ranking based scheme is more suitable for extracting airways, where structures of varying dimensions are observed.

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References


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Performance comparison of the modified MHT (mod-MHT) method with the original MHT (org-MHT), region growing on intensity (rg-irr), and region growing on probability (rg-prp).

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 r = 2. The decision at T_1 is made based on all data up to T_2, tracing back the best global hypothesis depicted in blue.

Figure 5: 3D tubular model of radius ε, with center at x, along the direction v. Intensity profile $p$ at a cross section is shown on right.

Figure 6: Generation of local hypotheses. 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: Centrelines of test set results overlaid with reference.

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