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 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:
• Distinction 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
   – Illogical decisions
   – Only the best hypothesis is propagated
   – Sensitive to noise
   – Highly local solutions

MHT-based methods

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 4: MHT tree, of search depth 2. The decision at T1 is made based on all the data up to T0, tracing back the best global hypothesis depicted in blue.

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

Figure 5: 3D tubular template of radius r, with center at (x, y), along the direction 6: intensity profile 1(0) at a crossing over 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:

\[
\text{image}(x, y, z) = \text{contrast} \cdot \text{template}(x, y, z) + \text{mean} + \text{noise},
\]

\[
T(x, y, z) = \frac{1}{\sigma^2} \exp \left( -\frac{1}{2\sigma^2} \left( x - x_c \right)^2 \right)
\]

\[
d^2(x) = \left( d(x) - d(x_c) \right)^2 + \frac{\ell}{\sigma^2}
\]

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

\[
\text{d}^2 = \left( d - d_{\text{ref}} \right)^2 + \frac{\ell}{\sigma^2}
\]

• d is minimum squared distance between x and line along c through x with γ = b

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:

\[
W = \sum_{i=1}^{N} \left( W(x_i, y_i, z_i) + \alpha T(x_i, y_i, z_i) \right)
\]

\[
\text{score} = \frac{\text{contrast}}{\text{std(contrast)}}
\]

Spectral clustering is performed
If two clear clusters are observed, best hypothesis within each is propagated as a new branch

Handling branching
• Spectral clustering is performed
• If two clear clusters are observed, best hypothesis within each is propagated as a new branch

Results
Data & Experiments
• Single seed point automatically placed at the origin of trachea; thus fully automatic
• Set of 32 images split into training, test sets
• Danish Lung Cancer Screening Trial data used [2]
• Probability images from KNN classifier

Centres of segmentation results are compared with reference segmentations, to quantify estimation error:

\[
\text{Error (mm)} = \sum_{i=1}^{N} \left( d^2(x) - d^2_{\text{ref}} \right)
\]

Conclusions
• MHT allows for improved tracking decisions, as tracking solutions are not local.
• Method in [1] has been modified 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