Multiple hypothesis tracking based extraction of airway trees from CT data

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MUTLIPLE 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:
• Distraction of the lung tissue (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
• Semi-automatic solutions—only the best hypothesis is propagated
• Sensitive to noise
• Highly local solutions

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:

\[
\text{image} = \text{contrast} + \text{template} + \text{mean} + \text{noise}, \quad \text{or} \quad E_{\text{obs}} = \sum_i E_{\text{obs}, i} = \sum_i \left(\text{contrast} \cdot \text{template} + \text{mean} + \text{noise}\right)
\]

• Template function \(T(x, x_0, V, \gamma)\) used to map probability variations to a profile function \(p\):

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

\[
d_i = \min_{x, x_0} \sum_{c} \left(\text{score} \cdot \text{contrast} \cdot \text{template} + \text{mean} + \text{noise}\right)
\]

MHT-based methods

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<th>Idea: Defeat decision at current step to a future step.</th>
<th>Meanwhile, maintain all hypotheses.</th>
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A tracking perspective to segmentation
• Prediction by regularly spaced guesses
• Image data is used to update the guesses

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

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.

Acknowledgements
Danish Council for Independent Research

References

Figure 1: Coronal, sagittal and axial views from a CT scan, 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 \(T_1\) is made based on all the data upto \(T_2\). Tracing back the best global hypothesis depicted in blue.
Figure 5: 3D tubular template of radius \(r\), with center \(c_0\) along the direction \(d\). 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 original 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: Comparison of the modified MHT (mod-MHT) method with the original MHT (org-MHT), region growing on intensity (rg-int) and region growing on probability (rg-prob).
Figure 10: Performance comparison of the modified MHT (mod-MHT) method with the original MHT (org-MHT). Results are compared with reference segmentation.

Figure 11: Coronal view of the probability image after classification. Darker regions correspond to high probability, and hence likely airway regions.
Figure 12: MHT-based methods

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