Multiple hypothesis tracking based extraction of airway trees from CT data
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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 designed 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 (emphysma)
- 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
- Instaneous decisions
- Only the best hypothesis is propagated
- Sensitive to noise
- Highly local solutions

MHT-based methods

Idea: Define 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
- Tracking perspective to segmentation
- Using statistical ranking of template-matched hypotheses

Using statistical ranking of template-matched hypotheses

MULTIPLE HYPOTHESIS TRACKING BASED EXTRACTION OF AIRWAY TREES FROM CT DATA
Using statistical ranking of template-matched hypotheses

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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 3: Overview of tracking between two steps.

Figure 4: MHT tree, of search depth 2. The decision at T1 is made based on all the data up to T2, tracing back the best global hypothesis depicted in blue.

Figure 5: 3D tubular template of radius r, with center c, along the direction d. Intensity profile I(x) at a crosssection 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.

Handling branching
- Spectral clustering is performed
- If two clear clusters are observed, best hypothesis in each is tracked as 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
- Centers of segmentation results are compared with reference segmentation results, to quantify estimation error:

\[
\text{Error distance:}
\]

- \(d_{ij} = \sum_{n=1}^{N} (e_{ij} - e_{ij}^\text{ref})^2\)
- \(e_{ij}^\text{ref}\) and \(e_{ij}\) are centerlines of reference, output predictions respectively, \(d_{ij}\) is Euclidean distance

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

Figure 9: Centrelines 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).

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

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Figure 11: Error distance:

\[
\text{Error distance:}
\]

- \(d_{ij} = \sum_{n=1}^{N} (e_{ij} - e_{ij}^\text{ref})^2\)
- \(e_{ij}^\text{ref}\) and \(e_{ij}\) are centerlines of reference, output predictions respectively, \(d_{ij}\) is Euclidean distance

Figure 12: 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).