Multiple hypothesis tracking based extraction of airway trees from CT data
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MÚLTIPLE HYPOTHESIS TRACKING BASED EX-
TRACTION 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 de-
vised 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 hy-
potheses 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:
• Destruction of the lung tissues (emphysema)
• Morphological changes to the airways

Existing methods:
• Airway tree segmentation is a challenging prob-
lem
• Most methods try to strike a balance between simplicity and necessity
• Room for improvement on both fronts
• Single hypothesis / greedy algorithms
  ~ instantaneous decisions
  ~ Only the best hypothesis is propagated
  ~ Sensitive to noise
  ~ Highly local solutions

Figure 1: Coronal, sagittal and axial view of a
CT, along with a reference segmentation.

Figure 2: Coronal view of the probability image
after classification. Darker represents correspond to
high probability, and hence likely airway regions.

MHT-based methods

Idea: Defoe decision at current step to a
future step. Meanwhile, maintain all hy-
potheses.

Multiple hypothesis tracking (MHT)

Philosophy: Delay decisions. Use more
data. Benefit from hindsight.
• Widely used in multi-target tracking [3]
• 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 3: Overview of tracking between two steps.

Figure 4: MHT tree, of search depth v = 2. The deci-
sion at τv is made based on all the data upto τv, tracing
back the best global hypothesis depicted in blue.

Figure 6: Generation of local hypotheses, L. Each hy-
pothesis inherits parameters from previous step, uses
a predetermined increment in direction and position to
trace to the next step.

Figure 5: 3D tubular template of radius r, with center at x, along the direction 6. 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:
image \cong contrast + template \cong mean + noise, or
E_{\gamma} = \gamma \times T(x, y) + \sigma_i (\gamma, x, y)
(1)

• Template function (T) used to map prob-
ability variations to a profile function (p)
T(x, y, \gamma) = p \gamma (\nabla \times T(x, y, \gamma)) = \gamma
(2)

de^2_i is minimum squared distance between x and line along 6 through x_i with y = \gamma

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

Handling branching
• Spectral clustering is performed
• If two clear clusters are observed, best hy-
pothesis 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
• Centrelines of segmentation results are
compared with reference segmenta-
tions, to quantify estimation error:

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 propa-
gated as a new branch.

Figure 9: Centrelines of test set results overlaid with reference

Conclusions
• MHT allows for improved tracking deci-
sions, 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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Figure 10: Performance comparison of the modi-
fied MHT (Org-MHT) method with the original MHT
(org-MHT), region growing on intensity (rg-rg1),
and region growing on probability (rg-prg).

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

Figure 11: Error distance:

$$d_{ij} = \sum_{n=1}^{N} d_{cn} - d_{cn}$$

$$d_{cn} = |x_{cn} - y_{cn}|$$