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. Individual 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:
- Destruction of the lung tissues (emphysema)
- Morphological changes to the airways

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

Existing methods:
- Airway tree segmentation is a challenging problem.
- Most methods try to strike a balance between specificity and sensitivity.
- Room for improvements on both fronts.
- Single hypothesis / greedy algorithms
  - Insensitive 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 classifiers ($K = 21$), airways ($p = 1$)
- Method in [1] is modified, while retaining the image model:

$$\text{image = contrast*template + mean + noise, or}$$

$$E(x) = k + T(x, x_0, \gamma)$$

$$\gamma$$ is a parameter, can be constant or be modulated to allow the image model to be adjusted to different scale.

$$x$$ is the centerline of the vessel.

$$T(x, x_0, \gamma)$$ is a template function used to map probability variations to a profile function ($p$)

$$T(x, x_0, \gamma) = \frac{(\hat{v}(x, x_0, \gamma))}{(\hat{v}(x, x_0, \gamma)) + \gamma}$$

$$(2)$$

$d^2$ is minimum squared distance between $x$ and line along $\gamma$ through $x_0$ with $\gamma = \delta$

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:

$$\min_{W(x_0, \gamma, s)} \left[ W(x_0, \gamma, s) (x - T(x, x_0, \gamma)) + 1 - E(x) \right]$$

$$W$$ is the weighting matrix.
- Guesses are ranked based on prominence of score, removing the dependence on scale

Error distance:
$$d_{CF} = \sum_{i = 1}^{n} \min (d_{CF,i} - C_{op}, 0)$$

Discussion
- 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

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