Multiple hypothesis tracking based extraction of airway trees from CT data
Raghavendra, Selvan; Petersen, Jens; de Bruijne, Marleen

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MULTIPLE HYPOTHESIS TRACKING BASED EXTRACTION OF AIRWAY TREES FROM CT DATA

Using statistical ranking of template-matched hypotheses

Selvan R., Petersen J., de Bruijne M.

Image Group, Department of Computer Science

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:
- Impaired function of the lungs (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 in both fronts
- Single hypothesis / greedy algorithms
  - Inconsistent decisions
  - Only the best hypothesis is propagated
  - Sensitive to noise
  - Highly local solutions

Methodology

Multi-hypothesis tracking (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 = 1111), airways (p = 11)
- Method in [1] is modified, while retaining the image model:

\[
\text{image}(\text{contrast}, \text{template}, r, \text{mean}, \text{noise}) = \sum_{m=1}^{M} (\text{image}(\text{m}) \times k_1) + (\text{image}(\text{m}) \times k_0)
\]

- Template function (T) used to map probability variations to a profile function (P)

\[
T(x, x_0, y_0) = \frac{e^{-d^2}}{d^2(\text{image}(x, x_0, y_0))^{1/2} + \epsilon}
\]

where

\[
d^2 = \min(\text{distance between} x \text{and} \text{line along} y \text{through} x_0, \text{with} \gamma = 8)
\]

- Fixed number of guesses are generated
- Gueses are 3D templates based on parameters from previous step
- Corresponds to the “prediction” step.
- Predictions are “updated” by solving the weighted minimization problem:

\[
\min_{\hat{y}} \sum_{j=1}^{N} (W(x, x_0, y_0) \times T(x, x_0, y_0) + 1 - E)\]

\[
W = (\begin{array}{ccc}
W_1 & W_2 & W_3 \\
W_4 & W_5 & W_6 \\
W_7 & W_8 & W_9 \\
\end{array})
\]

where

- Gueses are ranked based on prominence of score, removing the dependence on scale
- Score from the estimated contrast

\[
\text{score} = \frac{\text{contrast}}{\text{scale}}
\]

- Hypothesis tree is constructed to search for the best global hypothesis
- Each path through the hypothesis tree has an average global score

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