UNIVERSITY OF COPENHAGEN

Extraction of airway trees from CT data

Using Multiple Hypothesis Tracking and Statistical Ranking of Template-matched Hypotheses

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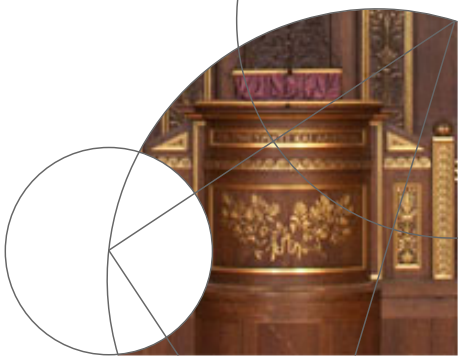

Objective

Automatic extraction of airway trees to derive biomarkers for COPD

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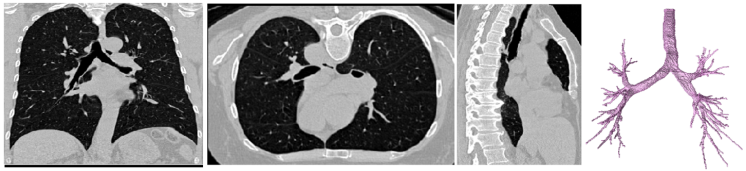

- Chronic Obstructive Pulmonary Disease (COPD):
  - Leading factor of morbidity & mortality
  - Destruction of lung tissue – Emphysema
  - Change of airway morphology
- Segmented airways to study morphology
- Dearth of useful biomarkers

Overview

- Introduction
- Method
  - Multiple Hypothesis Tracking
  - Template Matching
  - Application to Airway Trees
  - Statistical Ranking
  - Handling Branching
- Data and Experiments
- Conclusions and Future Work

Introduction

- State-of-the-art: Primarily, region-growing based methods
- EXACT Study[a] compares 15 methods; No clear winner
- Most methods trade-off between Sensitivity & Specificity

[a] Lo, P., et.al : Extraction of airways from CT (EXACT'09). IEEE Transactions on Medical Imaging, (2012)

Introduction

Contribution

Use of Multiple Hypothesis Tracking and Statistically Ranked Templates to automatically segment complete airway trees

- State-of-the-art: Primarily, region-growing based methods
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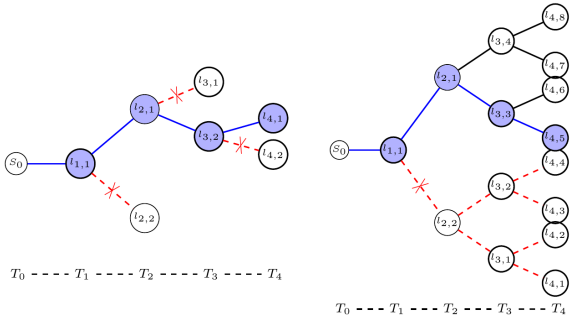
Single vs Multiple Hypothesis Tracking Methods



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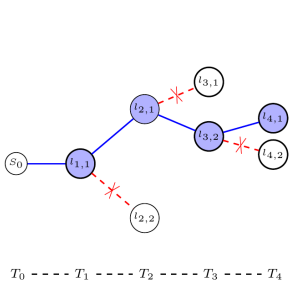

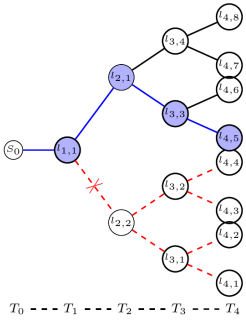

- Local hypotheses: l_i
- Global hypotheses : $(l_1, l_2, \ldots l_n)$

$$\text{globalScore} = \sum_{\text{loc.hyp.}} \frac{\text{loc.Score}}{\text{searchDepth}}$$

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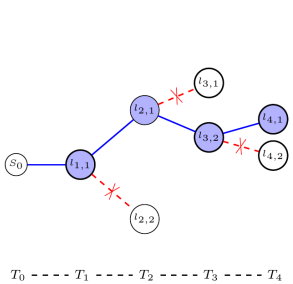

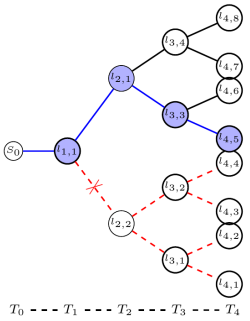

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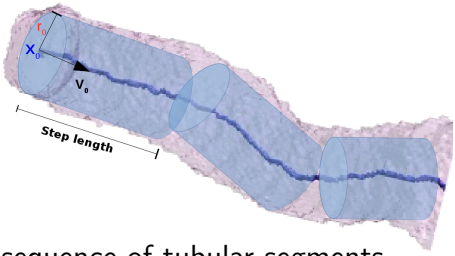
With MHT

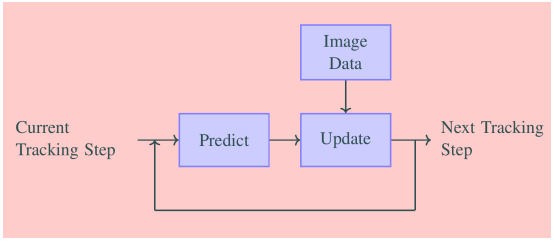
- Robust decisions, as solutions are more global
- Search Depth controls globalness/speed tradeoff

Tubular Template Matching



- Airways as a sequence of tubular segments
- Segments described using templates
- Templates comprise of orientation, location & radius: $(\mathbf{v}, \mathbf{x}, r)$
- Fitness measures by matching templates with image data

Tracking Individual Branches



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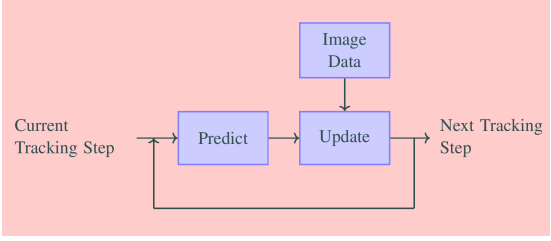
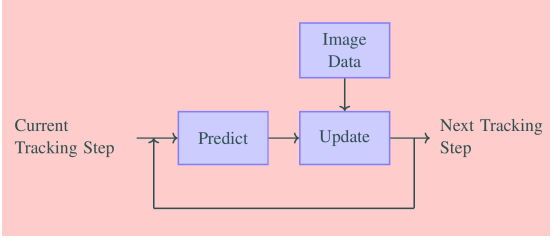
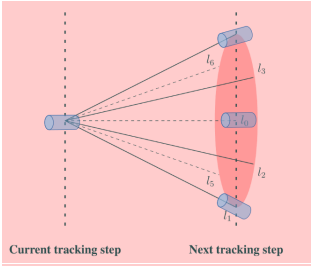
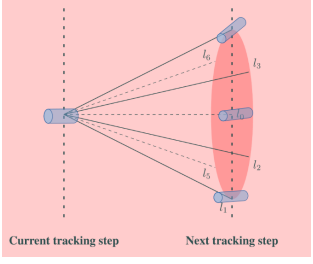


- Generate regularly spaced predictions
- Update predictions using image data
- Build MHT tree from updated predictions

Tracking Individual Branches







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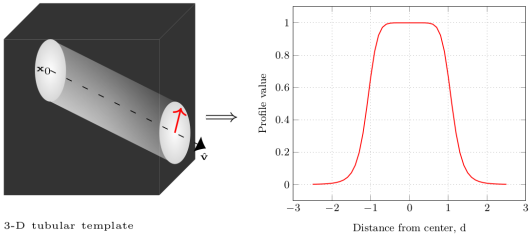
MHT in Medical Image Segmentation

- Earlier work by Friman *et.al*, 2009 [1]
- Successfully applied for tracking vessels
- Requires extensive user intervention
- Not immediately applicable for extracting airway trees
- Several tunable parameters
- Critical parameters are scale-dependent

[1] Multiple hypothesis template tracking of small 3D vessel structures, Ola Friman et al, 2009

Modifications to the Original MHT Method

Application to Airway Trees



3-D tubular template

- Bright tubular structures in dark background
- Obtain probability images using KNN-based voxel classifier

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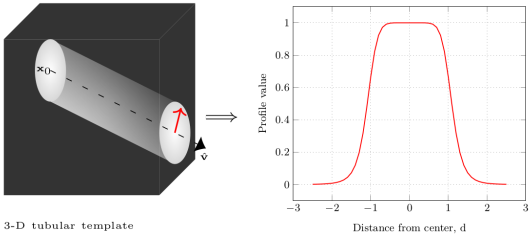

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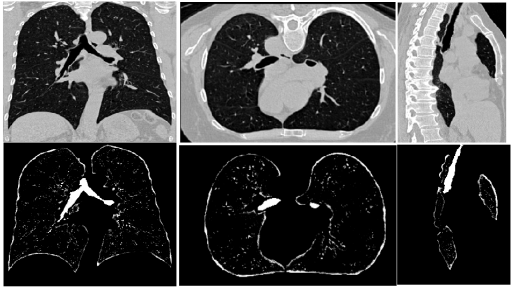

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Problem of Varying Dimensions

Fitness Measure

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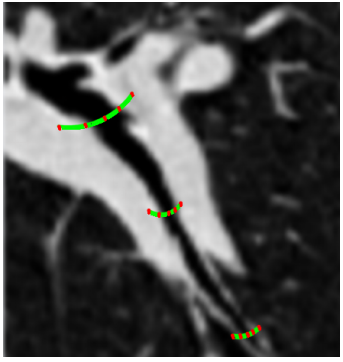

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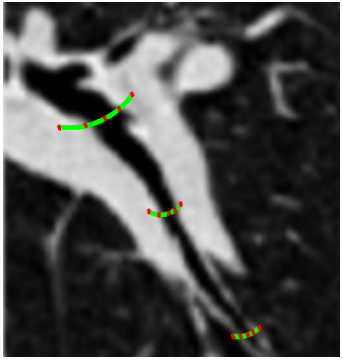


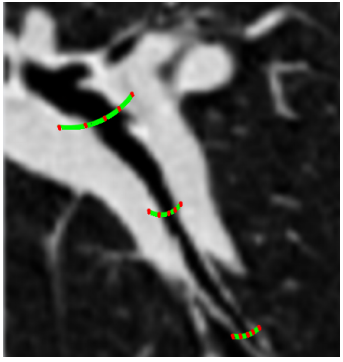
Org.	MHT
(0.7, 2, **9**, 4, 0.5)	
(0.1, 2, **5**, 3, 0.3)	
(0.2, 1, **2**, 0.4, 0)	

Problem of Varying Dimensions

Fitness Measure

$$\text{templateScore} = \frac{\text{contrast} - 0}{\text{std}(\text{contrast})}$$

- Larger structures yield large scores
- Hypothesis Thresholds tuned at one scale are not applicable at another



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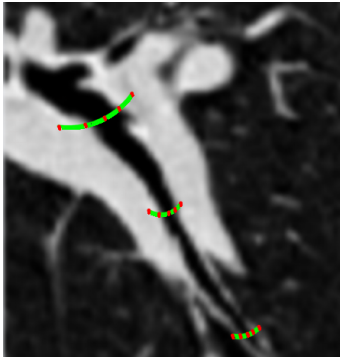

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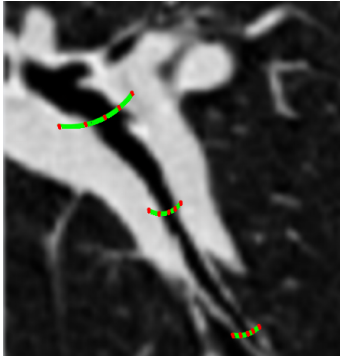
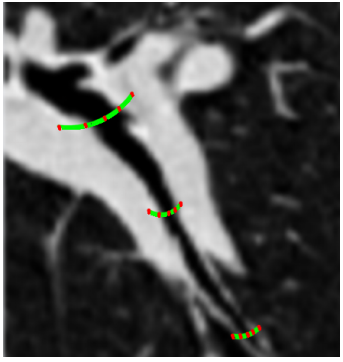


Mod. MHT
(0.1, 0.2, **1**, 0.4, 0.3)
(0.2, 0.3, **1**, 0.4, 0.2)
(0.1, 0.4, **1**, 0.3, 0.1)

Statistical Ranking of Hypotheses

- Local hypotheses are ranked
- Relative significance between hypotheses is captured
- Global hypotheses comprise of statistically significant local hypotheses
- Removes scale-dependence of global threshold
- One parameter fewer



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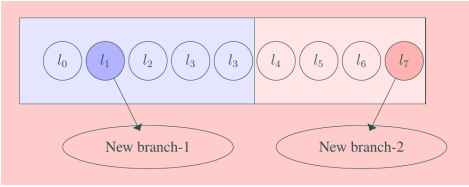
Handling Branching



- Perform spectral clustering of hypotheses at each step
- New branches are spawned if two clusters are observed
- Resume tracking from each branch separately
- Each new branch inherits MHT tree history of parent node
- Handles only bifurcations

Data and Experiments

Data

- CT data from Danish Lung Cancer Screening Trials (DLCST) [2]
- Independent training and test sets; 16 + 16 images
- Probability images obtained using a k-NN based voxel classifier [3]
- Reference data: Union of results from two previous methods verified by expert user

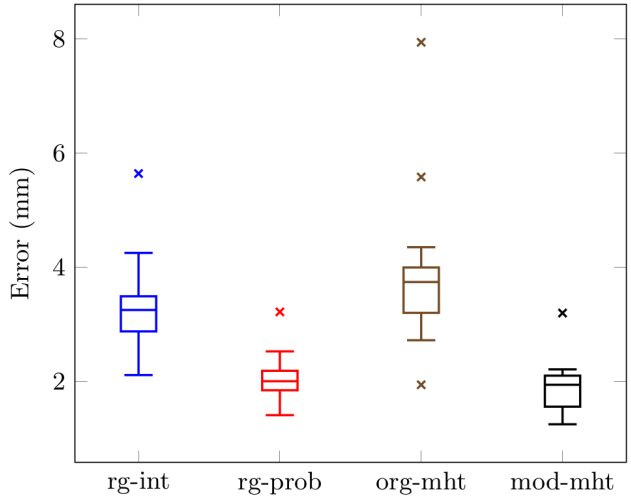
[2] Pedersen, J. H., et.al : The Danish randomized lung cancer CT screening trialoverall design and results of the prevalence round. Journal of Thoracic Oncology, (2009)

[3] Lo, P., et.al: Vessel-guided airway tree segmentation: A voxel classification approach. Medical image analysis,(2010)

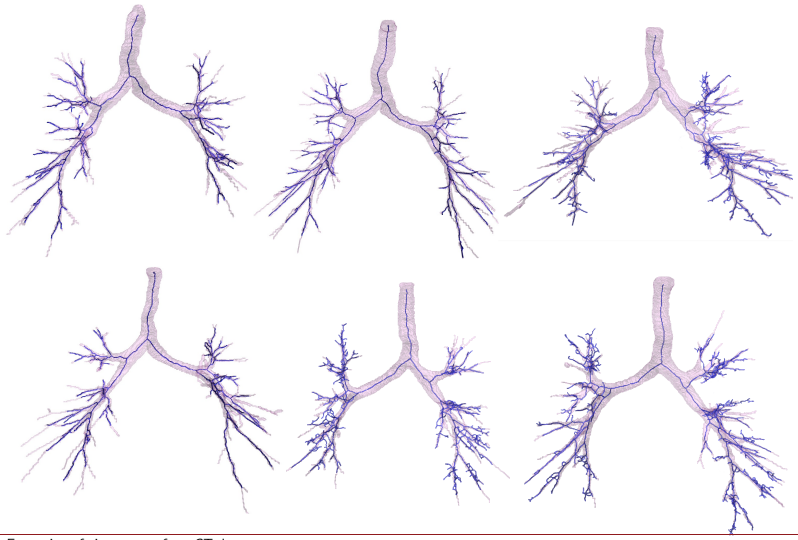
Experiments

- Error Measure: Distance between reference & segmented centerlines
- Parameters are tuned on training set
- Trained parameters are tested on independent test set
- Compared with: Original MHT method, Region Growing on Intensity and Region Growing on Probability

Performance Comparison



Some Results



Conclusions

- Interactive method for tracking vessels has been modified for extraction of airway trees
- Ranking eliminates scale-dependence of crucial parameters
- Modified method is applicable to wider range of problems
- Promising results, with scope for improvement

Future Work

- Compare the presented method in the EXACT platform
- Derive useful biomarkers from the obtained results
- Demonstrate applicability to different problems
- Possibility of handling bifurcations

Thank you.

Comments & Questions