Prior Models on Coronary Arteries to Support Coronary Artery Detection

Paper Review Presentation

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Gulsun, 2012
Coronary Artery Disease
- 53% of cardiovascular diseases. Leading cause of death in the United States!
- Coronary detection in CTA is important for diagnosis, treatment and monitoring.

Problem: Coronary detection from CTA is difficult due to
- their high anatomical variability
- pathologies and imaging artifacts

Project Goal: Build prior coronary models to
- improve detection
- allow for statistical analysis
Technical Approach

50 CTA coronaries

M1 Alignment

M2 Statistics on Territories

M3 Coronary Tree Matching

M4 Coronary Tree

M5 Average Tree

Gulsun, 2012
“An airway tree-shape model for geodesic airway branch labeling”


Relevance to my project:

Airway Branch Matching  \[\leftrightarrow\] Geodesic Deformation  \[\leftrightarrow\] Geodesic Deformation  \[\leftrightarrow\] Coronary Average Tree

QED: Quotient Euclidean Distance

Feragen et. al.
Problem Statement

- Diseases related to airway properties
  - Chronic Obstructive Pulmonary Disease
- Monitor disease progression
  - variation of airway properties at specific sites
  - need for airway tree correspondence between two subjects

- Airway tree shapes for correspondence
  - extracted in CT scans
- Difficult problem due to
  - spurious or missing branches
  - anatomical variability

Feragen et. al.

McGill University
Methods using either topology or branch shape

- Maximal cliques on association graphs
  - Only topology, NP-hard

- Recursive labeling
  - Prone to topological order of branches

- Path matching
  - Loses topological information, no branch matching

- Method proposed in this paper
  - Based on both topology and branch shape: main contribution
  - Continuous geodesic deformation

Feragen et. al.
Method – Geometric Space

\[ f : E \rightarrow \mathbb{R}^{3n} \]

Tree-shape space

\[ X = \prod_{e \in E} \mathbb{R}^{3n} \]

Quotient Space

\[ \tilde{X} \]

Project Overview
Paper Background
Method
Experiments
Critiques

Gulsun, 2012
Method – Quotient Euclidean Distance

- Euclidean distance in the quotient space
  - $L_2$ norm between nonidentical trees
  - 0 between identical trees

- Geodesic path: a series of internal structural changes with minimum cost

$\text{dist1} + \text{dist2} < \text{dist3}!$
Method – Quotient Euclidean Distance

- Unique Geodesic Path with L2 norm metric
  ➢ Well suited for registration and statistics

- L1 norm ⇒ Same geodesic distance as TED (Tree Edit Distance)
Method – Application to airways

- Airway tree shapes are in 3D and
  - branch orders unknown
- Consider all orders
  - computationally expensive
  - match each lobe separately

- Implementation: consider all possible paths and take the shortest path
  - too many paths!
  - put an upper bound on internal changes

- Propagate branch labels through deformation
- Majority vote
  - propagated labels from multiple trees
Experiments

- Airway centerlines from 20 EXTRACT’09 segmentation challenge data
- Labels by trained image analyst
- 6 landmarks sampled along each branch, short ones were pruned
- Each tree was normalized by the size of LMB branch
- 6 main branches were fixed and method was run on 5 lobar trees separately
- Branches down to 6-7 generations considered
- Only one internal topological transition was allowed in the deformation
- Airway trees were matched with a leave-one-out fashion
- Branches with less than 55% consensus or 4 votes were discarded
Results

- Average labeling success rate: 83%
- Authors opinion: Success rate was high taking the variation into account
- Comparison to other methods (with 97%, %90 success rates) was not possible because of different datasets used

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Critique - Cons

- Authors claim: 83% is high given the large variation in topology
- Plot supporting their claim:

- But they run their method down to 6 generations
  ➢ a similar plot for only down to 6 generations would be more supportive!
- Authors statement: airways trees may have missing branches

Mislabeling when branches missing

My implementation with branch partitioning

Gulsun, 2012
Critique - Cons

- Airway trees were normalized using LMB branch length
- No comment on the variability of LMB branch relative to airway tree
  ➢ does larger airway trees always have longer LMB branch?
- In my project, coronary trees normalized relative to heart size
  ➢ acceptable
- Were fixed branches included in the results?
  - if so, what are the results for only lobes?

- Authors claim: 30% accuracy in CASE39 was due to missing upper lobe
  - each lobe was matched separately
  - why other lobes were affected?

- no clue about runtime

- comparison to TED method missing
  - previously applied to cerebral vessel matching by Tang, et. al.
Critique - Pros

- A novel method that uses both topology and branch geometry
- Unique geodesic metric
  - suitable for statistical analysis
- Majority vote labeling: simple but effective idea
- Additional attributes can be used
- Presentation of QED to a broader community
- Similar problem: geodesic deformation between trees
  - 2D coronary centerlines
  - more resources for handling missing branches
- Prune small branches
- Fix certain main branches, e.g., LAD and CX branches

- Future work: comparison of TED and QED for branch matching
References

