Prior Models on Coronary Arteries

Computer Integrated Surgery II, Spring 2012

Mehmet Akif Gulsun[1,2], under the supervision of Gareth Funka-Lea[1]
[1]Siemens Corporate Research, Princeton, NJ, USA, [2]The Johns Hopkins University, Baltimore, MD, USA

SIEMENS
JOHNS HOPKINS UNIVERSITY

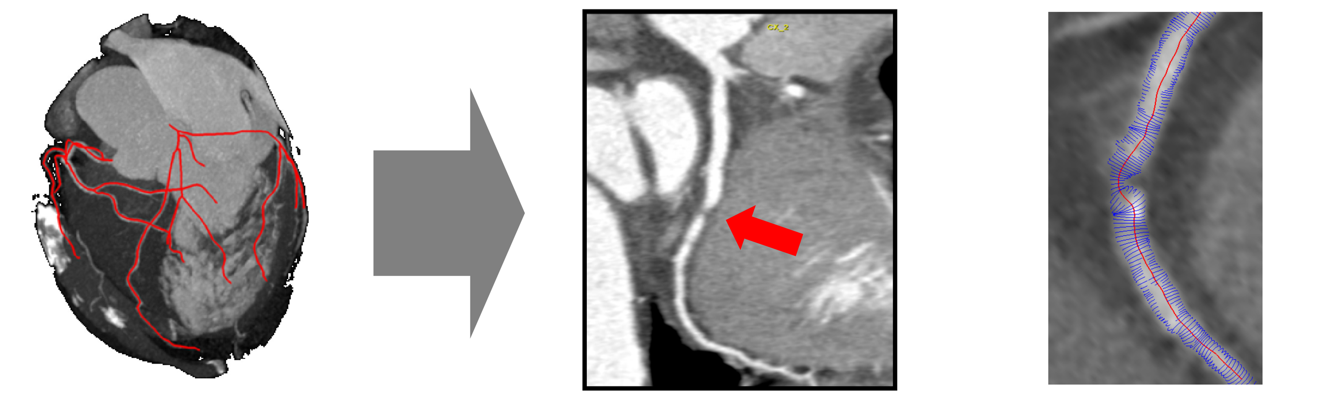
INTRODUCTION

Coronary arteries have large topological variations in their anatomy.

- Prior models that can capture these variations are needed
  - to support coronary detection in medical images
  - for statistical analysis
- Coronary prior models from
  - computing their distribution on territories
  - building tree-shape models and geodesic metrics that can account for topology
- Traditional statistical methods are well suited for shapes sharing a common topology which is not the case for coronaries.

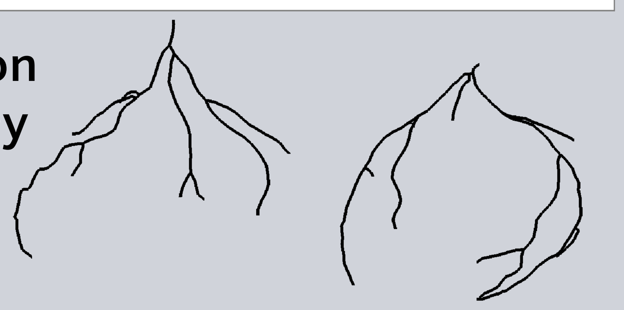
PROBLEM

- Coronary centerline detection is a necessary task



Centerlines in CTA — Advanced Visualization — Planning

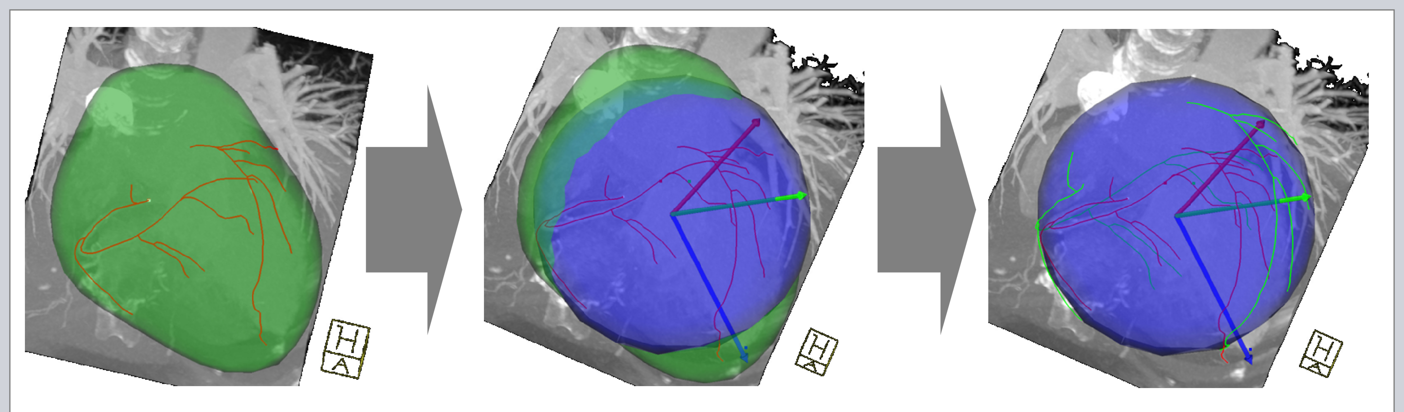
- Common difficulties for detection
  - irregular topology of anatomy
  - pathologies
  - imaging artifacts



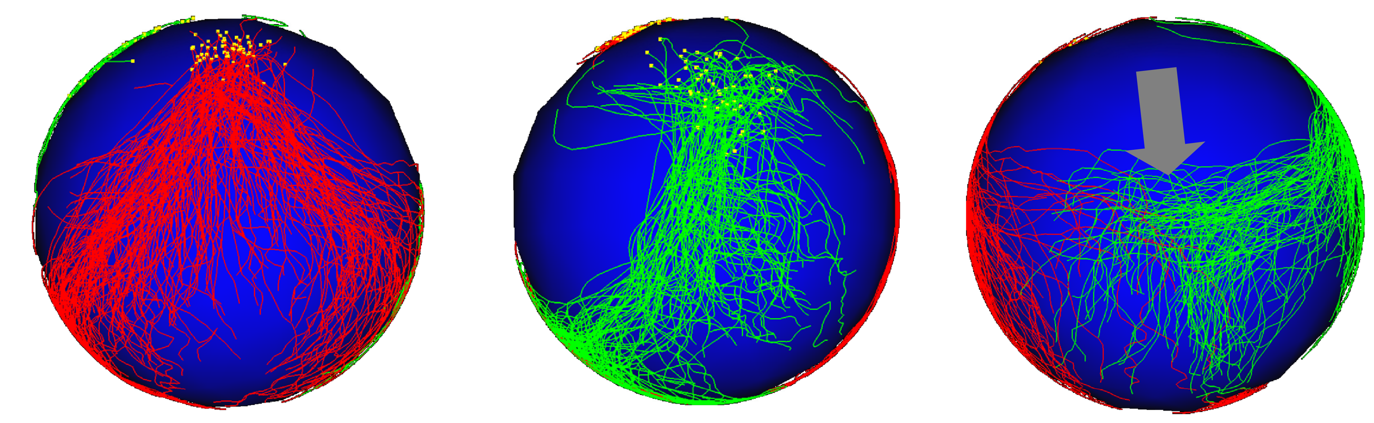
- Besides detection, statistical tools are also needed to
  - compute modes of variation in coronary shapes
  - correlate coronary artery diseases with coronary anatomy
  - register coronary trees
- Current methods do not address the large variation in coronary topology and geometry together.

METHODS

Alignment of Coronary Centerlines



Input Data — Defined Coordinate System — Projected Centerlines

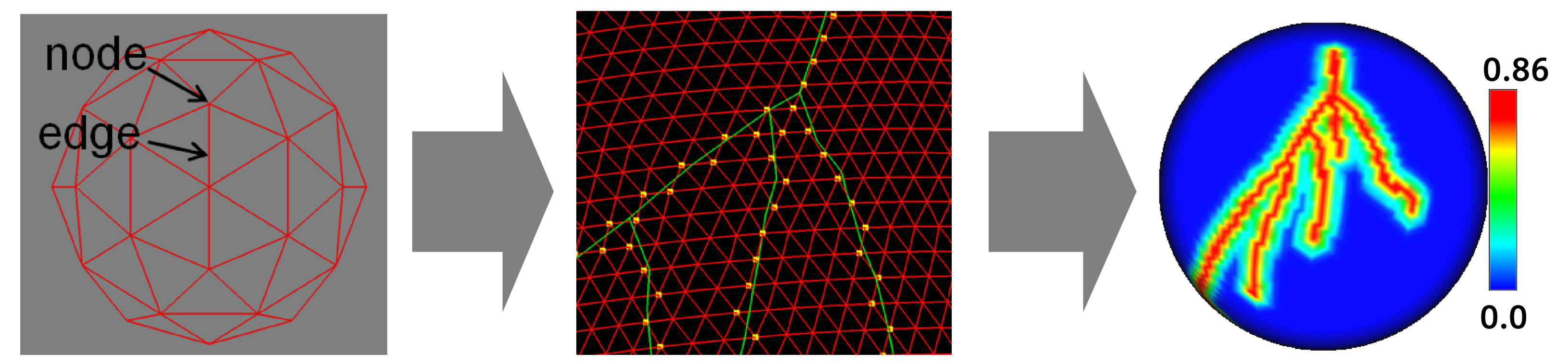


Aligned Left Trees — Aligned Right Trees — Right Dominancy

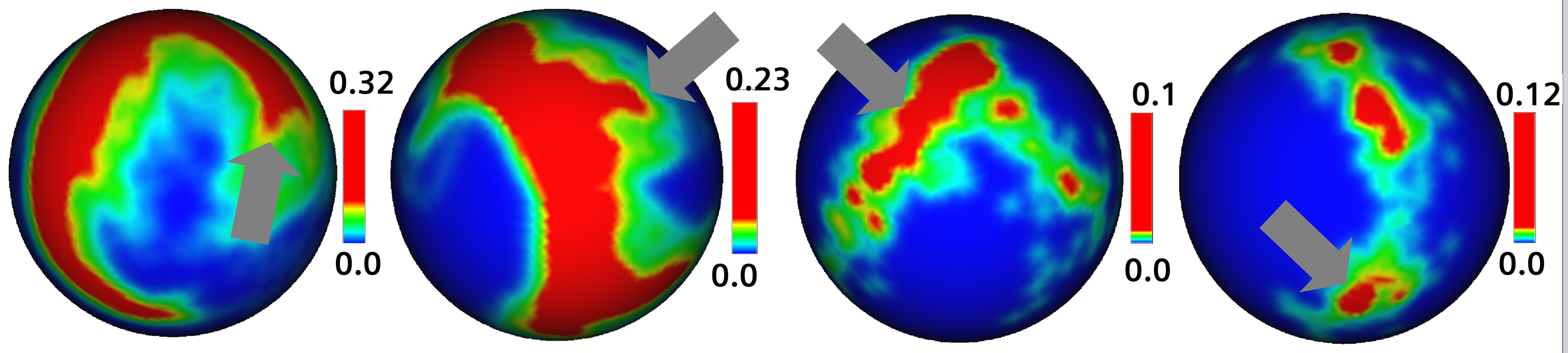
Statistics On Territories

Average density map from vessel distance maps

- Vessel distance map computation
  - construct a discrete graph on the canonical surface
  - initialize distance map by mapping centerline points
  - run Dijkstra's algorithm to obtain final distance map
- Density map from Gaussian weighting of distance map



Constructed graph — Mapping Coronaries — Density map

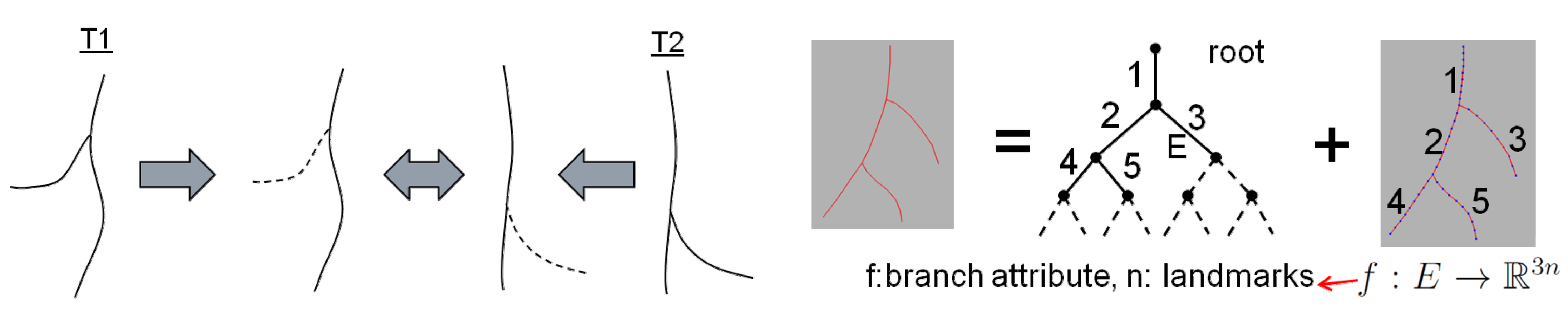


Left Coronaries — Right Coronaries: Mean Density Maps
Left Coronaries — Right Coronaries: Mean Bifurcation Density Maps

Tree-Shape Geodesics via Tree Edit Distance

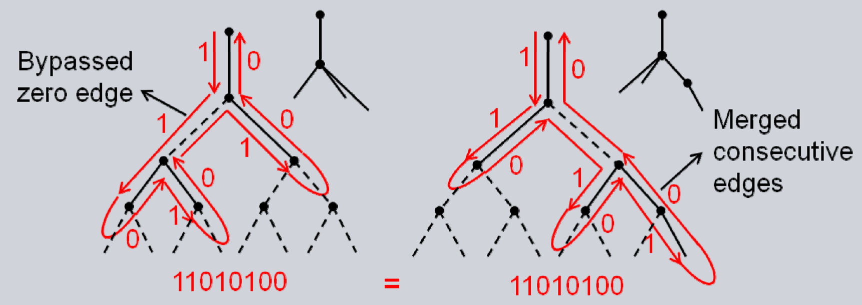
Best known method to compute geodesics between tree-shapes

- Match two trees with add, remove and deform edit operations



Bidirectional deformation — Tree-shape representation

- Implementation with bidirectional Dijkstra's minimum cost path
  - concurrent propagation from source and target tree-shapes
  - until trees from two fronts with same topology collide

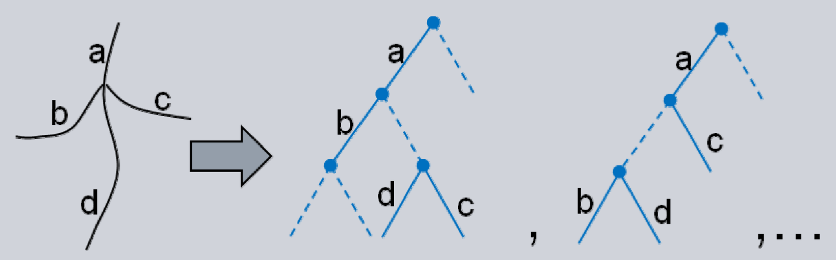


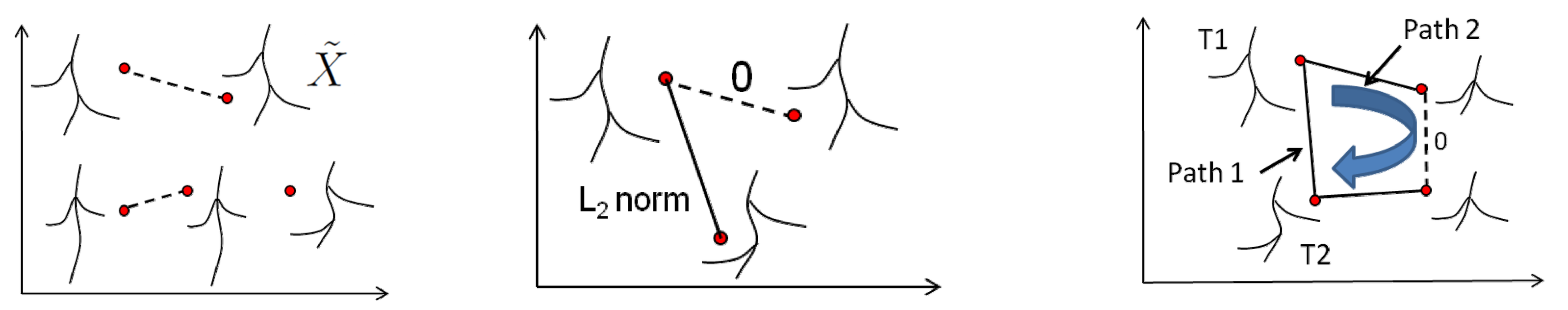
Topology Matching Algorithm

Tree-Shape Geodesics via Quotient Euclidean Distance

A unique tree-shape geodesic metric suitable for mean computation

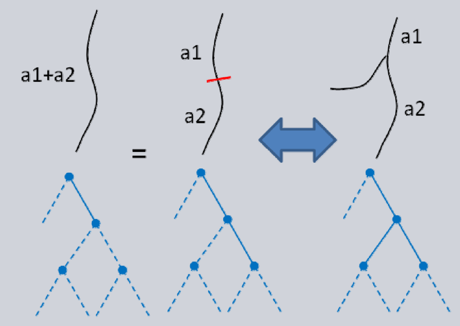
- Different representations of same tree-shape are identified in Quotient Space





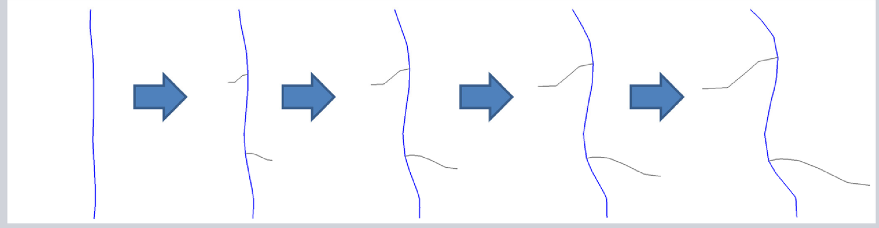
Quotient Space — Quotient Euclidean Distance — Paths in Quotient Space

- Extended definition of identical tree-shapes for handling missing branches

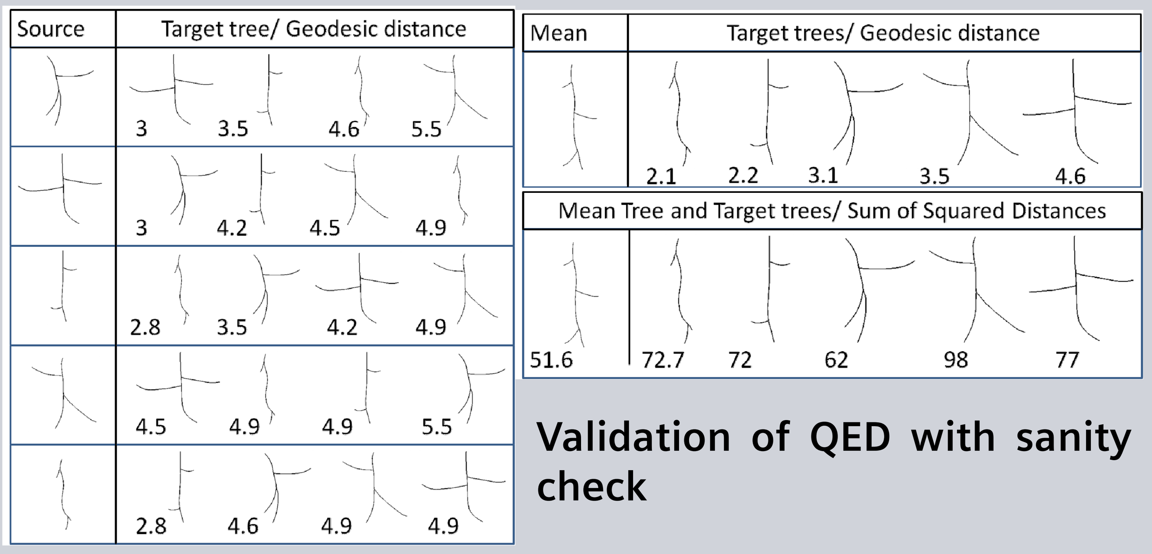


- QED metric is non-negative
  - implementation with Dijkstra's algorithm
- Approximation of mean tree using Birkhoff Shortening

RESULTS

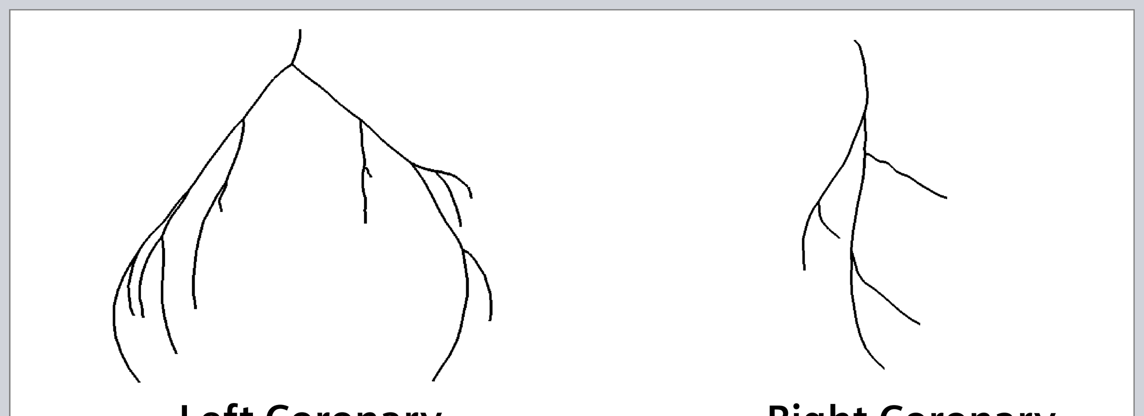


Missing branches are grown along the QED geodesic path



Validation of QED with sanity check

Application to coronaries using 50 hand annotated data
- Geodesic deformations are applied to LAD and CX sub-trees separately



Left Coronary Average Tree — Right Coronary Average Tree

Coronary Tree Matching

FUTURE WORK

- Evaluation of tree matching on labeled trees
- Correlation between average tree and specific patient data
- Running the algorithm in higher depth trees
- Integration into detection algorithms

LESSONS LEARNED

- Vascular structures have complex topology and traditional methods cannot be easily applied
- Learned a new way of building statistical models
- A good design and implementation are important for computational efficiency

Acknowledgements: Thanks to Dr. Yefeng Zheng from Siemens Corporation for his time on providing me with the annotated datasets