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Prior Models on Coronary Arteries to Support Coronary Artery Detection

Checkpoint Presentation

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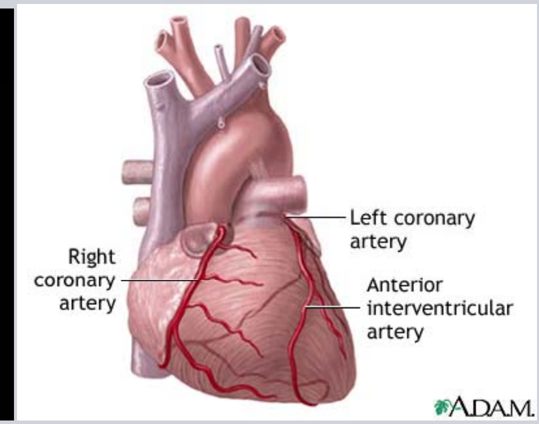
Project Overview

Coronary Artery Disease

- 53% of cardiovascular diseases. Leading cause of death in the United States!

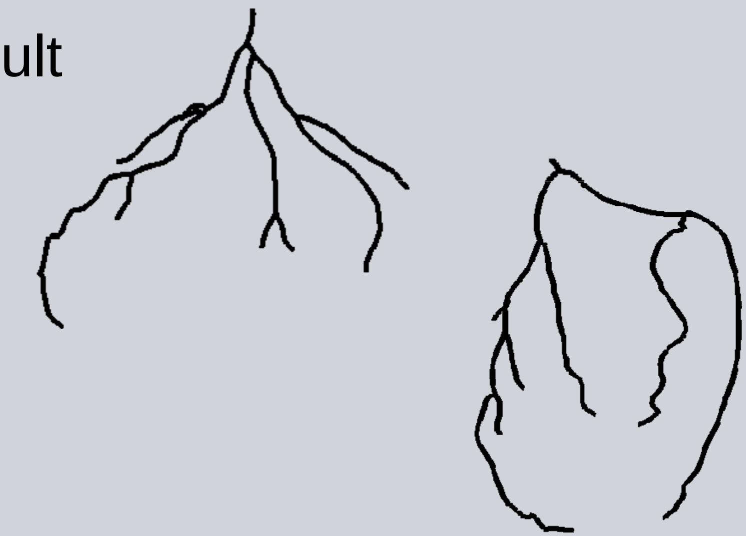
- Coronary detection in CTA is important for diagnosis, treatment and monitoring.



nlm.nih.gov

<u>Problem:</u> Coronary detection from CTA is difficult due to

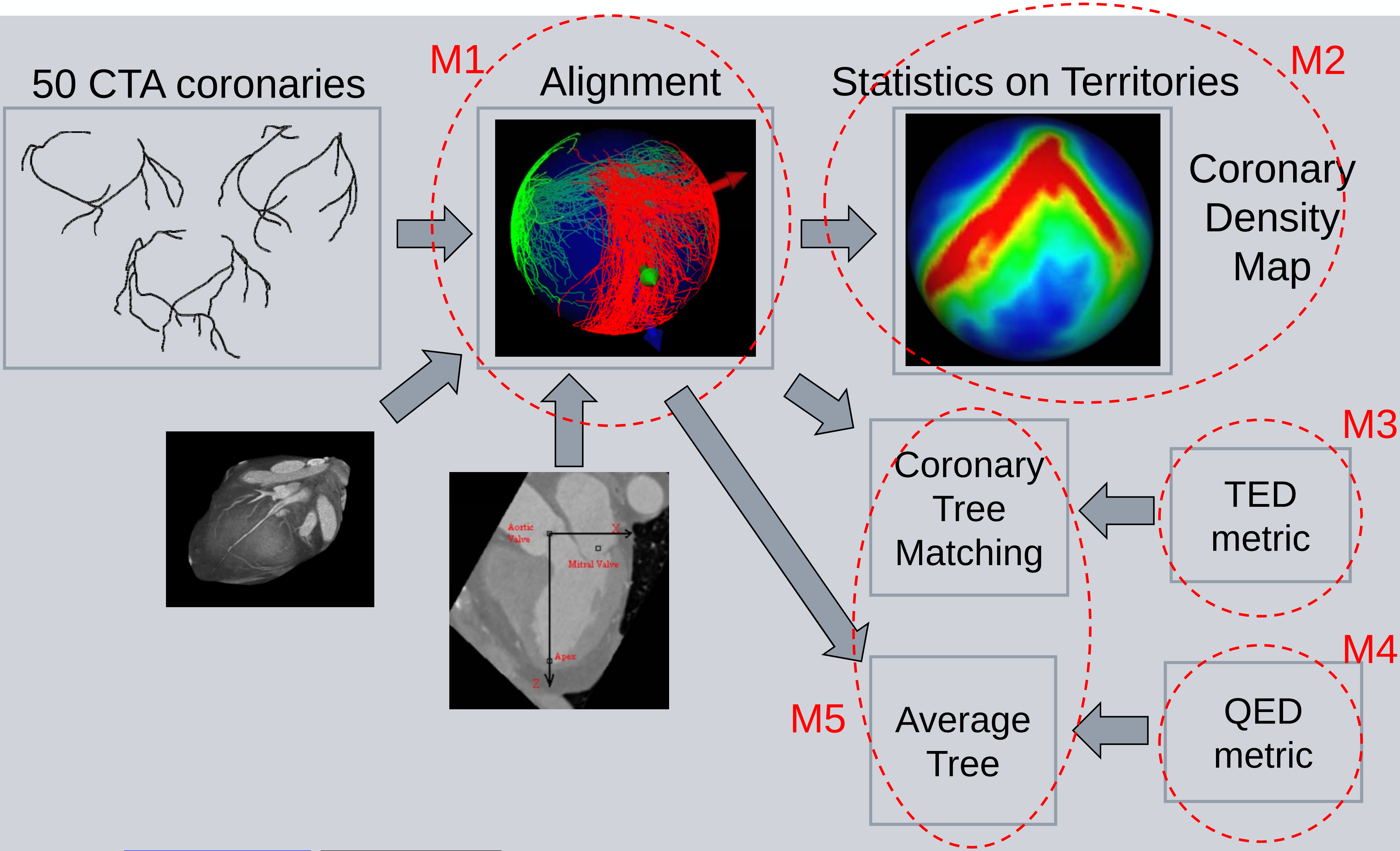
- ➢ their high anatomical variability
- ➢ pathologies and imaging artifacts



<u>Project Goal:</u> Build prior coronary models to

- ➢ improve detection
- ➢ allow for statistical analysis

Technical Approach



Milestones

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	Milestone	Planned	Achieved
1	Alignment of coronary centerlines (MINIMUM) ✓	Mar4	Mar2
2	Statistics on territories (MINIMUM) ✓	Mar11	Mar10
3	Geodesic with TED algorithm (EXPECTED) ✓	Apr8	Apr5
4	Geodesic with QED algorithm (EXPECTED) 50%	Apr29	-
5	Applications (MAXIMUM) Pending	May8	-

	Milestone Validations
1	Visualize coronary trees on the canonical surface ✓
2	Visualize both coronary trees and density map on the canonical surface ✓
3	Test on example trees with ground truth TED geodesic ✓

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Milestone 1 – Prototype setup

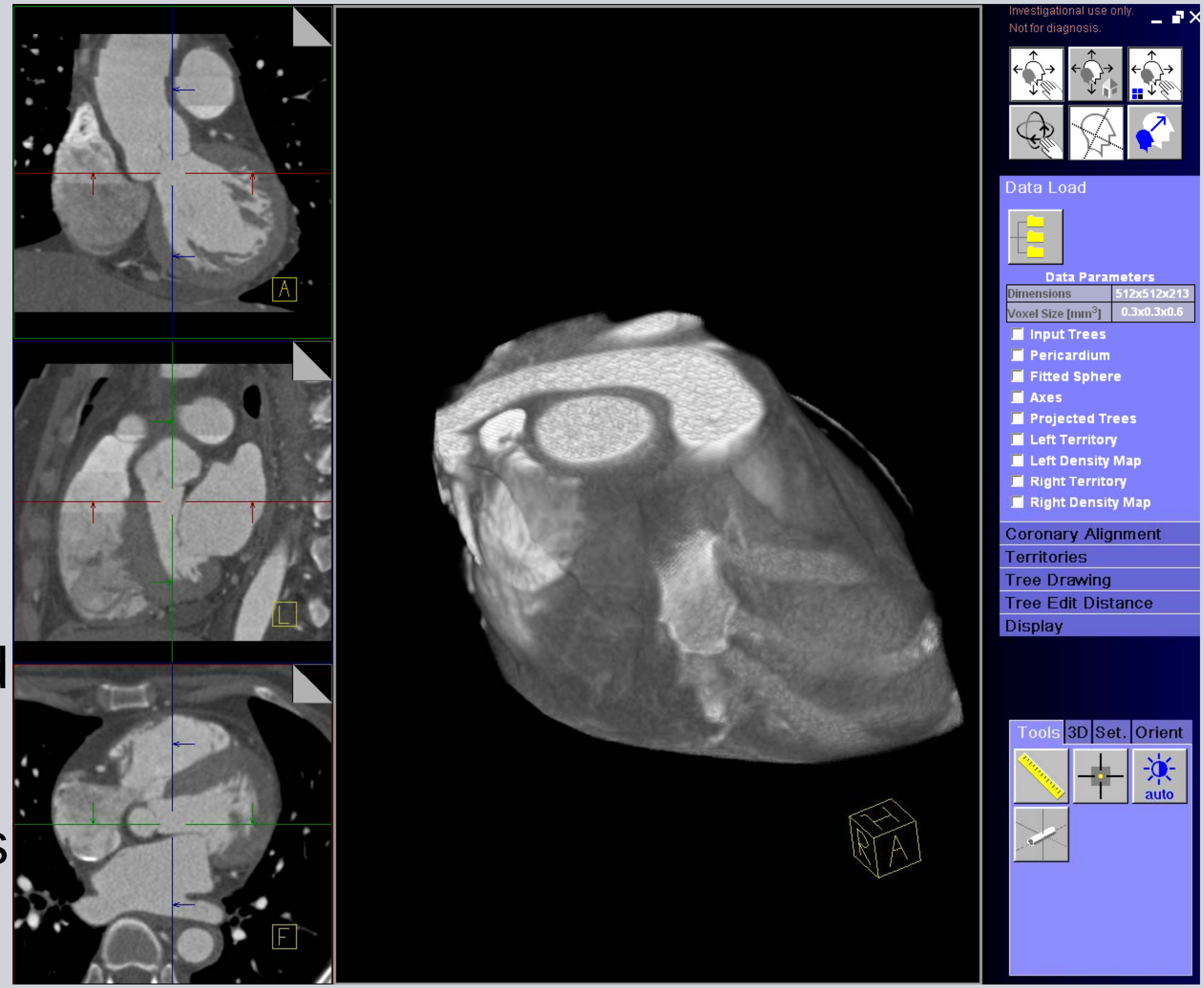
Prototype software

- Built using Siemens' rapid prototyping platform XIP (extensible imaging platform)

- Loading and visualization of data

- Each milestone is implemented in a separate task card

- Features to validate milestones



Milestone 1 – Coordinate System

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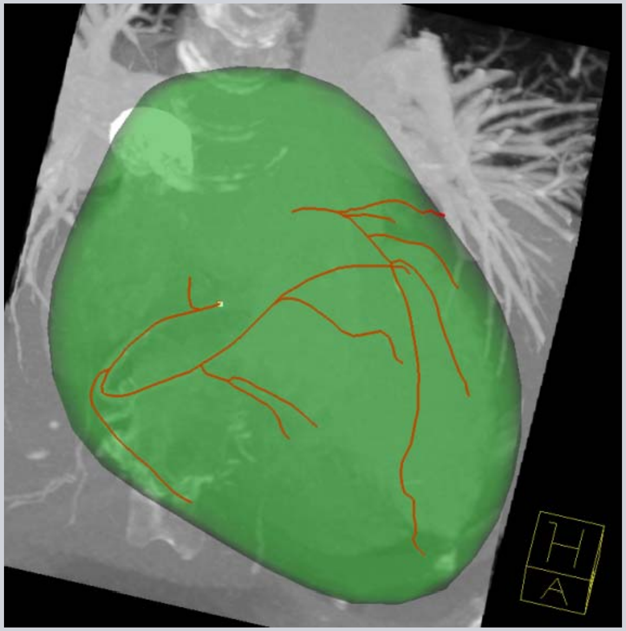
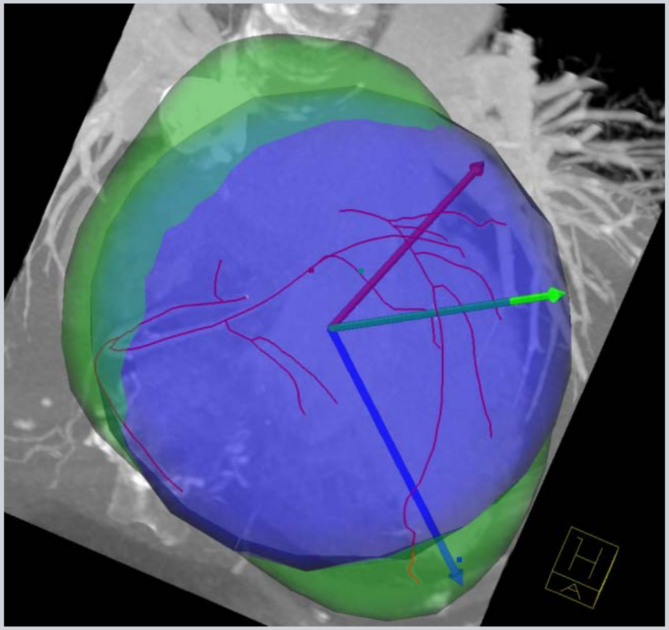
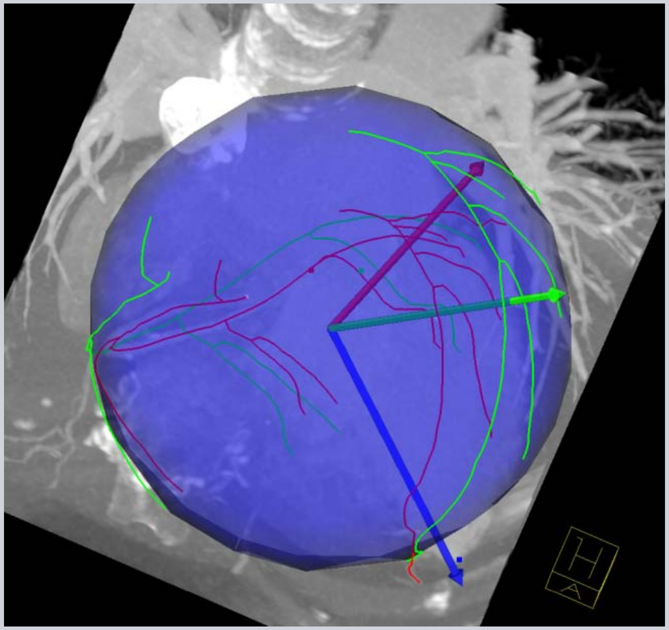
Definition of the Canonical Coordinate System



Input Coronary Trees and Pericardium Mesh



Fitted Spherical Model with Axes



Projected Trees

Milestone 1 - Alignment

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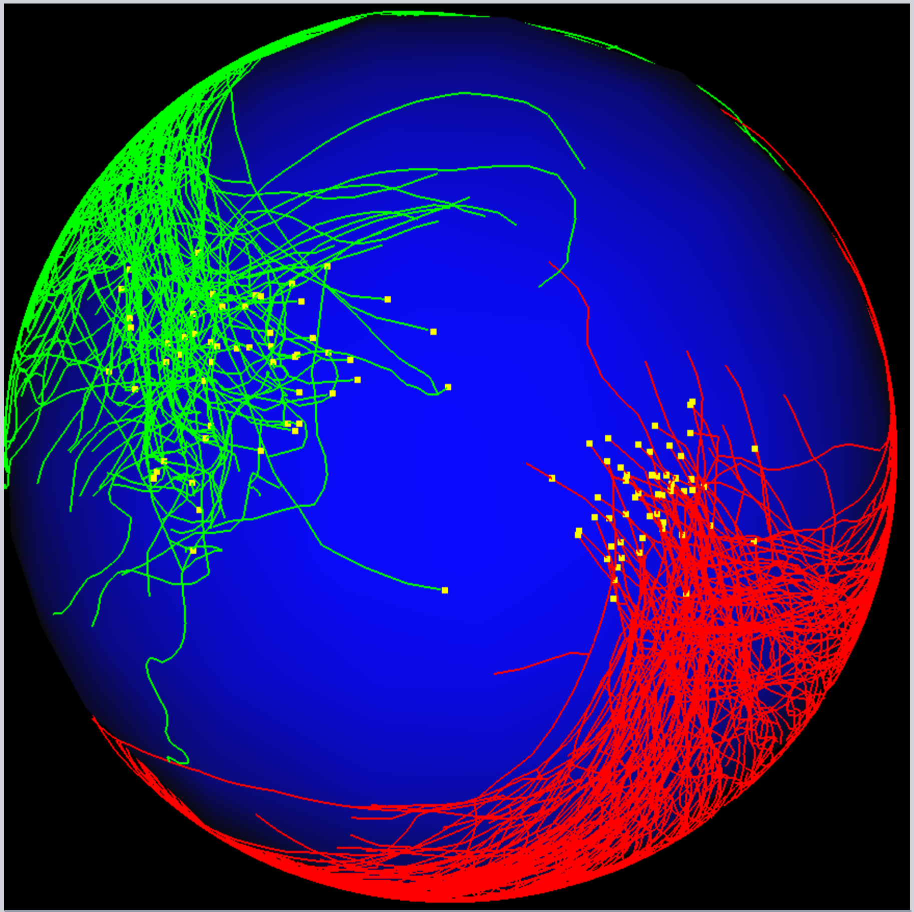

Ostia Distribution

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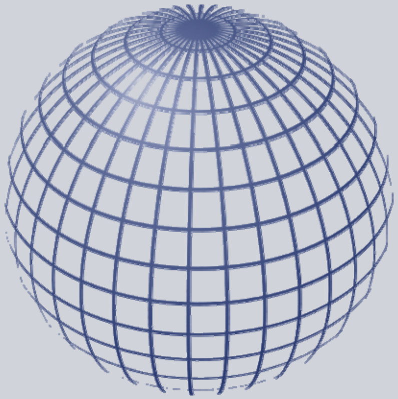
Milestone 2 – Coronary Distance Maps

Discretization of the spherical manifold

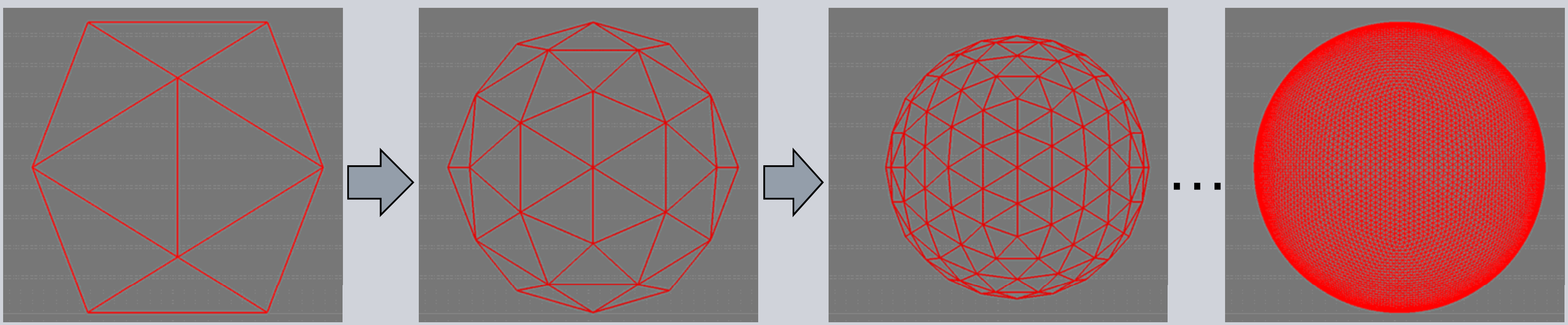
Spherical grid based on discrete polar coordinates

- Not uniform!



wikipedia.com

Solution: Recursive triangulation



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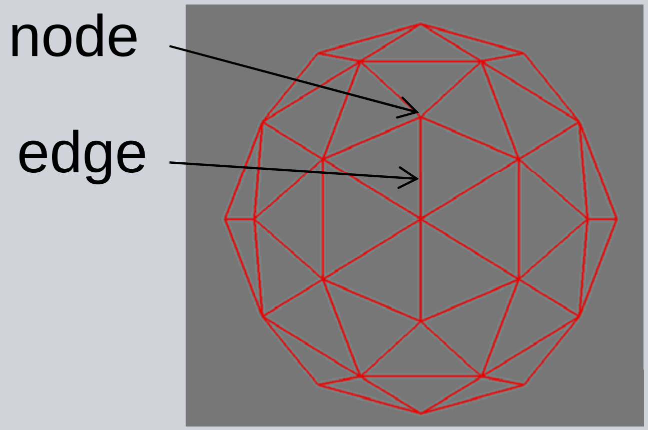
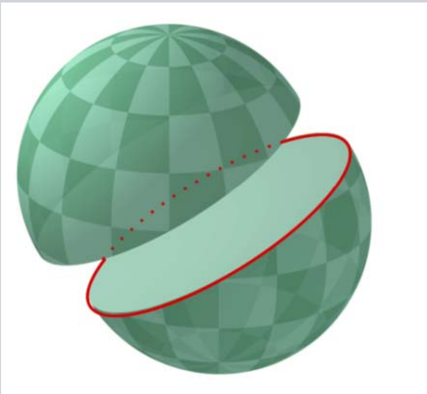
Milestone 2 – Coronary Distance Maps

Construct a graph G = (nodes, edges)



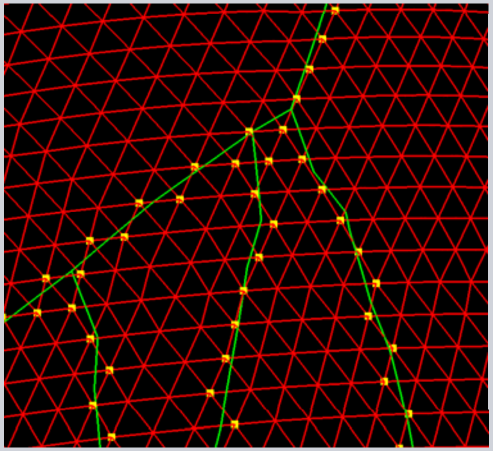
Cost of a graph edge:

- Great circle distance between the two neighboring nodes



wikipedia.com

Distance Map Computation



- Initialize distance map with infinity
- For each centerline point
  - ➢ find the closest node and update its distance
- Run Dijkstra's algorithm

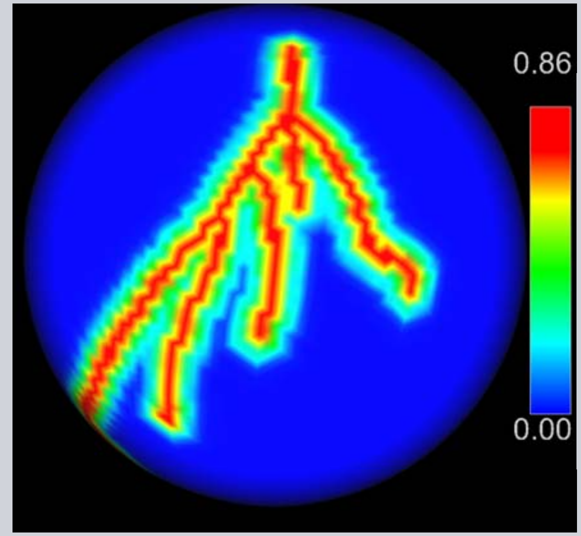
Milestone 2 – Coronary Density Maps

Computed from Gaussian weighting

density, distance

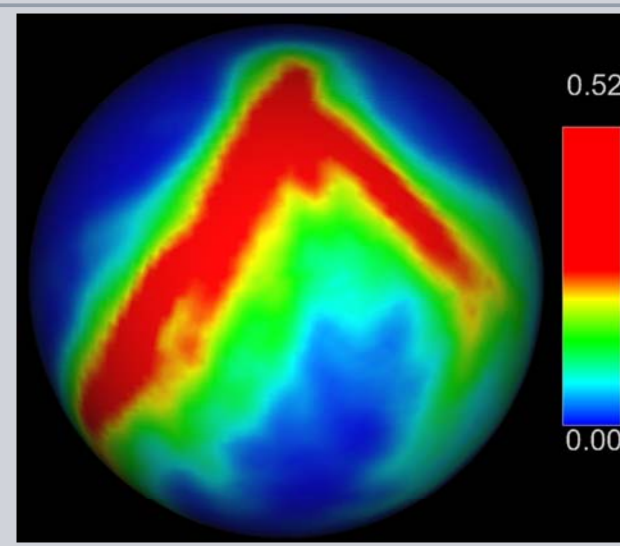
$$\rho(\mathbf{x}) = e^{-\frac{D(\mathbf{x})^2}{\sigma^2}}$$

standard deviation (~5 mm)

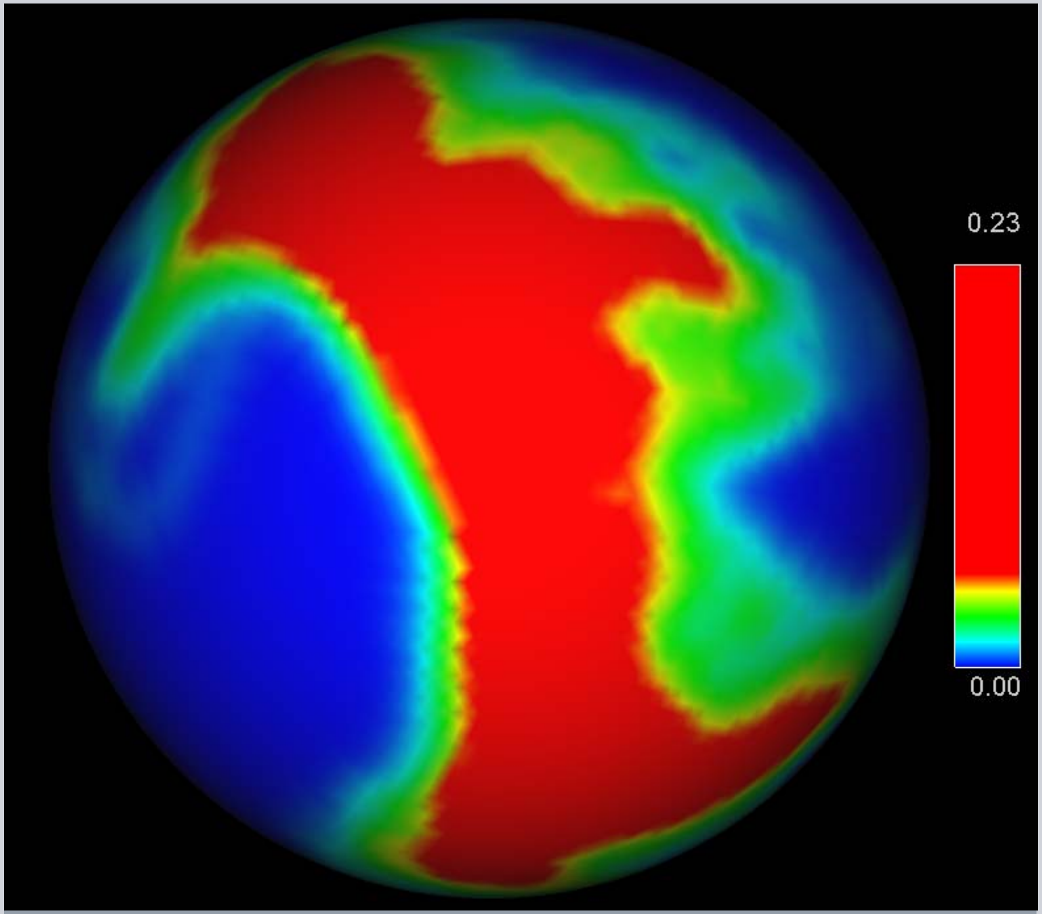


mean density

$$\bar{\rho}(\mathbf{x}) = \frac{1}{N}\sum_{i=1}^{N} \rho_i(\mathbf{x})$$

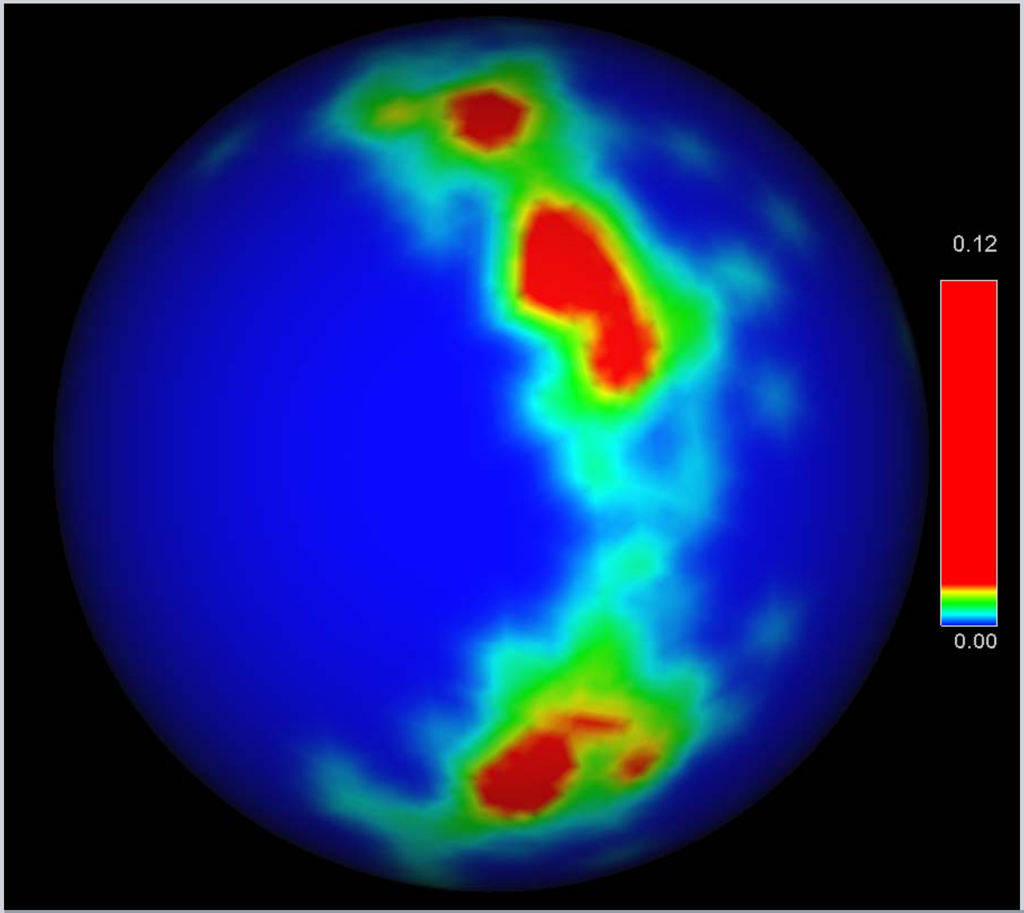


Milestone 2



Right Coronary Density Map

Milestone 2



Right Bifurcation Density Map

Milestone 3 – Tree Edit Distance

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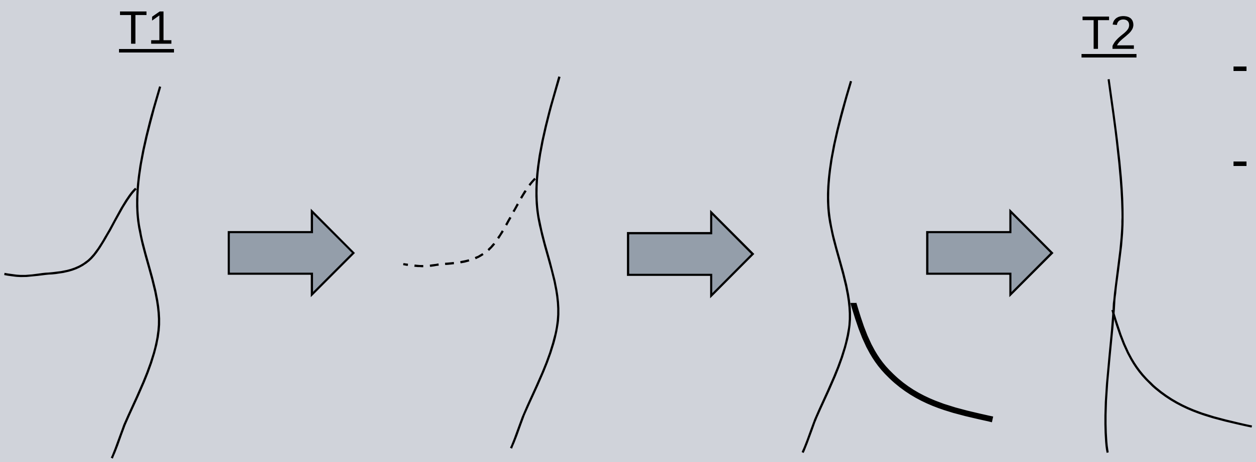
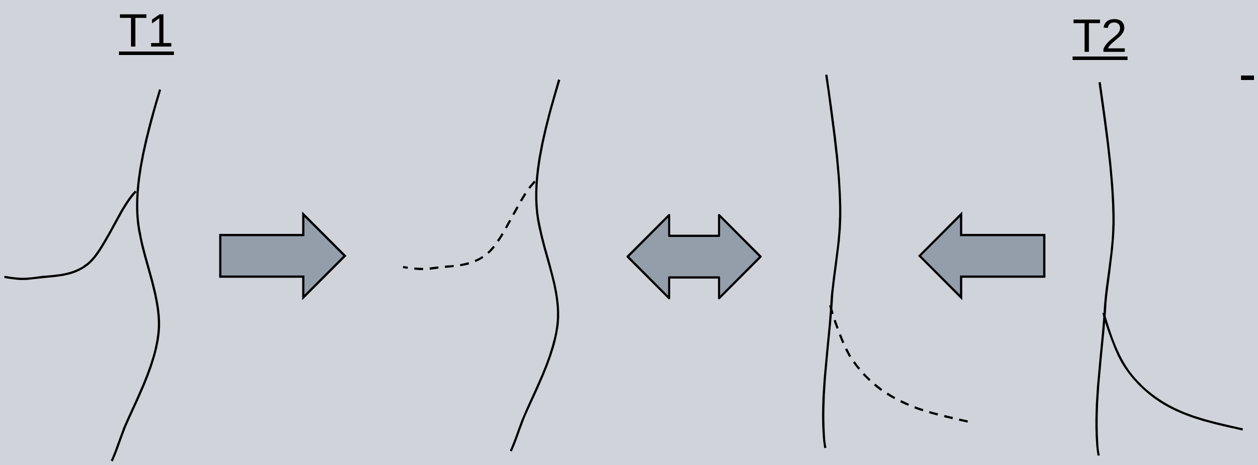
- Match one tree to another by adding, removing or deforming branches with minimal cost



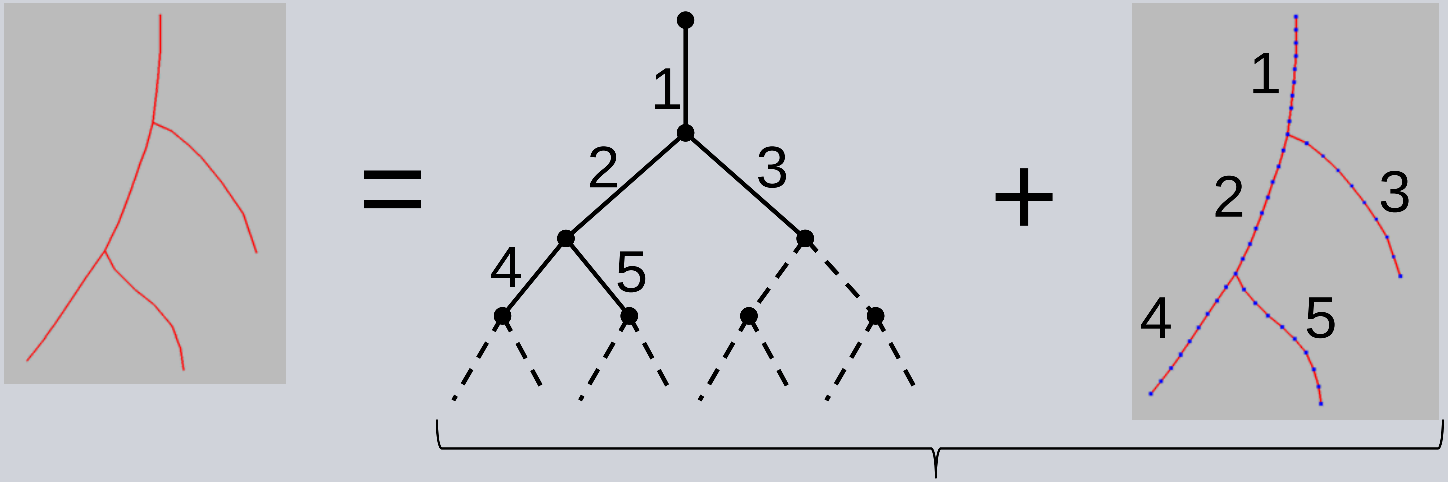
- Unidirectional Deformation
- Infinitely many branch adding



- Bidirectional Deformation
  - only branch removal
  - has the same path cost

[Tang, et. al]

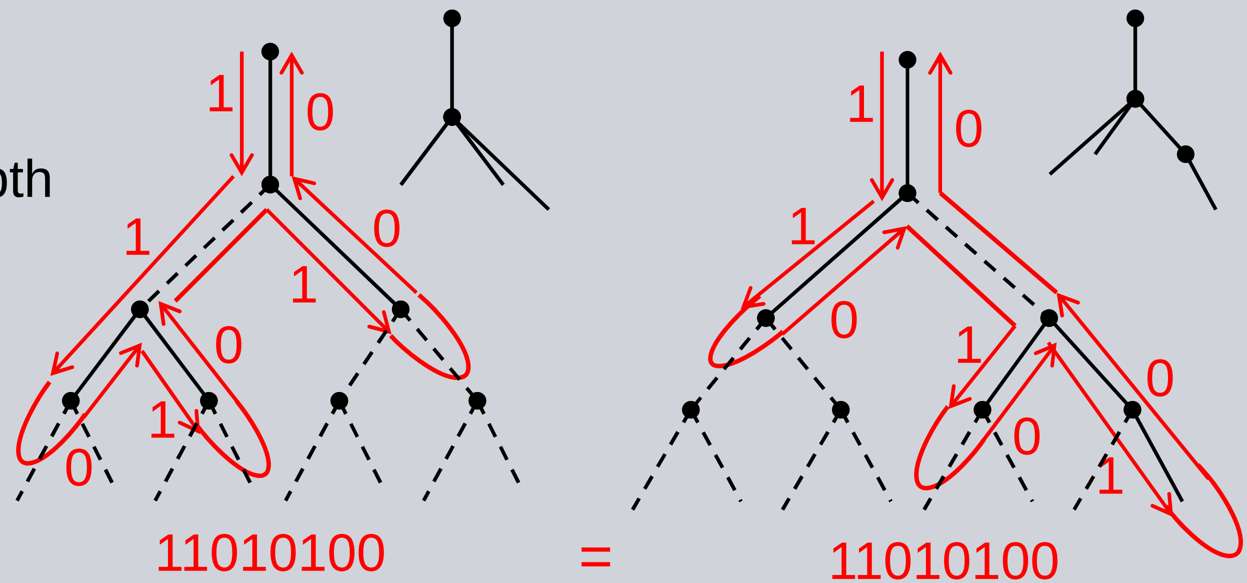
Milestone 3 – Tree Representation



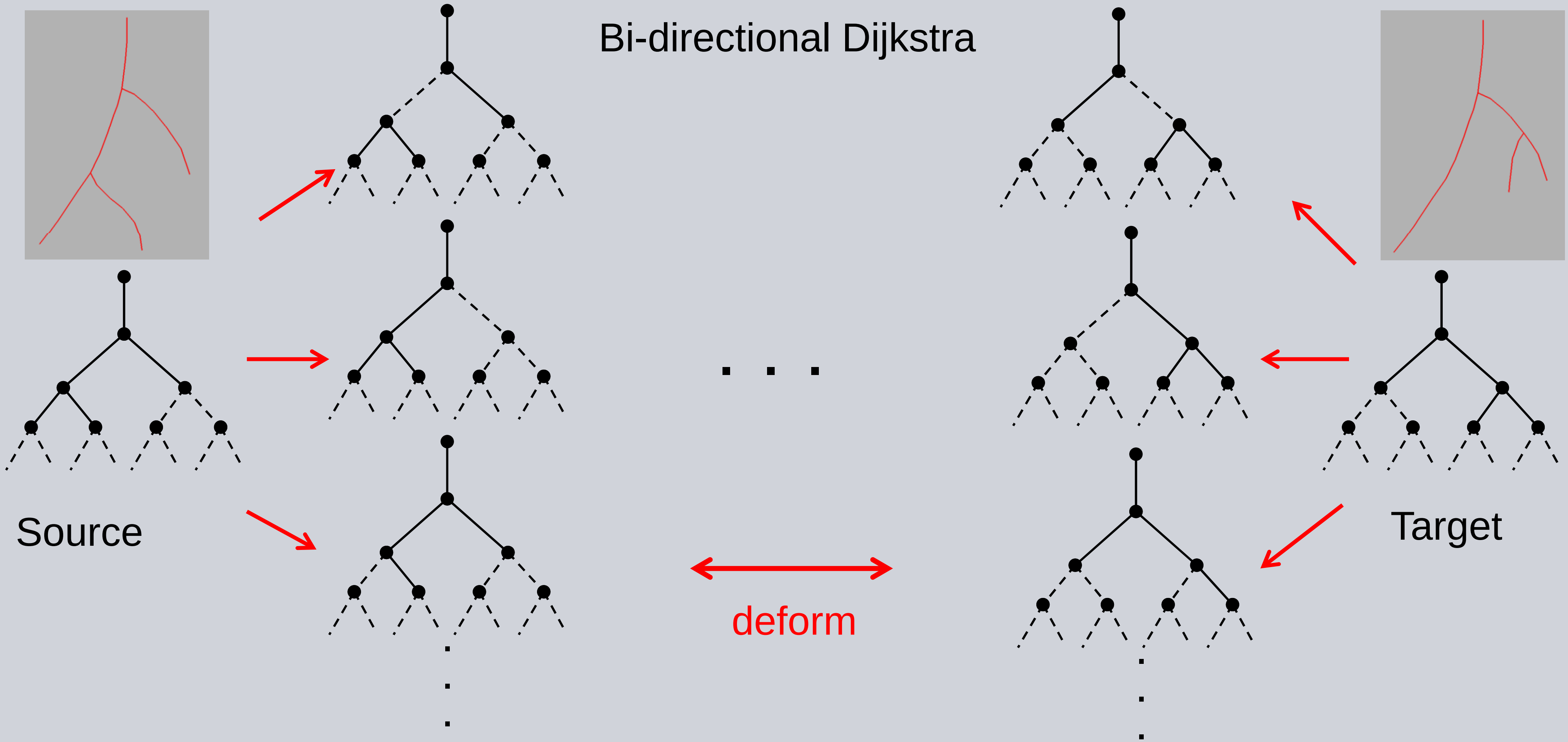
[Feragen, et. al]

Topology matching

- Tree encoding based on Depth First Search (DFS) order



Milestone 3 – Finding Least Cost Path



- Branch matching cost: Euclidean distance between landmarks
- Branch removal cost: matching it to a zero length branch

- Runtime 1-2 sec for depth 3 trees

Deliverables

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Build a research prototype that can

Minimum

- align coronary trees in a population ✓
- compute mean coronary density map ✓

Expected

- compute TED geodesic between two ~~coronary~~ ordered depth-3 trees ✓
- compute QED geodesic between two ~~coronary~~ ordered depth-3 trees

Maximum

- match two coronary trees using TED
- compute average coronary tree in a population using QED
- assign a membership score to an unseen coronary tree using QED

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Dependencies

	Data
1	Coronary centerlines, pericardium models and anatomical landmarks
2	Example trees with ground truth matching and geodesic path

	Software
1	Prototype development framework ➔ Live demo
2	TED solver pseudo code ➔ Implemented own algorithm

Management Plan

- 15 hours work per week.
- Weekly meetings with mentor located in Princeton, phone or in-person. On schedule

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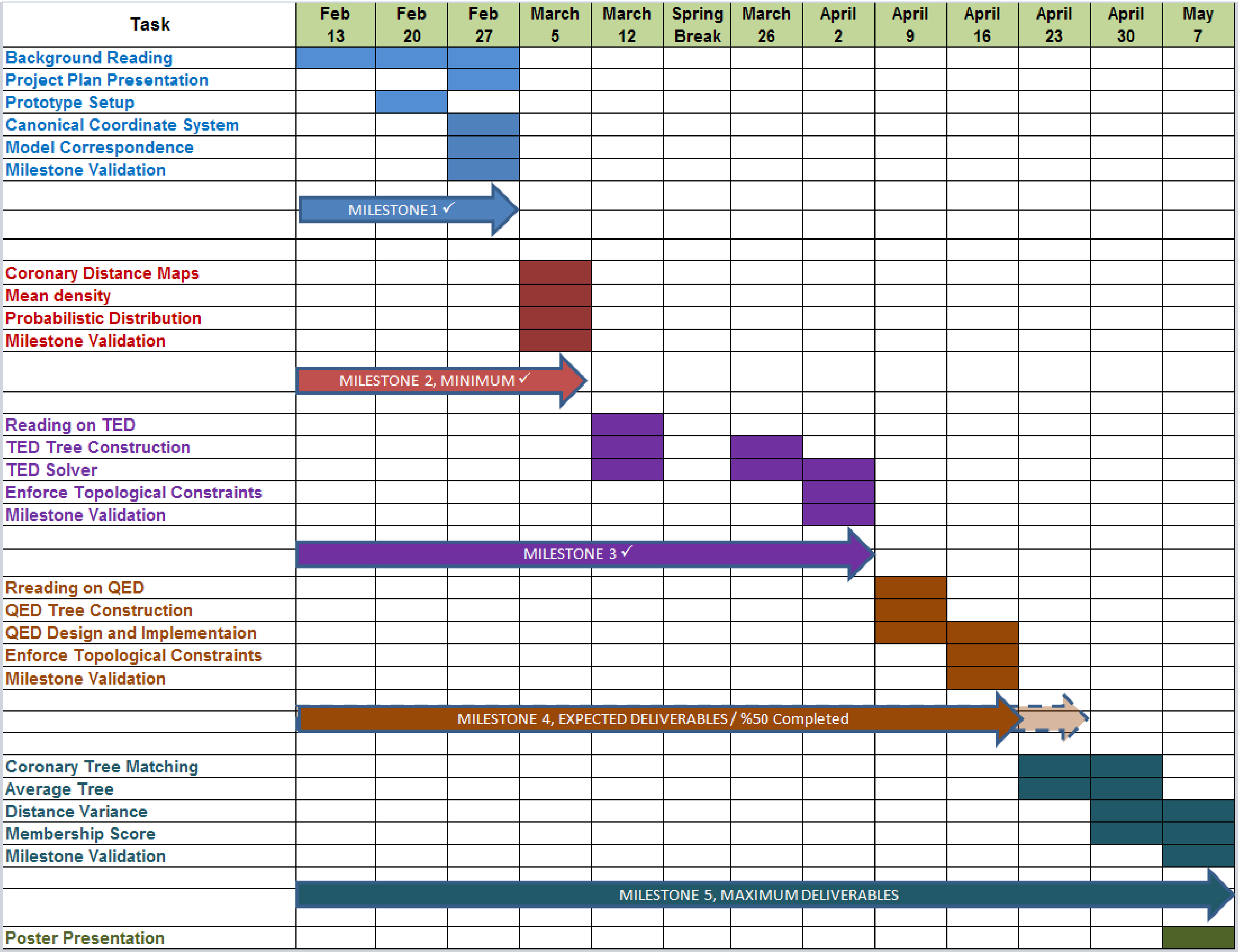
Updated Project Timeline



Gulsun, 2012

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