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Reconstruction of Coronary Trees from 3DRA Using a 3D+t Statistical Cardiac Prior

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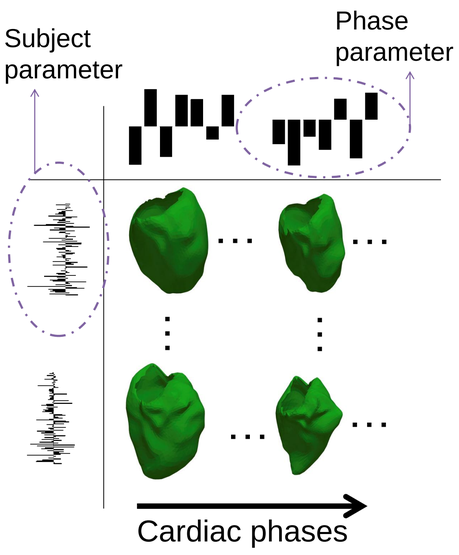
Introduction

- In this study, we propose a novel method for anatomical 3D reconstruction of coronary artery centerlines from 3DRA images.
- Our method assumes that the coronary arteries are attached to and move together with the ventricular epicardium. Therefore, a statistical model of the epicardial surface could implicitly describe the non-rigid structure of coronary arteries if the arterial locations on the model are known or estimated.
- Method employs a bilinear model of the left ventricle as the statistical model and Gaussian mixture model (GMM) based registration strategy to estimate the arterial locations on the statistical model.

Method

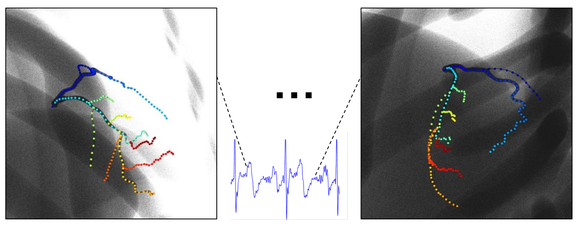
Spatially & Temporally Aligned Left Ventricular Surfaces

Bilinear Model Training



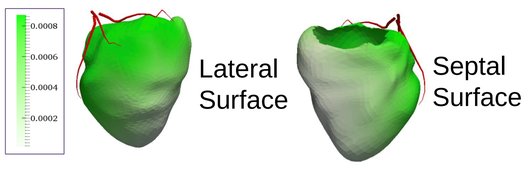
Bilinear model [1] parameterizes inter-subject & temporal variations of the ventricular surface.

Tracked Points on X-ray Images



Corresponding coronary artery points throughout the X-ray sequence are given. Also, a cardiac phase is assigned using recorded ECG signal.

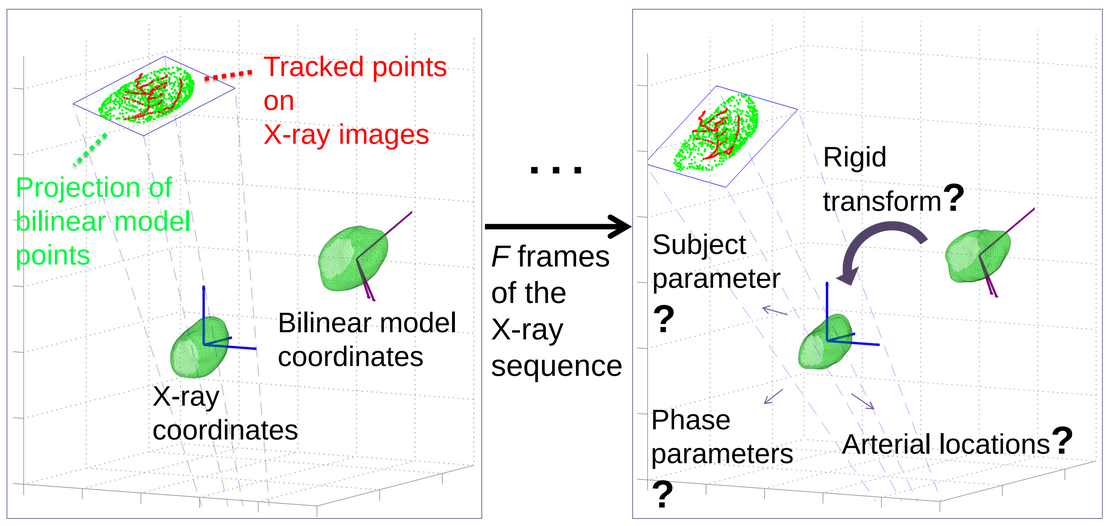
Prior Information



Probability of corresponding to an arterial location are assigned to each bilinear model point using a cardiac atlas [2]. These probabilities will define the weights of GMM.

GMM Based Registration Formulation

We formulate the reconstruction problem as GMM based 2D+t/3D+t registration between the tracked points on X-ray image sequence and the bilinear model landmark points.



Registration metric	=	Mean squared error between the tracked points and arterial points of the bilinear model projected onto the image plane	+	Negative log-likelihood of the learned prior distribution of bilinear model parameters

- Arterial locations are not known in advance ➔ Estimate arterial locations and solve for the bilinear model parameters and transform parameters iteratively [3].
- EM-like method [3] combines EM with a deterministic annealing scheme for the variances of the Gaussian distributions of the GMM.

Results

Training ventricle data:

Training surface meshes describing the left ventricular epicardium (2044 landmark points) are obtained using an atlas based segmentation algorithm [2] from 134 retrospectively ECG-gated multi-slice CT images and spatially/temporally aligned following [1].

Synthetic X-ray data:

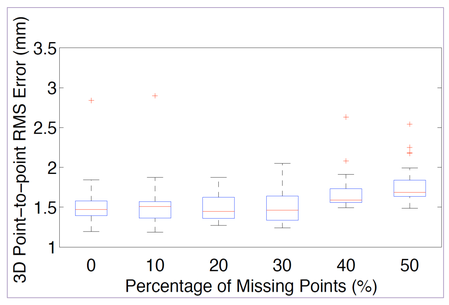
To quantitatively evaluate our algorithm, we generated synthetic rotational angiography data using the single left coronary artery geometry of the 4D XCAT phantom [4]. We also generated 208 2D points on the synthetic X-ray sequence describing the coronary artery over 117 frames.

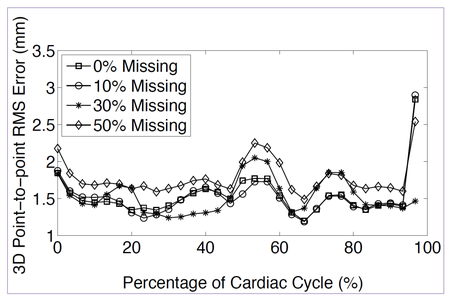
Experiments:

In all of the experiments, the reconstruction errors were measured as the root-mean-square errors in 3D between the reconstructed points and the true 3D positions.

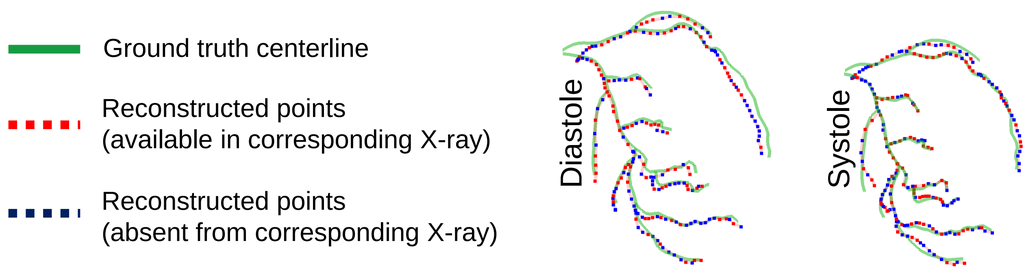
- **Experiment 1: Missing data**

We randomly removed 0% to 50% of 2D points which describe the projected 2D trajectory of each tracked coronary artery point along the sequence of projection images.



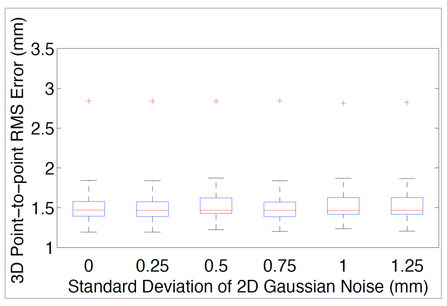


- **Qualitative results for Experiment 1**



- **Experiment 2: Noise**

We added zero mean Gaussian noise (σ = 0.25-1.25 mm) to all 2D points in order to evaluate the performance under uncertain measurements.



Conclusion & Future Work

- In order to cope with the ill-posedness of the reconstruction problem, we proposed to constrain the motion and the shape of the coronary arteries by a statistical spatio-temporal model of the epicardial surface of the ventricle.
- Currently, we assume that the 2D points tracked over the sequence of X-ray images are provided. However, automatic methods to determine the point correspondences must be explored. Future work will be focused on this topic.

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