Helical orientation of left ventricular (LV) myocardial fibers
- During systole: Not only radial contraction but also twist [1]
- LV twist invisible in X-ray imaging, but
- Coronary arteries are attached to the myocardium and therefore follow LV rotation

Phase-resolved coronary artery reconstruction
- Interventions: low temporal resolution
- Rotational motion may introduce limited angle problems

Materials and Methods

Extend XCAT heart [2] with rotation around LV long axis (Fig. 1):
- Twist angle \( \Phi(t) \) of XCAT control point \( e^{i(t)} \) at phase \( h_r \)
  \[
  \Phi(h_r) = \frac{b_1 - c_1(t)}{b_2 - a_1} \Phi(h_{a1}) + \frac{c_1(t) - a_1}{b_2 - a_1} \Phi(h_{a2})
  \]
- \( \Phi_a = -2 \cdot \Phi_b \): different sign and magnitude at apex and base
- \( \Phi(h_r) = \Phi_b^{\max} \cdot (1 - \frac{|h_r|}{2} - 1) \) and \( \Phi(T) = \Phi_b^{\max} - \Phi_b^{\max} [3] \)

ECG-gated interventional FDK-type reconstruction at \( h_r \) [4]
- Streak reduction: omit the smallest and largest contributions
- Distance weights \( \omega_i(x) \), gating function \( \lambda_i(h_r) [4] \)

Dense motion field compensated reconstruction
- Parzen-window interpolation on dense grids of sparse ground-truth displacement vector fields yields \( T^{(3D)}_{i,h_r}(x) [5] \)
  \[
  f_{h_i}(x) = \sum_{i=1}^{N_{2^{\text{NM}}}} \lambda_i(h_r) \cdot \omega_i(x) \cdot p_i(\hat{A}(x))
  \]

Experimental Setup (in CONRAD [6])
- 133 projections over 200° at 80kV (noise free)
- Detector: 620*480 pixels with 0.616mm isotropic spacing
- Reconstruction: 256³ voxels with 1mm isotropic spacing
- Five twist angles: \( \Phi_{\text{tot}} \in \{0°, 0°, 15°, 21°, 30°\} \)
- Evaluation at systole and diastole
- Vasculature: Area under Precision-Recall-Curves (AUPRC) [7]
- Overall: Cross-correlation (r) with ground-truth in ROI

Results and Discussion

AUPRC largely constant at all twist angles (cf. Tab. 1 and 2)
- Slight deteriorations at \( \Phi_{\text{tot}}(h_r=0.5) > 21° \)
  - Structures with \( \Phi_{\text{tot}} = 24.98° \): stationary during contraction
  - But: Deteriorations also at \( \Phi_{\text{tot}}(h_r=0.8) = 0 \)
  - Effects other than cardiac twist?
  - Streak reduction: Higher AUPRC for ECG-gated reconstruction

Correlation: substantially higher for motion field compensation
- ECG-gated reconstruction only used subset (56 and 57 of 133 projections at systole and diastole, respectively)
- Myocardium and cardiac chambers dominate the image, but are only marginally affected by cardiac twist

Conclusions

- Vasculature reconstruction: Slight quality decrease at larger twist angles as per-projection twist motion approaches average angular increment.
- Overall reconstruction quality (Pearson r) remained mostly constant.
- Twist angles of \( 21.1° \pm 15.2° \) were observed in pathologic cases [7]
  - Limited angle problems may occur, but should not drastically affect the acquisition.

References