Respiratory Motion Compensation in Rotational Angiography
Graphical Model-based Optimization of Auto-focus Measures

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Abstract

Non-recurrent intra-scan motion, such as respiration, corrupts rotational coronary angiography acquisitions and inhibits uncompensated 3D reconstruction. Therefore, state-of-the-art algorithms that rely on 3D/2D registration of initial reconstructions to the projection data are unfavorable as prior models of sufficient quality cannot be obtained. To overcome this limitation, we propose a compensation method that optimizes a task-based autofocus measure using α-expansion.
The proposed algorithm is validated on simulated and clinical data. In the phantom studies, we found a reduction of the RMSE between the true and estimated motion pattern of 82±2% when the proposed method was used, yielding residual errors well below the voxel size. For the clinical data set, we observed superior image quality. Our results are promising and suggest that the proposed method effectively handles non-recurrent motion while overcoming the need for prior reconstructions.

Introduction

Respiratory motion corrupts acquisitions

- Dominant motion in head-foot direction [1]

Motion estimation:

- 3D/2D: Prior model needed, may not be available [2]
- Consistency-based: Limited to simple motion models [3]

Reconstruction domain auto-focus optimization:

- Allows for complex motion models: 3D translation here
- α-expansion: robust in presence of large displacements

Materials and Methods

Auto-focus measure: Induce sparsity during backprojection

- Distance maps of vessel centerlines in projections: $\Gamma^{(i)}(\boldsymbol{u})$
- 3D cost map: Modified backprojection promotes sparsity [4]

$$S_r(\boldsymbol{x}) = \max_i \ \Gamma^{(i)}(\breve{\boldsymbol{x}}^{(i)})$$

- Auto-focus: Favor sharp responses with pronounced minima

$$a(S_r) = \left(\sum_{i=1}^{B} g_i \frac{C_i(S_r)}{V_i(S_r)}\right)^{-1}$$

where $\{V_i, C_i\}$ constitutes the histogram, and g_i is a gain

Optimization and details: Scale space-based

- 3D shifts parametrized as B-spline: Fewer parameters!
- Target function: Discrete minimization using α-expansion [5]

Evaluation:

- Phantom study: partial and complete breathing cycle from [1]
- Clinical data: residual motion due to imperfect breath-hold

Results and Discussion

- Complete: RMSE decrease from 1.5±0.5 mm to 0.29±0.11 mm
- Partial: Improvement from 0.85±0.49 mm to 0.13±0.07 mm
- Clinical: substantially more pronounced paths with very low cost

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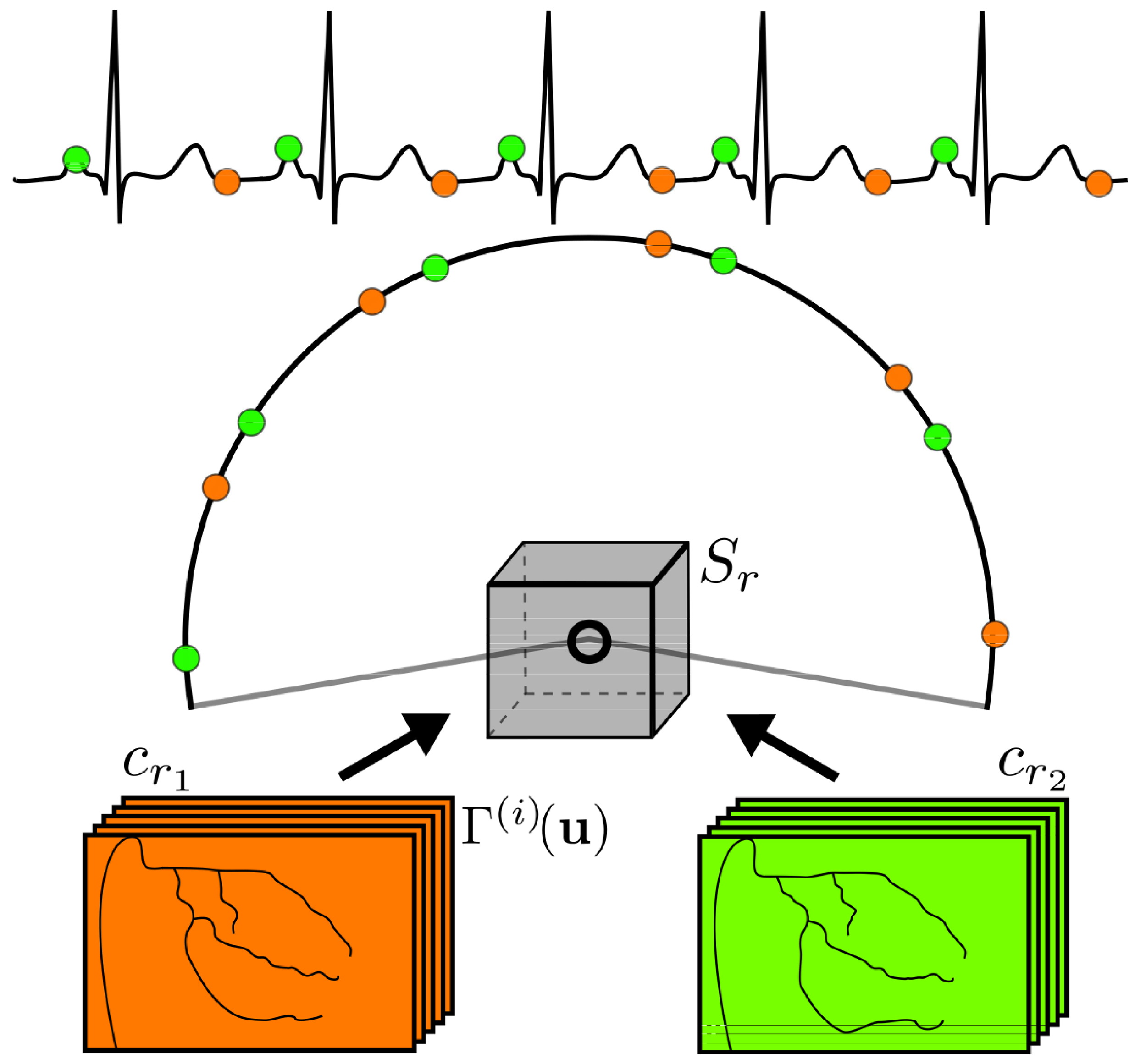

Figure 1: Images of distinct cardiac phases c_r are scattered over the scan range. Modified backprojection at a specific cardiac phase c_r yields the corresponding potential map S_r

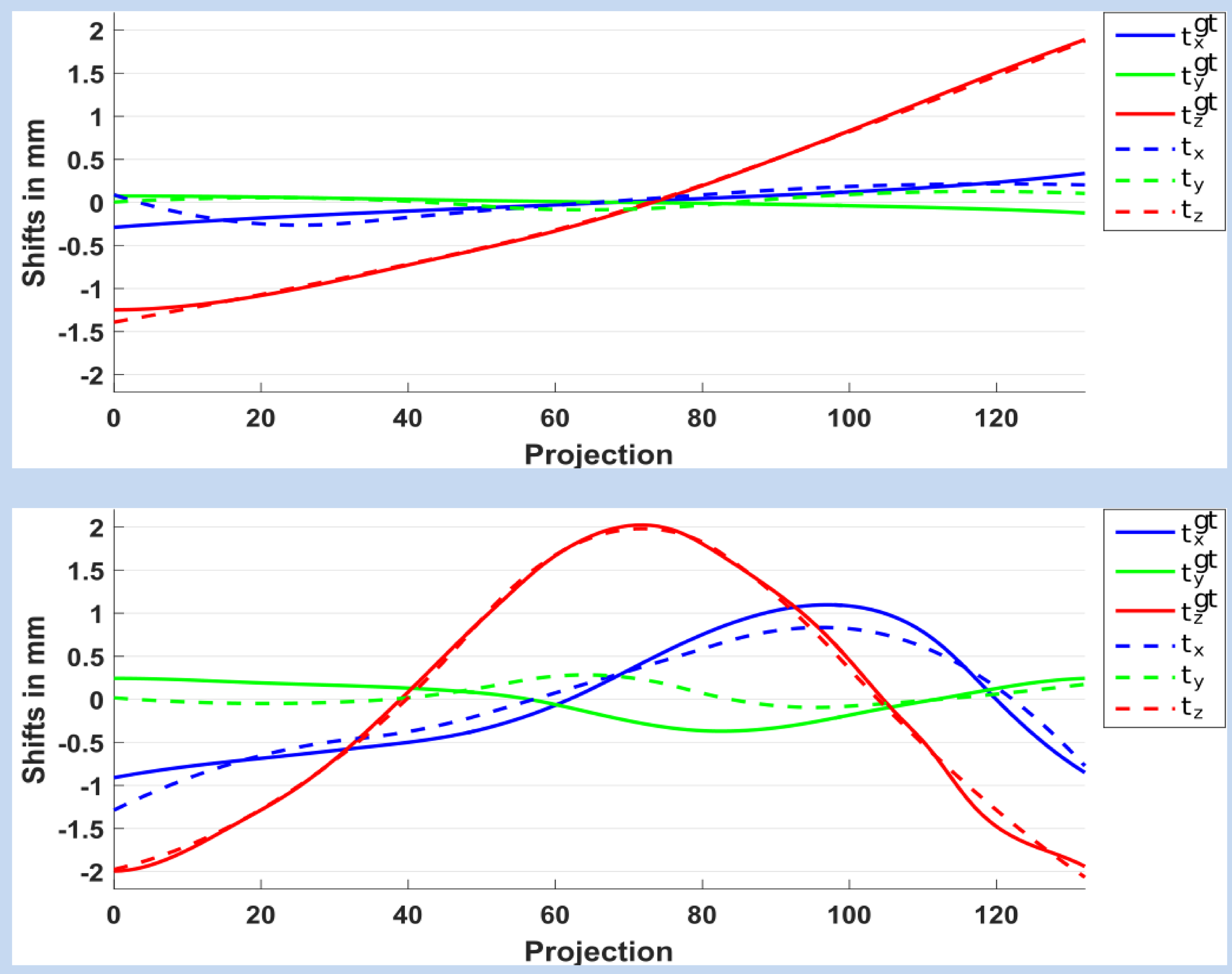

Figure 2: Estimated and ground-truth motion patterns of the phantom studies showing a partial and complete respiratory motion cycle in the top and bottom row, respectively.

Conclusions

- Auto-focus ➔ No need for prior models!
- Improvements for both phantom and clinical data.
- Promising for non-recurring motion patterns!
- Continuous optimization for complex motion models?

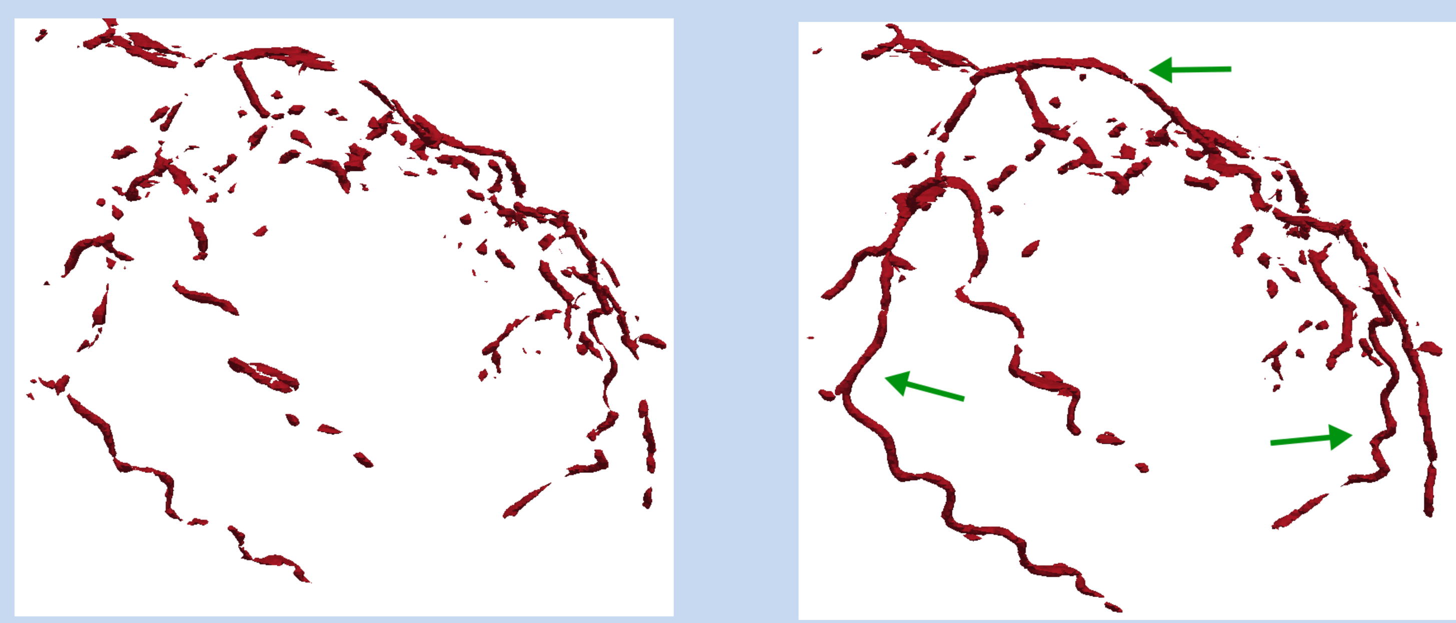

Figure 3: Potential maps of clinical data. Window is set to [0,1] mm.

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