Consistency-based Motion Assessment in Rotational Coronary Angiography

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Abstract

Background estimation in angiography allows for subtraction that approximates detector-domain material decomposition yielding non-truncated images. This enables epipolar geometry-based motion estimation. We outline a pipeline for virtual digital subtraction coronary angiography and evaluate it on phantom data. Shifts maximizing epipolar consistency are estimated that serve as surrogate for respiratory and cardiac motion. We devise an image-based surrogate for cardiac motion.

Figure 1: Crop to a region of interest. From left to right: the original projection, the estimated background, and the resulting digital subtraction image.

Introduction

Cardiac and respiratory motion corrupt acquisitions

- Significant motion in head-foot direction [1]

Motion estimation: vertical detector shifts

- Purely projection-based methods:
  Center-of-mass (CoM) and Epipolar Consistency [2]
- Not applicable to truncated images!

Single-frame decomposition via digital subtraction

- Contrasted arteries not truncated

Materials and Methods

Coronary artery segmentation:

- Hessian-based, exploits directionality of curvature [3]
- Hysteresis thresholding yields binary mask $\mathcal{W}$

Background estimation: non-local defect pixel interpolation

- Corruption in spatial domain $G(\mathbf{u}) = B(\mathbf{u}) \cdot \mathcal{W}(\mathbf{u})$
- Convolution in frequency domain: $\mathcal{g} = \mathcal{b} \star \mathcal{w}$
- Iteratively de-convolve using symmetry of $\mathcal{b}$ [4]

Epipolar consistency conditions (ECC):

- Epipolar geometry relates two views
- Integrals $\rho_i(\cdot)$ over corresponding detector lines $\mathbf{l}_i,\ i = 1, 2$ are redundant $\boxed{\frac{\mathrm{d}}{\mathrm{d}t}\rho_1(\mathbf{l}_1) - \frac{\mathrm{d}}{\mathrm{d}t}\rho_2(\mathbf{l}_2) \approx 0}$,

  with t the distance of the line to the image origin
- Mutual consistency allows to optimize for detector shifts $\mathbf{v}$

Image-based ECG and experiments:

- Separate $\mathbf{v}$ in high and low frequency components (threshold 1 Hz) related to cardiac and respiratory motion, respectively
- Dominant frequency in $\mathbf{v}_{\mathrm{card}}$ ➔ normalized linear time $\mathbf{t}_{\mathrm{card}}$

Evaluation:

- Phantom study: CAVAREV [5]
- Qualitatively: comparison of shifts with respiratory phase
- Quantitatively: Pearson R with ground-truth cardiac time

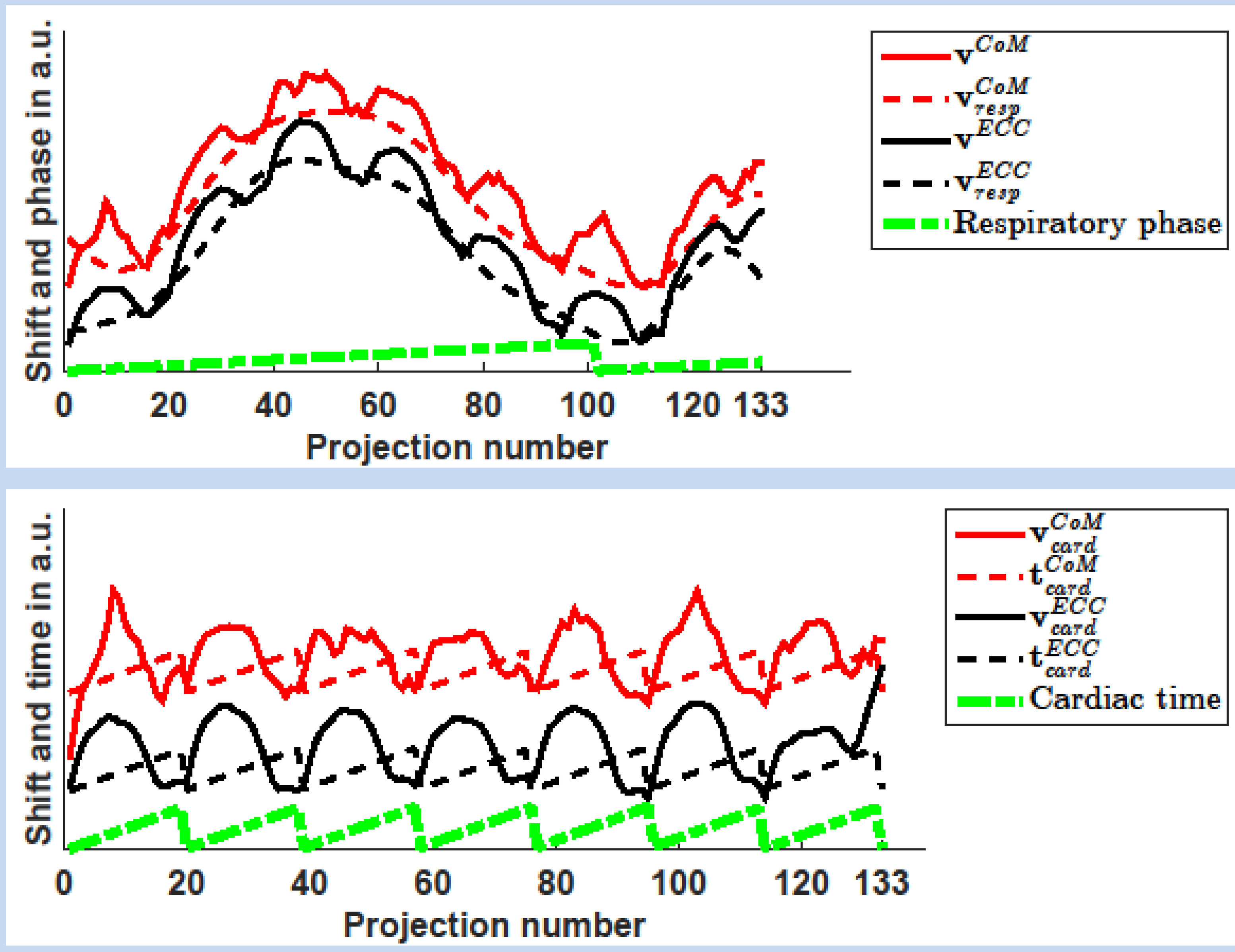

Figure 2: 1D motion estimation of CoM- and ECC-based methods, low frequency respiratory signal, and ground-truth respiratory phase are shown in the upper plot. The lower plot shows the high frequency signal, the corresponding normalized time, and the ground-truth.

Results and Discussion

- Background estimation (**Fig. 1**) yields satisfactory results, may become problematic for large defects
- Signals in **Fig. 2** correlate well with respiratory phase
- Correlation of **0.91** between $\mathbf{t}_{\mathrm{card}}$ and ground-truth
- How does it handle real data? Teaser in **Fig. 3**

Conclusions

- Background removal ➔ consistency-based methods
- Head-foot direction shifts: cardiac motion surrogate and respiratory motion assessment
- Purely projection-based: promising for non-recurring motion patterns!

Figure 3: Real data teaser.

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References

[1] Shechter, G. et al., TMI 25(3):369-375, (2006)
[2] Aichert, A. et al., TMI, 34(10):1-15 (2015)
[3] Frangi, A.F. et al., Proc. MICCAI, p.130-137, (1998)
[4] Aach, T. et al., Proc. Med. Imaging, p.824-835, (2001)
[5] Rohkohl, C. et al., PMB, 55(10):2905-2915, (2010)