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European Institute for Molecular Imaging

A Continuity Equation-Based Optical Flow Method for Cardiac Motion Correction in 3D PET Data

Mohammad Dawood[1,2], Christoph Brune[2], Florian Büther[1], Michael Schäfers[1] and Klaus P Schäfers[1]

[1]European Institute for Molecular Imaging, Münster, Germany [2]Institute for Mathematics and Computer Science, University of Münster, Germany

Introduction

The motion of the heart due to respiration and due to the cardiac contraction during PET acquisition blurs the images. This may cause errors in quantification. One method to avoid this problem is to use respiratory and cardiac gating. However, gating leads to a reduction in the amount of information per phase. Thus, an optical flow based method to correct 3D PET data for motion is presented which incorporates all information while correcting for motion.

Mass Conserving Optical Flow

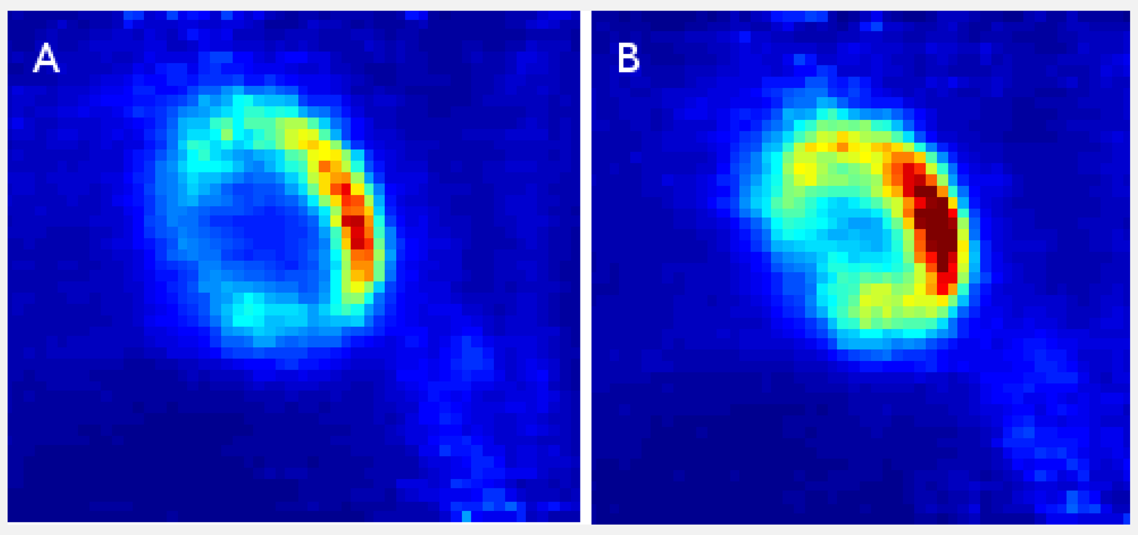

Figure 1: Myocardial images from the diastolic (A) and systolic (B) phase of the cardiac cycle. The intensity of voxels decreases in the diastolic phase due to partial volume effects.

The total amount of activity remains constant during the cardiac cycle, whereas the brightness of individual voxels varies due to partial volume effects. Therefore a continuity equation-based mass conserving optical flow method might be applied to cardiac gated PET data. The continuity equation is given as:

$$\frac{\partial I}{\partial t} + div(I\mathbf{u}) = 0 \quad (1)$$

where I is the intensity value and $\mathbf{u} = (u, v, w)^T$ is the velocity vector, i.e. the optical flow. Adding a smoothness term, the resulting optical flow functional can then be given as:

$$f = \text{argmin} \left[\int_V (div(I\mathbf{u}) + I_t)^2 + \alpha(|\nabla u|^2 + |\nabla v|^2 + |\nabla w|^2) dV \right] \quad (2)$$

The minimization of this functional was achieved by using the corresponding Euler-Lagrange equations. The resulting optical flow vectors are shown in Figure 2.

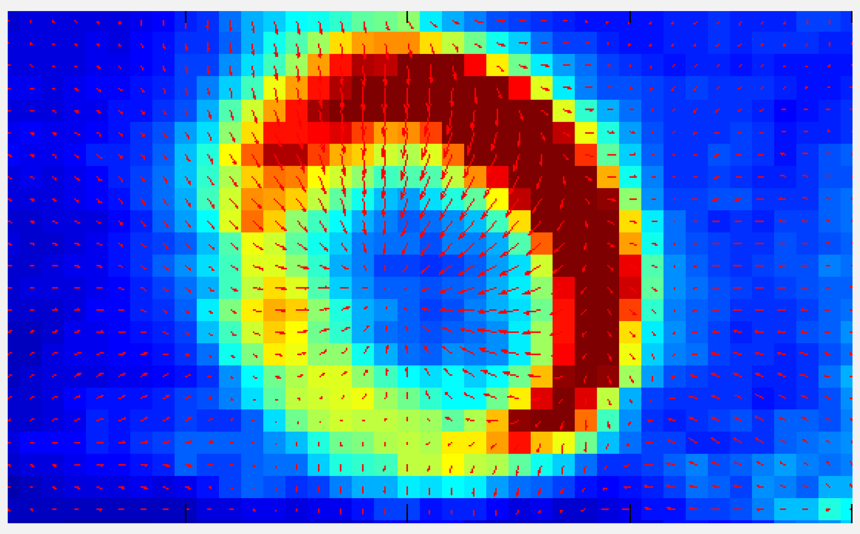

Figure 2: Coronal slice through the myocardium with motion vectors estimated with the proposed method.

The estimated motion vectors can then be applied to the 3D PET data to correct for the cardiac motion as shown in Figure 3.

Results

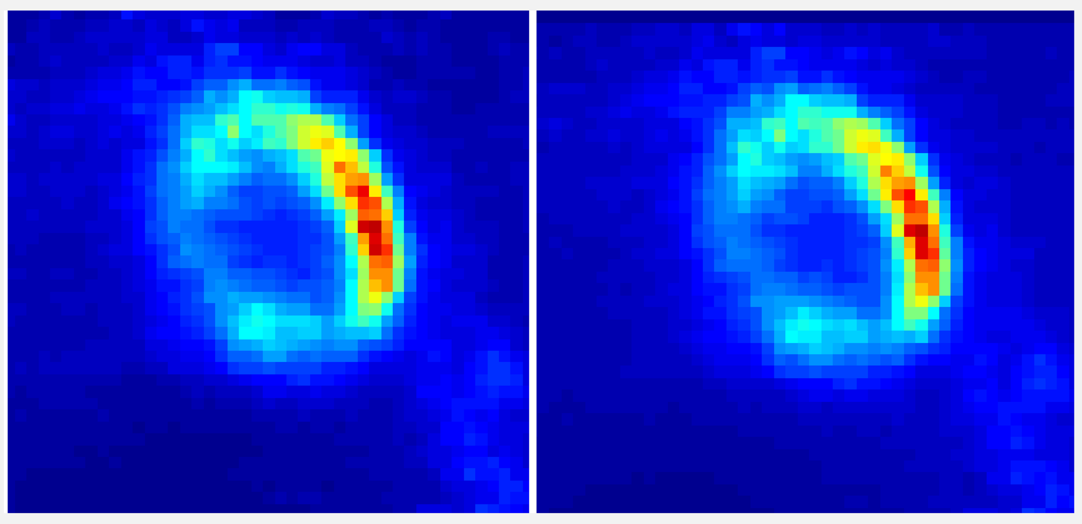

Figure 3: Left: diastolic phase, Right: systolic phase after motion correction.

The proposed method was evaluated on both software phantom and real patient data. The results for correlation coefficient analysis on the phantom data are shown in Table 1.

Phase	1	2	3	4	5	6	7	8	9	10	Avg
Before	100	94.5	93.0	86.7	81.7	80.3	80.8	82.2	90.9	95.1	88.51
After	100	99.9	99.9	99.9	99.8	99.8	99.8	99.8	99.9	99.9	99.86

Table 1: Correlation coefficient analysis on phantom data before and after motion correction.

The results of myocardial thickness analysis on real patient data are shown in Figure 4. The myocardial thickness was calculated as the FWHM of a line profile through the myocardium. After motion correction, the transformed end-systolic phase also showed the same wall thickness as the end-diastolic phase for all datasets.

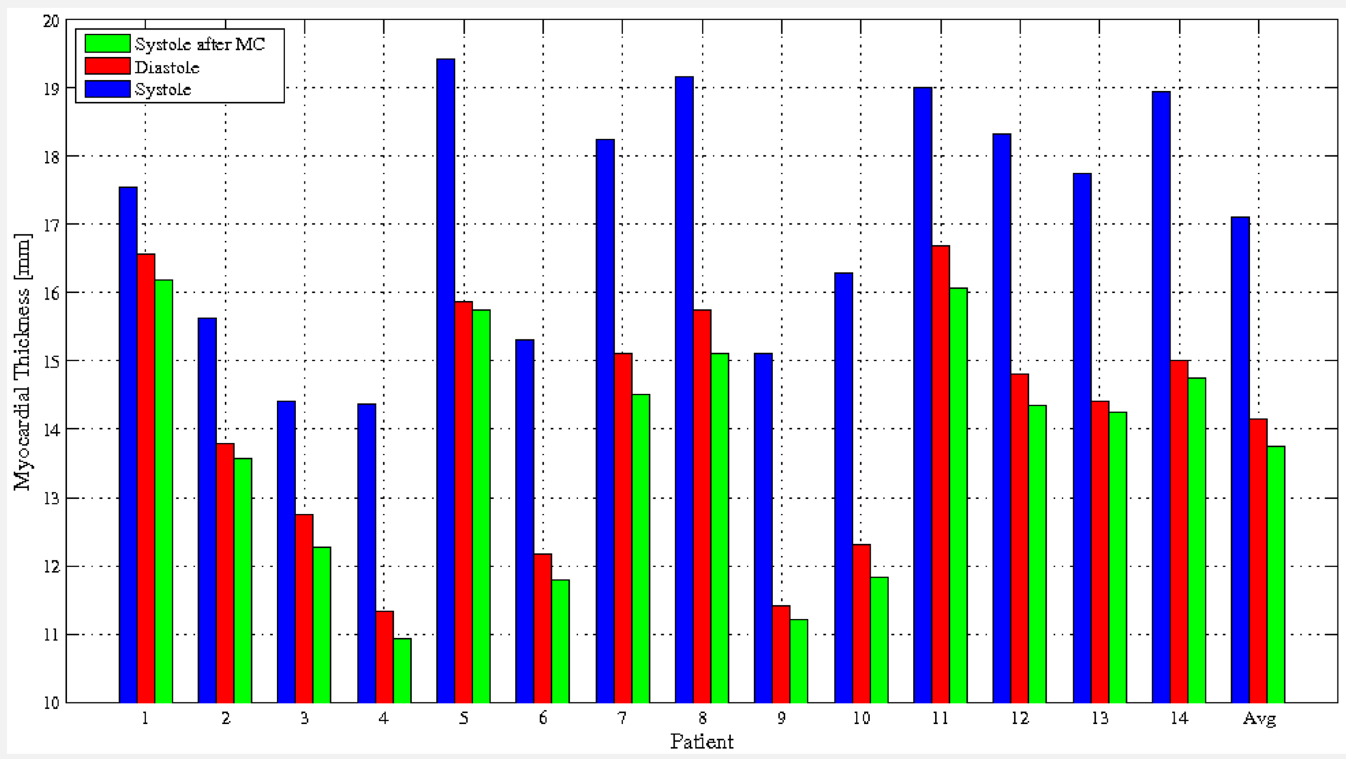

Figure 4: Myocardial thickness analysis on patient data.

Conclusion

A continuity equation based optical flow method for cardiac motion correction is presented. The method was evaluated on patient and software phantom data and shown to function precisely.

References

[1] Dawood et al., *A Continuity Equation Based Optical Flow Method for Cardiac Motion Correction in 3D PET Data*, LNCS 6326:88-97, 2010.

[2] Dawood et al., *Respiratory Motion Correction in 3D PET Data with Advanced Optical Flow Algorithms*, IEEE Trans Med Imaging, 27(8):1164-75, 2008.