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4D Image Reconstruction with Dual Respiratory and Cardiac Motion Correction for Cardiac PET

Dissertation Defense by

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Abstract

4D image reconstruction with motion correction is the solution to improve image quality and resolution degraded by respiratory motion (RM) and cardiac motion (CM) in cardiac PET scans. There are three steps for 4D image reconstruction with motion correction: 1) 4D data generation (gating), 2) 4D respiratory and cardiac (R&C) motion estimation, and 3) 4D R&C motion correction. We have developed and evaluated multiple methods for each step including (step 1) data-driven gating, MR-navigator-gating, (step 2) 4 different methods for dual R&C motion estimation after reconstruction (MEAR), CM estimation during reconstruction (MEDR), RM estimation before reconstruction (MEBR), and (step 3) dual R&C motion correction after (MCAR), during (MCDR), and before (MCBR) image reconstruction. Realistic Monte Carlo simulated 4D cardiac PET data using the 4D XCAT phantom and accurate models of the scanner design parameters and performance characteristics and clinical patient data were used to evaluate all different methods. Data-driven gating method was shown to provide robust gating results in high myocardium uptake situations while MR-navigator based gating showed better results in low myocardium uptake situations. Separate R&C MEAR with modeling of RM on CM estimation was shown to be the best option for accurate estimation of dual R&C motion estimation, while direct R&C MEAR was shown to be extremely sensitive to image noises and was not practical. The MCDR method yields the best performance for different noise situations for both patient and simulation, while MCBR reduces computational time dramatically but the resultant 4D cardiac gated PET images has overall inferior image quality when compared to that from the MCAR and MCDR approaches in the ‘almost’ noise free case. Also, the MCBR method has better noise handling properties when compared with MCAR and provides better quantitative result in high noise cases. When the goal is to reduce scan time or patient radiation dose, MCDR and MCBR provide a good compromise between image quality and computational times.

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