On Motion Estimation and Compensation Baseline Estimations in Dynamic Imaging: a Comparative Study with Cine Cardiac and Contrast-Enhanced Lung Imaging

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Introduction: Estimation of the baseline in a dynamic imaging series is an essential step in compressed-sensing-based acceleration methods for MRI acquisition [1,2], as an accurate baseline estimation helps sparsifying the remaining residues effectively. Recent literatures suggest improved baseline estimation using adaptive regularization [1] or motion estimation (ME) and motion compensation (MC) with block-matching [2]. While these methods perform well on translation-dominant images with moderate-varying contrast such as cine cardiac imaging, suitability on other dynamic images with fast-varying contrast and morphology such as dynamic contrast-enhanced (DCE) lung imaging has not been investigated. Therefore, the purpose of this study is to further explore the baseline estimation performance of the block-matching ME/MC algorithm and a phase correlation ME/MC alternative on both cine cardiac imaging and DCE lung imaging, in comparison with the conventional temporal averaging approach.

Theory: Block-matching ME method [3] estimates motion vectors (MVs) by minimizing the differences of pixel intensity between corresponding blocks on two frames. When large scale translation or fast-varying contrast leads to inaccurate estimation for block matching, phase-correlation ME is a better alternative. Phase correlation [4] directly measures the movement from the phase of cross-power spectrum between two blocks, and the estimation is robust for capturing large translation even with varying contrast since Fourier phases are hardly affected by shift or multiplication of the contrast. Although both methods accurately estimate MVs for translational-dominant motion, the contrast of the image cannot be preserved. This characteristic may lead to inaccurate prediction with fast-varying contrast and morphology at the same time. In such a case, conventional temporal averaging may be adequate for baseline estimation.

Methods: Baseline of dynamic images was estimated with (1) block matching, (2) phase correlation, and (3) temporal average, respectively. For (1) and (2), the baseline of every frame was predicted individually by applying ME and MC using several frames. In our testing series containing 60 time frames, 12 reference frames were picked up. For (3), a single baseline was predicted by temporal averaging the down-sampled frames, which is shared among all time frames as in conventional approach [4,5]. Each method was then incorporated into k-t FOCUSS upon reconstructing dynamic cardiac cine and DCE lung images to compare their effectiveness toward translational-dominant images and images with fast varying contrast and morphology, respectively.

The cardiac images were acquired using ECG-gated 2D TrueFISP short-axis cine sequence performed on Philips Achieva 3T scanner, matrix size 256x256, 32 cardiac phases, 35˚ flip angle, with 10mm slice thickness. DCE lung images were obtained using IR-prepared, segmented EPI with TI/TR/TE/ETL=180/6.5/1.2/4, matrix size 256x256, and slice thickness=10~12mm with two coronal slices. Reconstructed images adopting three individual baseline estimation methods are compared, and 5-fold down-sampled images were selected to represent the benchmarking results.

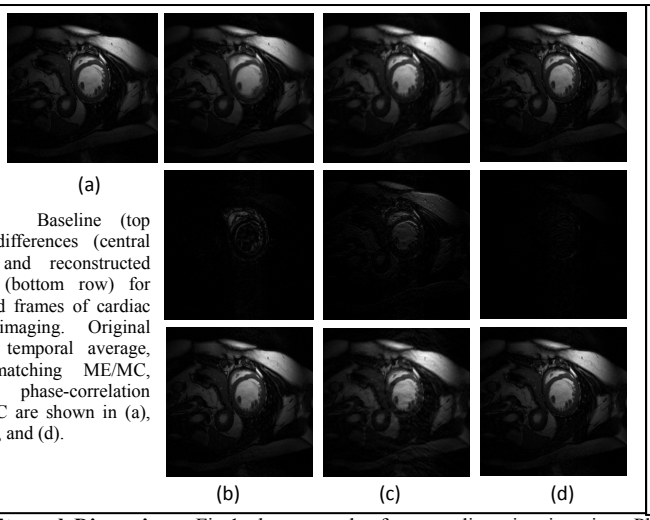

Fig.1: Baseline (top row) differences (central row), and reconstructed image (bottom row) for selected frames of cardiac cine imaging. Original frame, temporal average, block-matching ME/MC, and phase-correlation ME/MC are shown in (a), (b), (c), and (d).

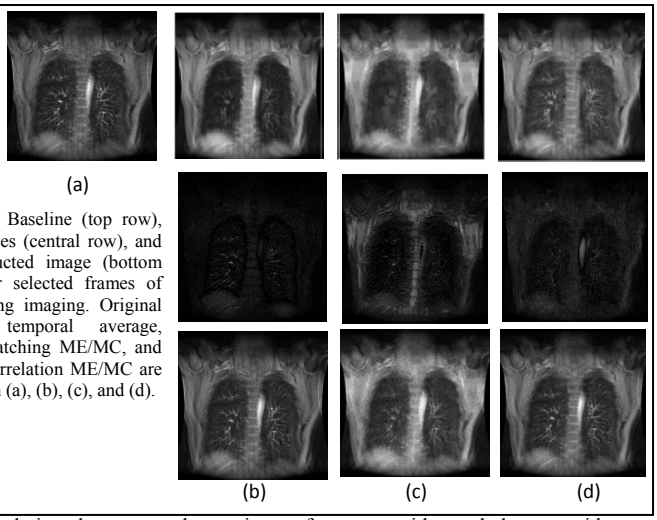

Fig.2: Baseline (top row), differences (central row), and reconstructed image (bottom row) for selected frames of DCE lung imaging. Original frame, temporal average, block-matching ME/MC, and phase-correlation ME/MC are shown in (a), (b), (c), and (d).

Results and Discussions: Fig.1 shows results from cardiac cine imaging. Phase correlation demonstrated superior performance with much lower residues compared with block matching as predicted. Such advantage is attributed to phase correlation's sensitivity to phase-changes reflecting inter-frame movements accompanying relative insensitivity toward contrast change. This makes phase correlation an ideal candidate upon estimating baselines in cardiac imaging.

Results from fast-varying contrast and morphology applications like DCE lung imaging, however, shows that while phase correlation still outperformed block matching in terms of image and time intensity curves (Figs.2,3,4), neither seems to benefit the overall reconstruction compared with the conventional temporal averaging approach. Further examinations on the estimated baselines suggest that while block matching failed to capture a substantial proportion of change, phase correlation suffered from loss of contrast which is better conserved in its temporal averaging counterpart. These inabilities equivocate the corresponding residues which are then adopted in k-t FOCUSS delivering inaccurate reconstructions. These insufficiencies suggest ME and MC methods' limitation on conserving complicated varying morphology and contrasts.

Conclusion: Baseline estimations based on ME and MC do enhance reconstructions of moderate-varying dynamic images like cardiac cine where alternative methods like phase correlation outperforms block matching on capturing contrast and morphologies. While phase correlation's comparative advantages remain in their DCE lung counterparts, both phase correlation and block matching demonstrate no clear benefit on capturing the fast-varying contrast and morphologies in this genre of images. This leads to the demand of future works on finding baseline estimation methods with potential robustness to such characteristics.

References: [1] D. Xu et al., Magn Reson Med 2007;57:918-930. [2] H. Jung et al., Magn Reson Med 2009;61:103-116.
[3] D. Le Gall, Communications ACM 1991;34:46-58. [4] H. Foroosh et al., IEEE T Image Proc 2002;11:188-200.
[5] J. Tsao et al., Magn Reson Med 2003;50:1031-1042.

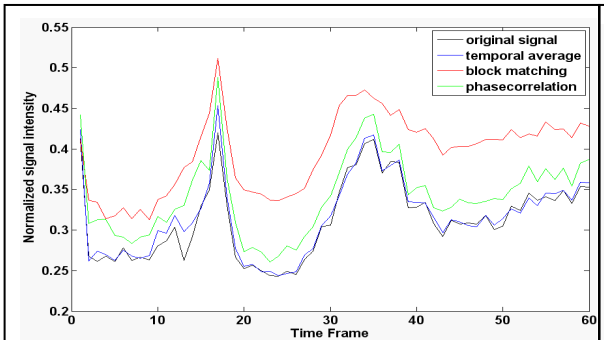

Fig.3: Time intensity curves from right lung.

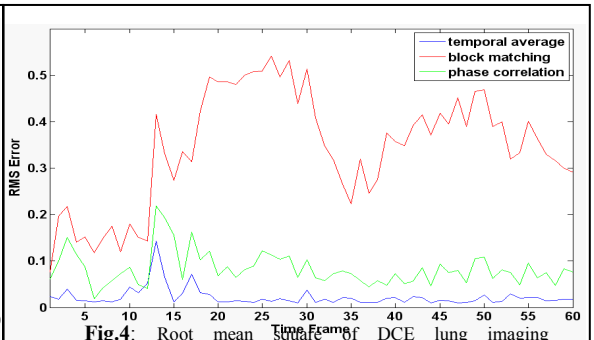

Fig.4: Root mean square of DCE lung imaging reconstruction for each time frame.