Fast Cardiac Imaging Using a Combination of HYPR, Center of Masses, and McKinnon-Bates algorithms

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Introduction

A typical cardiac exam requires a 10-20 sec breathhold depending on the acquisition technique and amount of viewsharing between cardiac phases. It would be desirable to shorten the breathhold time without compromising temporal resolution or introducing artifacts into the reconstructed time series. The recently introduced HighlY constrained backPRojection (HYPR) [1] algorithm allows reconstruction of artifact-free images from highly undersampled radial data without significant SNR loss. Initially, HYPR was thought to be sensitive to motion and thus unsuitable for cardiac imaging. We modify the original algorithm to make it applicable to cardiac imaging. We combine HYPR reconstruction with center of mass (COM) retrospective gating [2] and McKinnon-Bates algorithm [3] and demonstrate that this aggregate algorithm can be successfully applied to capture cardiac motion from radial data sampled over several heartbeats.

Theory and Methods

Our implementation of HYPR algorithm is tailored to the "stack of stars" acquisition, that is, radial sampling in the *xy*-plane and phase encoding in the *z* direction [4]. Typically, the duration of such exams is 20-24 sec. We stipulate that the modified HYPR algorithm can provide acceleration factors of 6-7, reducing the exam time to 3-4 sec. For such short imaging time, the number of projections in each phase is not sufficient to reconstruct artifact-free images. To compensate for this we apply HYPR processing where each cardiac phase is reconstructed by unfiltered backprojection using the composite image as a constraint. In the standard HYPR algorithm, the composite image is obtained by combining the data from several consecutive time frames. This approach alone is not suitable for cardiac imaging since temporal averaging of more than 3 consecutive time frames causes significant blurring due to the rapid heart motion. If we limit the temporal window to 3 time frames, then the resulting composite image will suffer from streak artifacts. Therefore, we take an alternative approach to obtaining a composite image. First, all acquired projections are divided into groups based on their COM values: projections whose COMs are close are assigned to the same group. The number of projections in each group varies depending on the corresponding cardiac phase: systolic groups have fewer projections than diastolic groups. This assures a minimal degree of blurring when an image is reconstructed for each group. However, the number of projections in each group is still not sufficient to avoid streaking artifacts, especially in systole. To improve the image quality, we reconstruct the composite image using projections from the corresponding group as well as two neighboring cardiac phases using the McKinnon-Bates algorithm. The amount of artifacts and blurring in composite images is minimized by such processing and reduced even further when HYPR is applied.

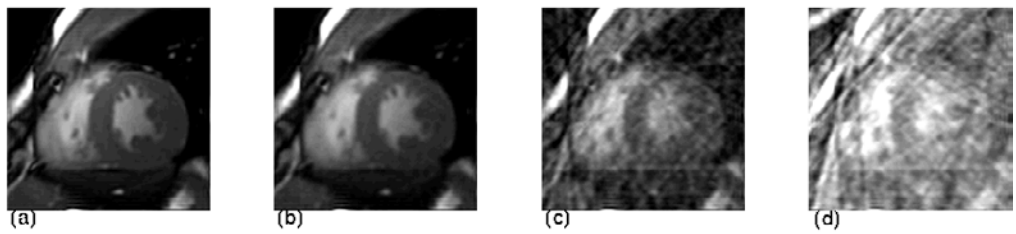

Figure 1. Systolic time frame in (a) original time series, (b) HYPR reconstruction, (c) McKinnon-Bates reconstruction, (d) FBP reconstruction

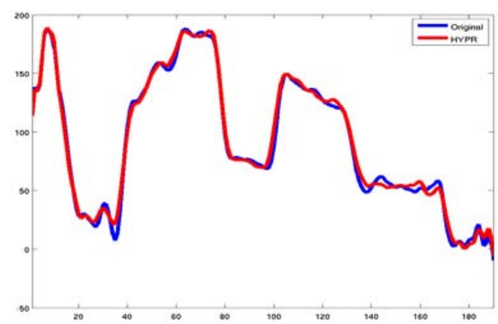

Figure 2. Comparison of the image profiles through systolic frame for the original image (blue) and HYPR reconstruction (red)

Results and Discussion

Three simulated cardiac cycles were used with 20 cardiac phases per cycle and 12 radial projections per slice acquired for each phase. COM processing assigned the total 720 projections into 11 groups. Systolic groups contained as few as 36 projections while the group corresponding to diastole had 144 projections. Using the procedure described above, we obtained relatively artifact-free composite images from the available undersampled data. The blurring that appears in the composite image is reduced by subsequent HYPR processing. This can be confirmed both visually and by comparing cardiac wall motion of the original and reconstructed time series. Figure 1 compares the original systolic time frame to the same frame reconstructed using the modified HYPR algorithm, the McKinnon-Bates algorithm without additional HYPR processing and standard filtered backprojection (FBP). The precision with which HYPR processing captures cardiac wall motion can be validated by comparing image profiles for the original and HYPR reconstructed systolic time frames as presented in Figure 2.

Conclusions

Using a combination of HYPR, COM gating and McKinnon-Bates algorithms, we have been able to reconstruct cardiac wall motion with acceleration factor of 7 relative to Cartesian acquisition without the use of parallel imaging. The temporal resolution and image quality of the reconstructed time series were preserved. The new reconstruction algorithm can be used to reduce scan time for cardiac imaging or to increase temporal resolution.

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