Simulation study of motion correction technique in 3D projection Reconstruction using spherical navigator method

Y. Wu[1], S. Leng[1], C. A. Mistretta[1]

[1]Medical Physics, University of Wisconsin Medical School, Madison, WI, United States

INTRODUCTION

VIPR (Vastly undersampled Isotropic PRojection imaging) has been shown to have intrinsic advantages over Cartesian trajectories for imaging dynamic objects. Motion artifacts in VIPR appeared as blurring, and streaks degrade the image quality. Subtraction of motion-corrupted images introduces more artifacts. Many techniques have been proposed to correct in-plane motion artifacts in 2D PR using moments of spatial projections [1,3]. The center of mass (first moments of spatial projections) approach adapted for VIPR was able to correct the translational motion in three dimensions [4]. Welch et al [2] demonstrated that a 3D spherical navigator echo technique was able to measure rigid body motion in all six degrees of freedom by sampling a spherical shell in k-space. In this work, we simulated the application of the spherical navigator echo in VIPR by extracting a reference sphere from reference VIPR data. Simulation results show the ability of correcting both 3D translational motion and rotation.

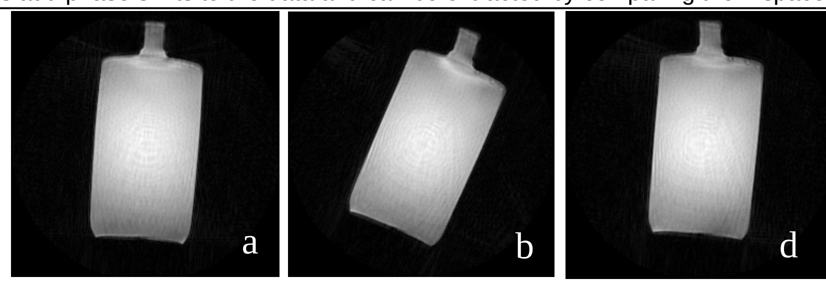
THEORY AND METHODS

It is well known that 3D rotations of an object in the spatial domain produce identical rotations in k-space and can be detected by registration of k-space magnitude values. 3D translations add phase shifts to the data and can be extracted by comparing the k-space.

In the simulation of rotation correction, two VIPR k-space data sets were acquired before and aft rotating the phantom. Images are shown in Fig. 1 a and b. Our goal is to align these two images by comparing two spherical shells, S_{ref} and S_{rot}, extracted from k-space before and after rotation respectively, representing two navigator echoes. There are accurate and efficient methods of estimating this rotation [2]. The method we used was chosen for its simplicity to implement. S_{rot} was rotated by a series of 3D angles. The magnitude correlation of S_{ref} and S_{rot} was measured as a function of rotation angle. This correlation should be largest when S_{ref} and S_{rot} are aligned. The detected angles were then applied to rotate the coordinates before VIPR reconstruction.

In the simulation of translation correction, two VIPR k-space data sets were acquired. One was static and the other was corrupted by moving the phantom during acquisition. Two corresponding spherical shells, S_{ref} and $S_{tr,}$ were extracted from each k-space. The phase difference can be found by multiplying S^*_{ref} by $S_{tr.}$ This phase was then applied linearly to the corrupted VIPR data.

All data were acquired using basic VIPR acquisition with 5000 projections per k-space. All spherical shells were extracted at kr=5.



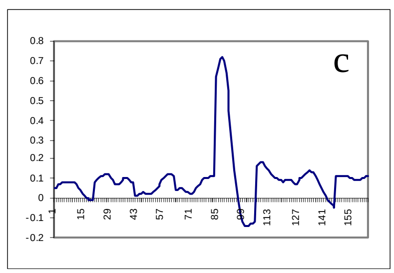


Figure 1 Images before (a) and after (b) rotation. Magnitude correlation as function of rotation index (c) showing the detected rotation angle at the maximum correlation, image (b) was then rotated back (d) according to the detected angles.

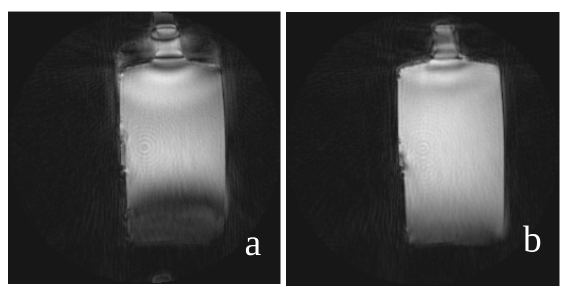


Fig. 2 Images corrupted by translational motion (a) and after correction (b)

RESULTS AND DISCUSSION

Figure 1 c shows the magnitude correlation as function of rotation index (corresponding to rotation angles). The angle with maximum correlation was applied to obtain the corrected image (Fig. 1d). Figure 2a shows the image with translational motion artifact and Fig. 2b is the image after correction. Although the accuracy related to number of samples on the shells and the radius of the shells needs to be investigated, both corrections worked well with the simulated navigator echoes. In the real case, navigator shells will be inserted every certain number of VIPR projections. Each set of projections will be corrected based on the corresponding navigator shell. For rotation correction, this might cause non-uniformity of the k-space trajectory. Density weighting should be considered during reconstruction. Translation correction was robust for both in plane and through plan translational motion and can be readily applied to any VIPR application.

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