Reducing artifacts in dynamic MRI movies using a spline interpolated sliding window technique

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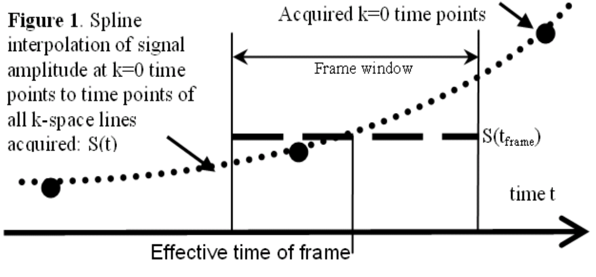


Figure 1. Spline interpolation of signal amplitude at k=0 time points to time points of all k-space lines acquired: S(t)

Introduction

Dynamic movies provide an opportunity to understand how a system changes over time. The concepts behind these techniques have been used as early as 1988 when Riederer *et al* demonstrated the feasibility of using a sliding window technique to visualize the motion of a syringe rolling underwater [1]. Today, numerous methods exist to visualize time-dependent phenomena in the human body. [2] The issue we are concerned with here occurs for sliding window rectilinear reconstructions of dynamic processes. When the trailing edge of the sliding window passes through a k=0 line and the leading edge encompasses a new k=0 line, one may notice intensity pulsations in the movie that are not physiological in nature. We propose an algorithm to reduce these artifacts in certain situations.

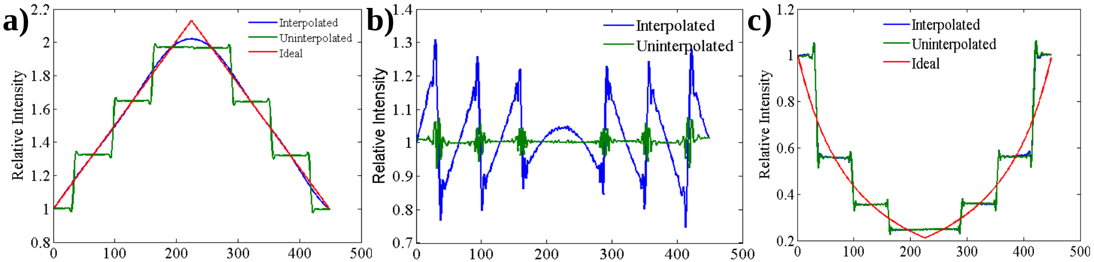


Figure 2. a) The phantom used in the simulations. b), c), and d) Plots comparing the sliding window techniques to an ideal sequence of images for three scenarios: b.) the pixel intensity increased and decreased, c.) the pixel intensity remained fixed while the phantom expanded and contracted, and d) the pixel intensity was conserved while the circle expanded and contracted.

Methods

Computer simulations: The computer simulation used a sequence of images of a uniform circular phantom that evolved in three ways over 512 frames: 1) the radius remained fixed while the intensity increased and then decreased, 2) the radius increased and then decreased while the intensity in any given pixel was constant, and 3) the radius increased and then decreased while the total pixel intensity was conserved. These images were converted to k-space and one line was read from each image in a sequential fashion to simulate the acquisition of dynamic MRI data. The lines were reconstructed using both a traditional sliding window method (no correction) and the proposed interpolation technique schematically shown in Figure 1. The k=0 time points from the original set of images are used to spline interpolate the signal intensity. The signal intensity at each k=0 time point is spline interpolated to estimate the k=0 signal intensity for each k line acquired. Each k line is then amplitude scaled to the amplitude at the center of the sliding window found from the interpolation plot. The resultant uncorrected and corrected images were compared to the source images.

MRI experiments – Phantoms: All of the phantom data were acquired on a 30cm bore 4.7T Bruker system (200MHz). The phantoms were made using phosphate buffered saline (PBS) and various concentrations of iron powder, either Fe_2O_3 and Fe_3O_4. To observe gravitational settling of these particles, a FLASH imaging sequence was used with TR=100ms, TE=4ms, an image matrix of 64x128, FOV of 4cm, and an imaging time of 6.4s. The images were sequentially encoded to match the simulation parameters. Prior to imaging, the phantoms were sonicated and shaken to insure the particles were homogeneously distributed throughout the sample just prior to imaging.

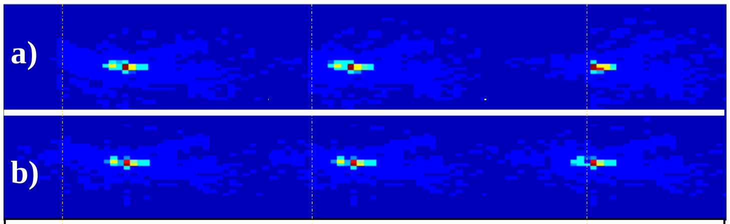
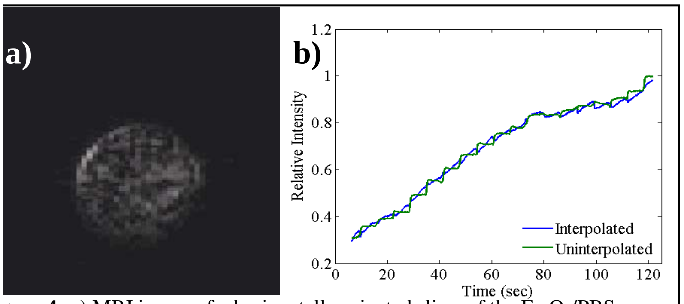


Figure 3. Close up of sliding window k-space data. The frames shown are separated by 4 actual time frames: a) uncorrected and b) corrected. The dashed vertical line denotes the border between old and new original images within the sliding window. The uncorrected data has different noise intensity in these two regions while the corrected date's noise intensity remains constant.



gure 4. a) MRI image of a horizontally oriented slice, of the Fe_3O_4/PBS antom and b) a plot of the signal intensity that monotonically increases as due the gravitational settling the iron particles. Note that in a), the force of gravity ints into the page.

Results

Figure 2 b), c), and d) compare the traditional sliding window technique to the proposed interpolation algorithm for the three simulation scenarios described in the methods section: b) varying intensity with fixed radius, c) varying radius with fixed pixel intensity, and c) varying radius with total pixel intensity conserved. The signal intensity was measured from ROI's in the simulated images. Figure 3, compares the transition of the k-space data for the traditional sliding window and the interpolated method. In Figure 4, the algorithm was applied to the phantom images which contained ferrous particles that settled out of the horizontally oriented image plane due to gravity.

Discussion

As displayed in Figure 3, the algorithm smoothes the discontinuities in signal intensity that occur as the sliding window refreshes the central portion of k-space data. The resultant movies more closely approximate the source data because the intensity jumps which occur between images are smoothed out by the algorithm as seen in Figure 2 b) and 3. However, when there is significant motion and the intensity in an image is not conserved, this interpolation algorithm fails. This failure may be due to improper scaling of the images. In Figure 2 d), the intensity is conserved during the motion so the low frequency errors may be small. When applied to the PBS/saline data, one can observe a steady increase in the signal as the particles aggregate to the bottom of the container.

References

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Acknowledgements

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