Improved Scan Efficiency using Multiple Interleave Acquisitions for Optimal Windows (MIAOW)

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Aim

Navigator acceptance imaging methods have been hindered by the loss in scan efficiency which results from the changes in the breathing pattern during a scan. A technique, Phase ordering with Automatic Window Selection (PAWS) (Jhooti et al, MRM 2000), has previously been presented which is resistant to changes in breathing whilst allowing the use of phase ordering to provide effective motion artefact reduction in an optimal time. The drawback of the PAWS technique is that images are only available once enough data has been acquired within the range of motion specified. Whilst the acquisition may terminate with the optimal scan time for the particular respiratory trace and acceptance window size, this optimal time may still be quite long. Techniques such as the Diminishing Variance Algorithm (DVA) (Sachs et al, MRM 1995) acquire the whole image before attempting to limit the respiratory motion. Whilst this has the advantage of allowing scans to terminate at any point after the initial image has been collected the algorithm was found to be less effective in subjects with a variable respiratory pattern (Jhooti et al, MRM 2000). The proposed technique, Multiple Interleaved Acquisitions for Optimal Windows (MIAOW) attempts to combine the noted benefits of the DVA and PAWS technique to provide a technique which: enables images to be reconstructed quickly with all further data acquisition reducing the acceptance window and improving image quality; ensures that the scan automatically terminates in an optimal scan time for a given acceptance window size regardless of respiratory pattern.

Method

The Multiple Interleaved Acquisition for Optimal Windows (MIAOW) Technique, uses predetermined algorithms which are independent of the breathing pattern of a subject and, therefore, resistant to changes in breathing. The technique aims to ensure that all ky groups of data are acquired rapidly to enable early reconstruction with further acquisitions improving image quality whilst not compromising the scan time if the breathing pattern is variable. In the example in Figure 1, Ky lines are acquired through k-space in a non-sequential manner. Each successive 4[th] line is acquired from one side of k-space. Once the other side is reached, the direction of acquisition is reversed. For each group of four successive diaphragm positions, this acquisition order is shifted by one place to the right, as shown in Figure 1b. This is to allow a more rapid coverage of k-space with a range of diaphragm positions. This pattern over four successive diaphragm positions is repeated throughout the user defined search window. Window size is altered by altering navigator resolution.

(a)

Ky line	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0	8	7	15	1	9	6	14	2	10	5	13	3	11	4	12

(b)

Diaphragm Position \ Ky line	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
3	11	4	12	0	8	7	15	1	9	6	14	2	10	5	13	3
2	4	12	0	8	7	15	1	9	6	14	2	10	5	13	3	11
1	12	0	8	7	15	1	9	6	14	2	10	5	13	3	11	4
0	0	8	7	15	1	9	6	14	2	10	5	13	3	11	4	12

Figure 1.

Data acquisition and completion is demonstrated in Figure 2 for a simple case where only 16 lines of data are to be acquired with an acceptance window of 2mm. A representation of k-space is shown in Figure 2a after 16 cardiac cycles. The ordering strategy is such that a complete data set can be acquired sooner than was possible in techniques such as PAWS. In this example a data set can be acquired after 29 cardiac cycles (Fig. 2b). The corresponding respiratory trace and the acceptance window used to reconstruct the data is also shown. As data acquisition continues the algorithm continues to select the best window for the acquired data (Fig. 2c). After 51 cardiac cycles an image can be acquired in the desired range of motion and the scan terminates automatically. The corresponding respiratory trace, acceptance window and state of k-space is shown in Figure 2d. In this example the optimal scan time for a 2mm acceptance window with the given respiratory trace was calculated to be 51 cardiac cycles.

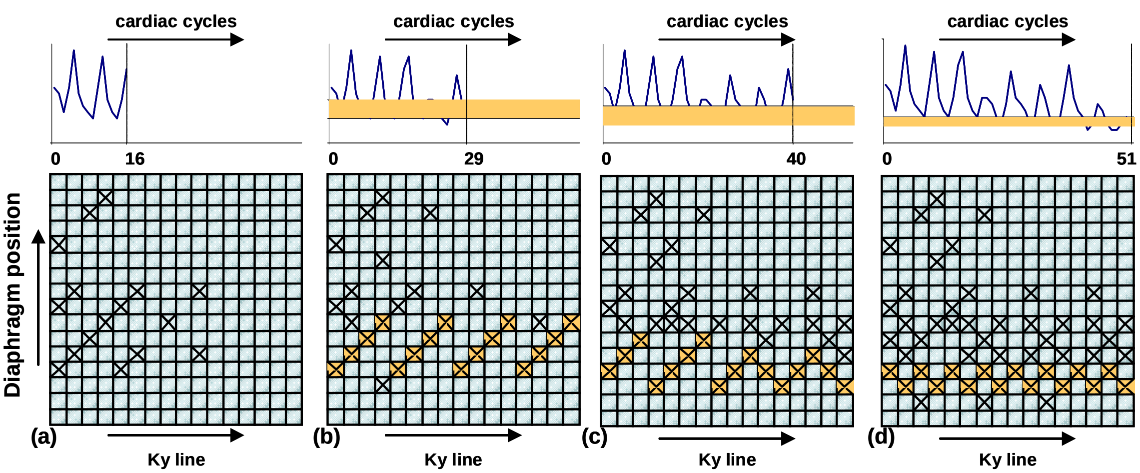

Figure 2.

Results/Discussion

The final MIAOW image had an average percentage difference of less than 4.3% and a standard deviation less than 4 for all window sizes (2mm, 4mm, 6mm) when comparing the final scan time to the optimal scan time possible. The comparable result for PAWS with a 6mm window was a percentage difference of 4.7% from the optimal scan time with a standard deviation of 4.6%. As PAWS only completes once its final image is acquired this is also its quickest scan. The quickest MIAOW image is over 40% quicker than the most efficient scan time with a 2mm window and almost 30% quicker with a 6mm window.

Conclusion

A technique is presented which automatically completes in the optimal time given the required acceptance window, as with PAWS. However, the acquisition of data is such that images may be reconstructed much sooner with further acquisitions improving image quality. The operator may therefore terminate the scan sooner if image quality suffices in the knowledge that the slowest automatic termination will still be done in an optimal time. Only one sampling strategy has been shown and many variations are possible allowing, for example, the incorporation of phase ordering to potentially further improve image quality.