Phase ordering with Automatic Window Selection (PAWS) with Half Fourier for Increased Scan Efficiency and Image Quality

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Aim

Navigator acceptance imaging methods are hindered by the loss in scan efficiency which results from the changes in the breathing pattern of a subject over time. 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. Whilst the technique was shown to improve both scan efficiency and image quality over other navigator acceptance methods, imaging time can still be quite long, particularly when acquiring high resolution 3D coronary images. The aim of this work is to investigate the application of a modified PAWS algorithm which is specifically tailored to partial Fourier acquisitions.

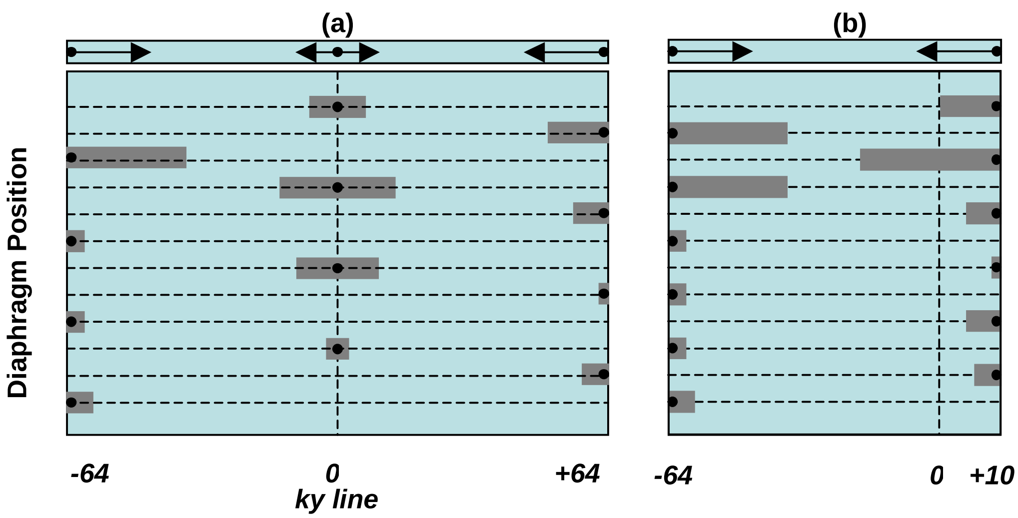
Method

The original PAWS technique uses a multi-level approach where no acceptance window is specified. Instead, the initial position of the diaphragm is taken as the reference and all further diaphragm positions are given an index position which is the displacement from this reference. Each index position is allotted a starting position in a region of k-space, hereafter called a "bin", as shown in Figure 1a. The modified PAWS algorithm uses two bins to acquire the data as opposed to the original three bin version, as shown in Figure 1b. The k-space region is filled according to the direction of the arrows. In the original work on PAWS, it was found that the most efficient scan time possible (the quickest time it is possible to acquire a complete image given the size of the acceptance window) was always achieved if two bins were used. However, the use of only two bins increases the likelihood of two bins joining near the centre of k-pace which can increase image artifacts. The use of only two bins may also increase the scan time which is unacceptable if a large number of lines are to be acquired. Although it is possible to use a larger bin size, the benefits of phase ordering would diminish significantly. It was therefore decided to use three bins as it would be possible to limit motion around the central region of k-space by confining it to the central bin, whilst increasing the sizes of the outer bins to allow reductions in scan time. The use of partial Fourier techniques reduces the data to be acquired, whilst the central line of k-space is now towards the edge of the data to be acquired. The two bin technique was therefore employed with a bin size of 1.5mm giving an acceptance window of 3mm.

The use of phase ordering limits motion between successive phase encode lines and motion artefacts are therefore minimised. Scan time is further reduced from the three bin method as any slight efficiency errors previously encountered with overlapping regions from the outer to inner bin, are now eliminated. Data acquisition is completed once one row from the left meets an adjoining row from the right.

The use of slice following also allows any left-right combination to be used, further increasing the possibility of reduced scan times in a way not possible ,so efficiently, with the three bin technique.

Images were acquired *In vivo* with normal subjects. The PAWS method, using a 3mm two bin scheme and Partial Fourier of up to 5/8, was compared with the original PAWS technique using a 5mm three bin weighted scheme (2mm outer bins, 1mm inner bin) to acquire a complete data set.



Results/Discussion

The two bin approach ensures that the images are acquired in the optimal scan time possible for every scan. Whilst PAWS consistently acquired images at the optimal scan time or within 95% of this time, the two bin approach acquires images at the optimal time in every scan. The reduction in data which needs to be acquired allows a smaller acceptance window to be used, further improving the image quality. In studies of 10 normal subjects the two bin Partial Fourier approach reduced acquisition times by a mean of 20%. If slice following is employed then each row of data is aligned at the same position. It is therefore possible to lift the restriction that only two contiguous edges can be joined up and it is now possible to construct a data set whenever any edges join. Whilst this was also possible with the original three bin approach it was unlikely that three bins ever did join up perfectly with no duplicate acquisitions. Whilst there are errors associated with inaccuracies of slice following, such errors are minimised between contiguous k-space lines through the use of ordering inherent in the PAWS technique.

Conclusion

A technique has been developed which exploits the advantages of partial Fourier imaging to allow further improvements in the PAWS algorithm. The two bin PAWS technique is robust against changes in breathing and allows images to be acquired in the optimal scan time in every acquisition. The use of slice following can further be exploited in this technique by allowing any two bins to join up to provide the requested data for an image.