Smart Algorithm for the Acquisition of the Optimal Set of Projections for Functional MRI

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Introduction

Reconstruction from projections, RP (1), has been revaluated for MRI applications, especially for real time and functional MRI (fMRI). In fact, RP methods reduce the effects due to motion because the centre of k-space is over-sampled and it is sampled at the start of the reading time, thus eliminating movement occurring in the last period of the reading interval. Moreover RP methods improve the signal to noise ratio (SNR) in the reconstructed image as a result of over-sampling of the central region of the k-space. It has been demonstrated elsewhere (2) that it may be possible to reduce the number of collected projections, below the minimum required to obtain an image of a given dimension without artefacts, if information about sample internal symmetries and shape can be collected during acquisition. In fact, the method presented in (2) is able to collect a near optimal set of projections without any a-priori information about the sample, by calculating the information content of the projections through an entropy function, during the progress of the acquisition process (for this reason, we refer to it as the blind adaptive method). This method, suffers from two limitations: some important projections are excluded from the acquired set, especially in the proximity of entropy function minima or maxima; it is necessary to use efficient software (dedicated hardware is also to be recommended) to calculate the information content of the collected projections during the sequence repetition time, without wasting time. Aims of this work is to overcome these limitations by presenting a method which collects a-priori information about the sample through the preliminary measurement of two circular paths at different distances from the k-space centre. The directions of the most informative projections can then be set using information acquired from the power spectra of these paths of coefficients.

The algorithm

The idea behind the algorithm is that the power spectrum of a standard MR image, for example that shown in Figure 1A, is mainly distributed along particular radial directions, as shown in Figure 1B. The acquisition algorithm consists of the preliminarily collection of two circular trajectories having the centre in the image k-space centre and radii of s_1R and s_2R (where $0<s_1<s_2<1$ and R is the image radii in pixels), see figure 1B. The choice of these values is quite arbitrary but it is necessary to intercept the most informative radial directions. The value of s_1R must not be too close to the k-space centre in order to collect the start of "star-like" differentiation (near the centre the star effect has not yet been highlighted). The value of the s_2R must be chosen not too close to the k-space border to avoid noise effects, mainly evident at high frequencies with $s_1=0.2$ and $s_2=0.9$. From the power spectra of the collected trajectories, the mean values are calculated and maxima above the mean value, in both curves, are used to indicate the presence of the most informative radial directions. All the local maxima above this value are chosen; the others are discarded. The set of these angular directions is considered as the optimal, most informative, set of projections to be collected in a standard way. The number of samples in the circular paths has been fixed to maintain the Nyquist criterion.

Results and Discussion

The presented algorithm has been tested on k-space data obtained by inverse Fourier Transform of a complete coronal MRI 256*256 spin density image of a head obtained with a commercial 1.5 T apparatus, shown in Figure 1A. Subsets of the projections were extracted using either the proposed method or the blind adaptive criterion (2). The images have been compared numerically by using the mean square error, MSE, calculated between the image to be tested and the image reconstructed by using the whole set of projections. The comparison with the image obtained with the whole set of projections, and not with the theoretical starting image, was made so as to eliminate the effects of the reconstruction method from the calculated error of the image under inspection. The images obtained by using a set of 89 projections, obtained by the application of the proposed method, and by using a set of 106 FIDs whose orientations have been calculated by applying the blind adaptive acquisition method, are shown in Figures 2B and 2C respectively. It is important to note that the optimal numbers obtained by the two methods are not so different, but the blind adaptive acquisition method collects a greater number of projections because it acts without a-priori information about the sample. The estimated number of projections is 40% and 53% of the minimum number of projections, 201, necessary to reconstruct an image having dimensions and resolution of the given test image. The images obtained by the two methods are quite similar. The similarities between the two images are also demonstrated by the values of the MSE function (MSE=0.070 for Figure 2B and MSE=0.08 for Figure 2C).

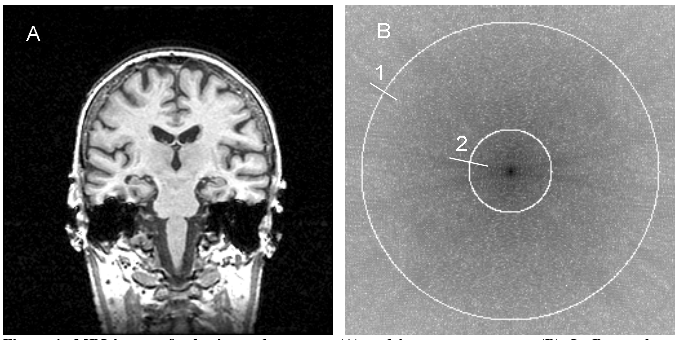

Figure 1: MRI image of a brain used as a test (A) and its power spectrum (B). In B are also indicated the circular paths of power spectrum coefficients used to estimate the most informative radial directions and two of these directions are labelled (with the number 1 and 2 respectively).

The proposed method produces a further 20% reduction in the number of collected projections with respect to the blind method. Obviously, the proposed method requires the collection of the two circular paths before data acquisition. In spite of this, it is completely deterministic and follows the shape of the imaged object whatever it is. Conversely, the blind method has two main drawbacks: some informative maxima cannot be collected; optimal calculation hardware/software are required for a real time implementation. The proposed method maximises the image information content while reducing the number of collected projections. Further investigation should be dedicated to the definition of "importance" of the projections: here we decide to select, as most important, the projections whose power spectrum represented a local maximum above the mean value. An alternative choice could be the choice of the projections whose power spectrum has a maximum variation (by collecting the maxima of the power spectrum derivate). Because these choices are all reasonable and are strictly dependent on the interpolation algorithm used to resample a full Cartesian grid, this argument will be the subject of a future paper.

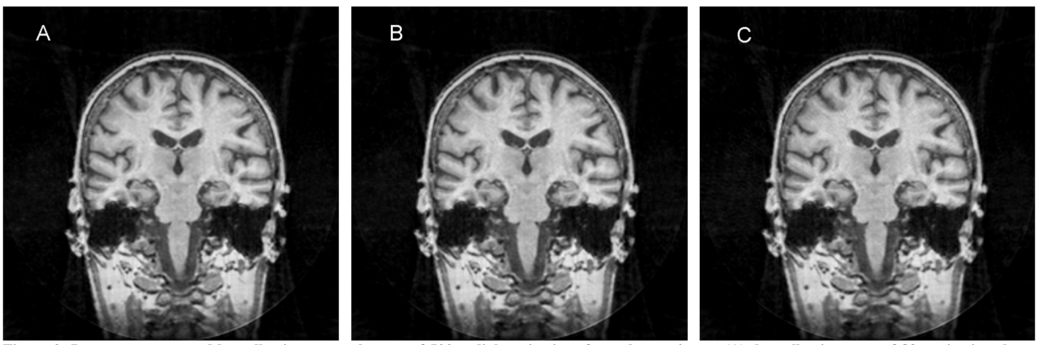

Figure 2: Image reconstructed by collecting a complete set of 500 radial projections from the test image (A), by collecting a set of 89 projections by using the proposed method (B) and a set of 106 projections collected by using the blind adaptive method (C).

References

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