A Reconstruction Algorithm of MR Images Acquired on a Radial k-Space Trajectory for Parallel Imaging

S. Yun[1], Y. Han[1], H. Park[1]

[1]Department of Electrical Engineering, Korea Advance Institute of Science and Technology, Daejeon, Korea, Republic of

Introduction

A reconstruction method was presented by Pruessmann et al. for Sensitivity Encoding (SENSE)[1] with arbitrary k-space trajectory [2]. The method can be applied to the MR data acquired on a radial, spiral and random k-space trajectory as well as Cartesian k-space trajectory. However, in the reconstruction procedure, the method requires gridding step which converts the coordinates from arbitrary grid to Cartesian grid. Therefore, it suffers from the gridding interpolation error in the reconstructed image. In this study, we proposed a reconstruction algorithm for parallel imaging with radial k-space trajectory. The presented method does not require gridding step and can reconstruct the images using only magnitude information of the projection data which is obtained after the Fourier transform along the radial direction.

Methods

3 Tesla MRI scanner (ISOL, Korea) equipped with 4-channel phased array coils was used for the implementation of the algorithm. The schematics of the proposed algorithm are described in Fig.1.

1. MR data were acquired on a radial k-space trajectory with phased-array coil, and taking the 1-D Fourier transform of the data yields the projection data (sinogram) for each channel.
2. We can make the relationship between the reconstructed image (Cartesian grid) and projection data (radial grid) using the Radon transform (Fig. 1(a)). The formulation is given by: $p_\theta^i(x') = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} S_i(x,y) f(x,y)\delta(x' - (x\cos\theta + y\sin\theta))dxdy$ ··· (1), where, $p_\theta^i(x')$ is the projection data at view angle θ and a distance x' for *i*-th channel coil, $f(x,y)$ is the reconstructed image at (x,y) and $S_i(x,y)$ is the sensitivity map at (x,y) for *i*-th channel coil. The discretized version of formula (1) can be represented in the matrix equation as shown in Fig. 1(b), where N is the number of samples in both image and projection data, V is the number of view angles, and C is the number of channels in the phased array coil. The matrix $\mathbf{b}$ is the projection data whose dimension is $[NCV \times 1]$, matrix $\mathbf{A}$ is the relationship matrix whose dimension is $[NCV \times N^2]$, and matrix $\mathbf{x}$ is the reconstructed image whose dimension is $[N^2 \times 1]$. Therefore, the reconstructed image can be obtained by solving the matrix equation, $\mathbf{b} = \mathbf{Ax}$. In order to determine the solution, the row dimension of matrix $\mathbf{A}$ must be equal or larger than the column dimension of matrix $\mathbf{A}$ ($NCV \ge N^2 \rightarrow \therefore V \ge N/C$). This means that the number of view angles (V) can be reduced by factor C (number of channels in coil) and this results in shortening the acquisition time in radial imaging. In this study, the parameters (N , V and C) were 128, 64 and 4, respectively.
3. In solving the matrix equation, so small errors in projection data ($\mathbf{b}$) can lead to large changes in reconstructed image ($\mathbf{x}$). To suppress this effect, we used Tikhonov regularization [3]. And due to the huge size of the matrix, conjugate gradient iterative approach [4] was used to solve the equation.

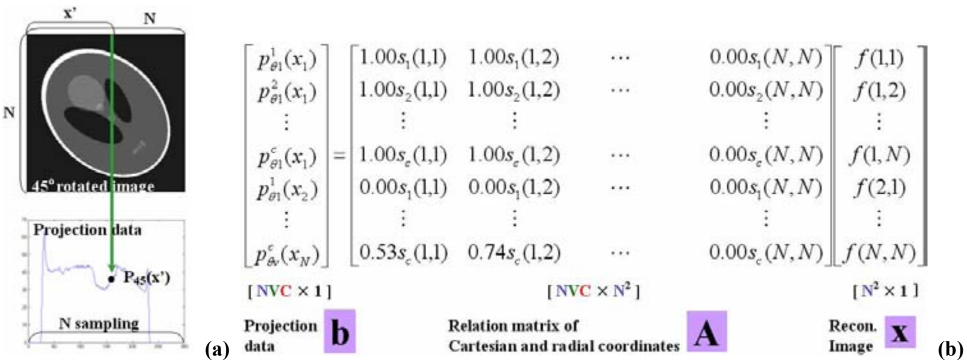

Fig. 1 **(a)** Projection schematics, **(b)** Proposed matrix equation to reconstruct radial data for SENSE

Results

The performance of the proposed algorithm was measured by comparing the images reconstructed from the Radon transform with the reconstructed images from the proposed method. The parts on the top show the reconstruction using our technique with 64 views, and the parts shown on the bottom represent the images obtained by summing the magnitude of the images reconstructed using Radon transform with same number of views. As evident from Fig. 2, the algorithm uses the multi-channel data effectively and reconstructs the images with higher resolution than the Radon transform.

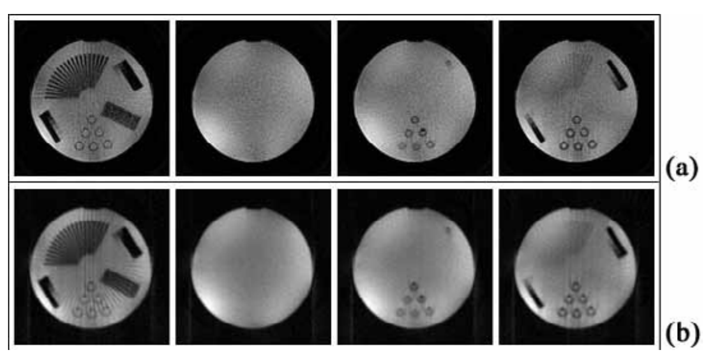

Fig. 2 Reconstructed images (4 slices, 64 views) using **(a)** the proposed method **(b)** radon transform

Conclusion

In this study, we implemented an algorithm to reconstruct the MR data acquired on a radial k-space trajectory for parallel imaging. The proposed algorithm does not require gridding step and can reconstruct the images using only magnitude information of the projection data. The motion artifact can be reduced by using only magnitude information of the projection data and radial acquisition helps us obtain DTI image with higher spatial resolution. We believe the algorithm of this kind can be effectively deployed for reconstructing DTI data acquired on a radial k-space trajectory to obtain higher spatial and temporal resolution images.

References

[1] Pruessmann KP et al., "SENSE: Sensitivity Encoding for Fast MRI", Magn Reson in Med 1999;42;952-962.
[2] Pruessmann KP et al., "Advances in Sensitivity Encoding With Arbitrary k-Space Trajectories", Magn Reson in Med 2001;46;638-651.
[3] Tikhonov AN et al., "Solution of Ill-posed Problems", Winston & Sons, Washington; 1977.
[4] Bertsekas DP et al., "Parallel and Distributed Computation: Numerical Methods", Athena Scientific, Belmont, Massachusetts; 1997.