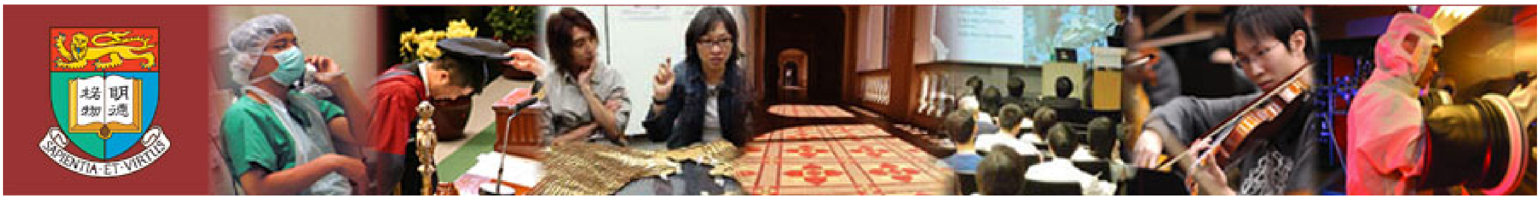

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Algebraic Rreconstruction for Parallel Imaging with Radial Trajectory

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Introduction

Recently a reconstruction algorithm for sensitivity-encoded non-Cartesian imaging has been suggested. This method combines gridding principle with conjugate gradient (CG) iteration [1, 2]. The gridding-based technique involves complex data processing. In this work a new, fast reconstruction algorithm for sensitivity-encoded radial imaging is proposed. As the extended use of algebraic reconstruction techniques (ART) in multi-channel acquisition case, this approach also involves iteratively solving a large linear system of equations (LSE), but the bulk work of gridding is eliminated by taking advantage of the projection-slice theorem and directly making use of the data in non-Cartesian coordinate.

Theory

In radial MRI, based on the projection slice theorem, the projection of an object *I(x,y)* taken at angle φ correspond to a line with angle φ in k-space:

$$p(k,\varphi) = \sum_x \sum_y I(x,y) e^{jk(x\cos\varphi + y\sin\varphi)} \tag{1}$$

One effective way to reconstruct this kind of non-Cartesian encoded images is algebraic reconstruction technique, which can be described by iteratively solving a system of linear equation of the form $B = AX$, where *X* is a vector aligning all the pixels, *B* is a vector aligning all the projection data, and *A* is a coefficient matrix. This scheme can be easily extended to multi-channel acquisition. In this case, the LSE is expanded by combining the linear equations of all channels and introducing the sensitivity profiles into the coefficient matrix. By this means, the expanded linear system can be solved as long as $N_{pixel} \le N_{projection} \times N_{readout} \times N_{channel}$. As such, under-sampling is allowed for accelerated imaging, and theoretically the maximum acceleration factor is equal to the number of channels.

Method

The proposed method can be presented by two steps. First, a 1D DFT is performed to get the projections $p_\rho(r,\varphi)$ of the object *I(x,y)*; then the image pixels are solved from a LSE of the form as Eq. (2).

$$P_\rho(r,\varphi) = \sum_x \sum_y w(x,y) \cdot C_\rho(x,y) \cdot I(x,y) \tag{2}$$

In Eq. (2), $P_\rho(r,\varphi)$ is the *rth* projection taken at angle φ from the ρth channel, $w(x,y)$ is a geometry-dependent weight describing the contribution of each pixel to the projection, and $C_\rho(x,y)$ is the sensitivity of the ρth coil. $w(x,y)$ can be selected in various ways, one of which is to make them proportional to the length of projection line through the corresponding pixel. Note that the coefficient matrix of this linear system is highly sparse. Lately, iterative procedures based on the conjugate gradient method have been shown to substantially facilitate this task. With this scheme the image pixels in Cartesian coordinate are directly solved from the non-Cartesian projection data, eliminating the bulk work of gridding.

Result and discussion

In order to demonstrate the feasibility of our method, simulated reconstructions of the 64 × 64 Shepp-Logan phantom are shown in Fig. 1. In Fig. 1(a) are non-accelerated PR data (72 projections × 64 readout points) using a body coil with homogeneous sensitivity profile, and in Fig. 1(b) are 2-fold accelerated PR data (36 projections × 64 read out points) using a 4-element coil array. The sensitivity profiles of the coils are simulated by Biot-Sarvart Law. For both cases CG iteration reconstructions are performed based on Eq. (2). A satisfactory image quality, i.e. no remaining visible artifacts, is achieved after 30 iterations in (a), and 65 iterations in (b).

The results show that in sensitivity-encoded parallel imaging the noise level is amplified using the proposed reconstruction method. More careful investigation shows that like in Cartesian SENSE, the noise distribution is highly dependent on the geometry of the coil array. The more orthogonal of the sensitivity profiles, the better of SNR and the faster of iteration convergence.

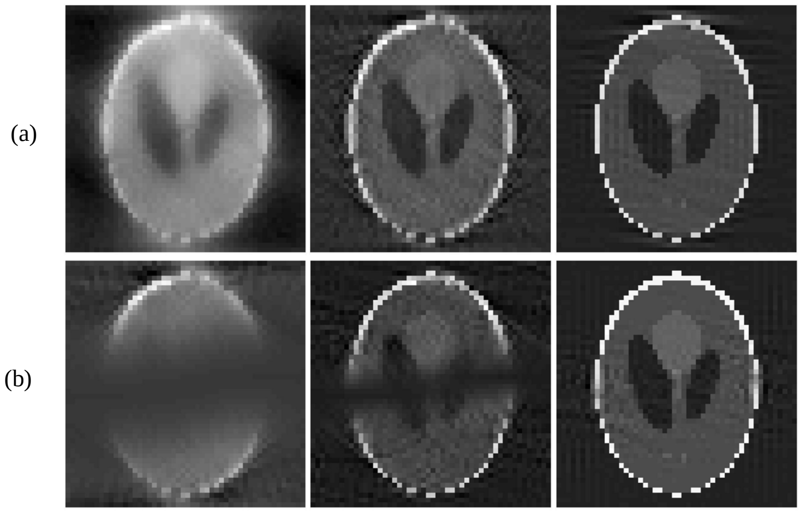

Fig. 1 Progression of the iterative reconstructions. Shown are , from left to right, (a) intermediate images resulting after 2, 7, 30 iterations from 72×64 PR data; (b) intermediate images resulting after 2,13,65 iterations from 36×64 PR data.

Conclusion

A novel algebraic reconstruction method for parallel imaging with radial trajectory is proposed. Taking advantage of projection-slice theorem, the reconstruction can be performed by first carrying out a 1-D FFT and then iteratively solving a system of linear equations. The feasibility of this method was demonstrated by simulations. Since the data in non-Cartesian coordinate are directly used, the bulk work of gridding is not required. Hence, for projection parallel imaging, this algorithm is simpler and faster than gridding-based methods.

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