3-D progressive EPR imaging with adaptive projection acquisition

Y. Deng[1], P. Kuppusamy[2], J. L. Zweier[2]

[1]Davis Heart and Lung Research Institute, The Ohio State University, Columbus, 43210, United States, [2]Davis Heart and Lung Research Institute, The Ohio State University, Columbus, OH, United States

Abstract

In this work, a 3-D progressive EPRI technique was implemented based on inverse Radon transform (IRT) in which an EPR image is acquired and reconstructed gradually from low to high resolution. An adaptive data acquisition strategy was proposed to acquire projections in an order from the most important to the least important. Both simulation and experimental results showed that the data acquisition efficiency has been remarkably improved compared with the regular EPRI data acquisition.

Introduction

In continuous wave (CW) EPRI, an n-dimensional EPR image is reconstructed through (n-1)-stage back-projection operations. The multi-stage reconstruction algorithm is easy to implement and fast in computation speed. However, it requires the acquisition of all the projections before image reconstruction. More critically, all the projections are assigned with equal importance and acquired in a nested-loop order. The content-independent acquisition method is not optimal [1]. Here we present a progressive EPRI technique with adaptive projection acquisition.

Method

The inverse Radon transform (IRT) was used to reconstruct 3D EPR images [2]. To increase the data acquisition efficiency, the uniform gradient scanning path was also adapted [2, 3]. We developed a content-sensitive adaptive data acquisition algorithm in which the mean-square amplitude of the filtered projection is used as the criterion to evaluate the significance for each projection. We proposed the following strategy to acquire projections. (i) Given the imaging parameters, calculate the uniform gradient scanning path. (ii) Acquire a pre-defined number of projections, say, 10% of the entire projections. These projections will be used as "seeds" to determine the acquisition order for other projections, as in step (iii). To shorten the time within which all the important projections are collected, these "seed" projections should be distributed evenly in the pre-calculated gradient scanning path. (iii) Calculate the significance values for all the acquired projections and predict the significance values for all other uncollected projections using linear interpolation. Acquire the projection with the highest significance value in the prediction. (iv)Filter and back-project the projection acquired in step (iii) and update the reconstruction result and image display. Repeat steps (iii) and (iv) until all the projections are collected or the data acquisition is stopped.

Results

Simulation: The simulation parameters were: central field = 10 mT, sweep width = 0.75 mT, data points = 128, field of view (FOV) = 50x50x50 mm^3. The Lorentzian absorption line shape was used with a full-width at half-height (FWHH) 0.02 mT. The gradient strength was 15 mT/m. Fig. 1 shows the progressive image reconstruction results with and without adaptive data acquisition. In the adaptive acquisition, 66 projections (10%) were acquired as "seeds". Compared with the regular EPR projection acquisition, up to 70% acquisition time has been saved using the adaptive algorithm.

Experiment: The phantom was constructed by machining the letters "E", "P", and "R" on three plastic bricks (35x27 mm^2). Each letter was filled with approximately 15 mg of DPPH powder mixed with Agar (Aldrich Chemical Company) and distilled water. The experiment was performed on the laboratory-developed 300 MHz EPRI system using the following imaging parameters: sweep width = 2.4 mT, FOV = 60x60x60 mm^3, modulation amplitude = 0.05 mT, scan time = 3.9 s and time constant = 10 ms. The gradient strength was 40 mT/m. The imaging results are shown in Fig. 2. A 3-dimensional regular EPR image was acquired (32x32 = 1024 projections with uniform angle sampling) as the reference image. About 50% of projection acquisition time has been saved using the adaptive algorithm combined with the uniform gradient scanning strategy in this experiment. In summary, both Fig. 1 and Fig. 2 show that the reconstruction results from the adaptive data acquisition algorithm converged much faster to the original phantom (image) than that from the regular data acquisition.

Conclusion

We implemented a 3-D progressive EPR imaging technique based on the inverse Radon transform. By using the proposed adaptive projection acquisition strategy, 50% to 70% data acquisition time can be saved with negligible loss of image quality.

Reference:

1. G. Placidi, M. Alecci, and A. Sotgiu, Theory of Adaptive Acquisition Method for Image Reconstruction from Projections and Application to EPR Imaging, J. Magn. Reson. Series B 108, 55-57 (1995).
2. K. Jain, "Fundamentals of digital image processing," Prentice-Hall, Inc., Englewood Cliffs, Jew Jersey (1989).
3. C.-M. Lai, and P. C. Lauterbur, A gradient control device for complete three-dimensional numlear magnetic resonance zeugmatographic imaging, J. Phys. E: Sci. Instrum. 13, (1980).

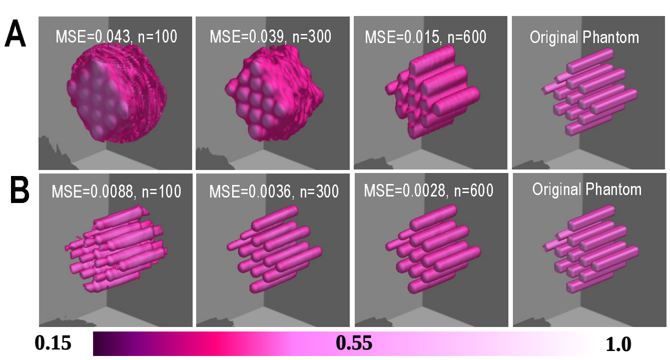

Fig. 1 Simulation results of "Tubes" phantom. A: regular; B: adaptive

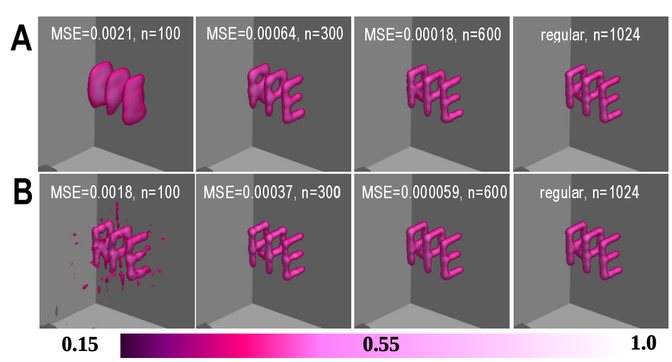

Fig. 2 Imaging results of "EPR" phantom. A: regular; B: adaptive