Phase Encoded Acquisition with Compressed sEnsing

Marc Rea[1], Xavier Boullier[2], Ian Young[3], and Donald McRobbie[1]
[1]*Radiological Sciences Unit, Imperial College Healthcare NHS Trust, London, United Kingdom,* [2]*Bioengineering, Imperial College, London, London, United Kingdom,*
[3]*Electrical Engineering, Imperial College London, London, United Kingdom*

Introduction

Artefact reduction techniques in the region of metallic implants are important since spatial distortions and signal voids often obscure any useful diagnostic information. Numerous sequences have been implemented to reduce local artefacts with varying degrees of success [1,2,3]. While there has recently been clinical adaption of these methods, it remains a current area of research. The underlying cause of image artefacts is frequency modulation of RF which occurs during slice excitation and frequency encoding. Single-Point-Imaging (SPI) is one method with the potential to sidestep these problems by using phase to spatially encode data in three orthogonal directions [4]. However it is seldom used in practise due to long imaging times. Compressed Sensing (CS) has been shown to be a useful method in MRI, reducing the amount of data required to form images by iterative solving of the image matrix after data transformation to a sparse representation [5,6].

This abstract reports upon the application of compressed sensing to reduce the data requirements of a 3D SPI sequence; allowing high-resolution 3D images to be acquired around metal implants in clinically feasible times.

Methods

A 3D SPI sequence was designed as shown in Fig 1a. with a non-selective RF pulse, gradient spoiling, and imaging gradients applied in three dimensions to loop through k-space in the X, Y and Z directions. The RF and data acquisition were done during the application of the gradients. In the first instance, a full 3D SPI acquisition was performed on a 3T Siemens Verio scanner (Siemens, Erlangen, DE) with parameters (FOV=300mm, matrix 64x64x64, 32 datapoints, rBW=1000Hz/px, $\alpha = 7°$, TR=10ms, TE=2-8ms), using a bottle phantom, and a hip implant in an agar gel phantom. The scan time was 52 minutes. These data were then used for simulations to find the optimum TE and the best acquisition strategy for the CS algorithm.

The acquisition and reconstruction schemes used software coded in MatLab (Mathworks, MA, USA). Simulations were performed by selectively zero-filling k-space data using a range of reduction factors, and a range of filters to favour of the central portion of k-space while still retaining a factor of randomisation. The filters used were a 3D Gaussian filter, and 2D Lorentzian and Gaussian filters repeated at each Z location. The reduced subsets of data were reconstructed using the RecPF CS algorithm with 2D FT [7] on a slice-by-slice basis, before recovery of the 3D data using a 1D Fourier Transform in the slice direction. Each measurement was averaged from 20 repetitions of the randomised filtering.

After compiling the simulation results, the sequence was implemented on the scanner with parameters FOV=200mm, matrix 128*128*128, 32, $\alpha = 7°$, TR=3ms, TE=2ms, reduction factor = 4, and configured to use run-time input from an external PC to selectively acquire or skip data points in a pattern determined by the chosen filter (reduction factor = 4, standard deviation=0.3) with a scan time of 17 minutes. The exported raw data was later reconstructed on an external computer.

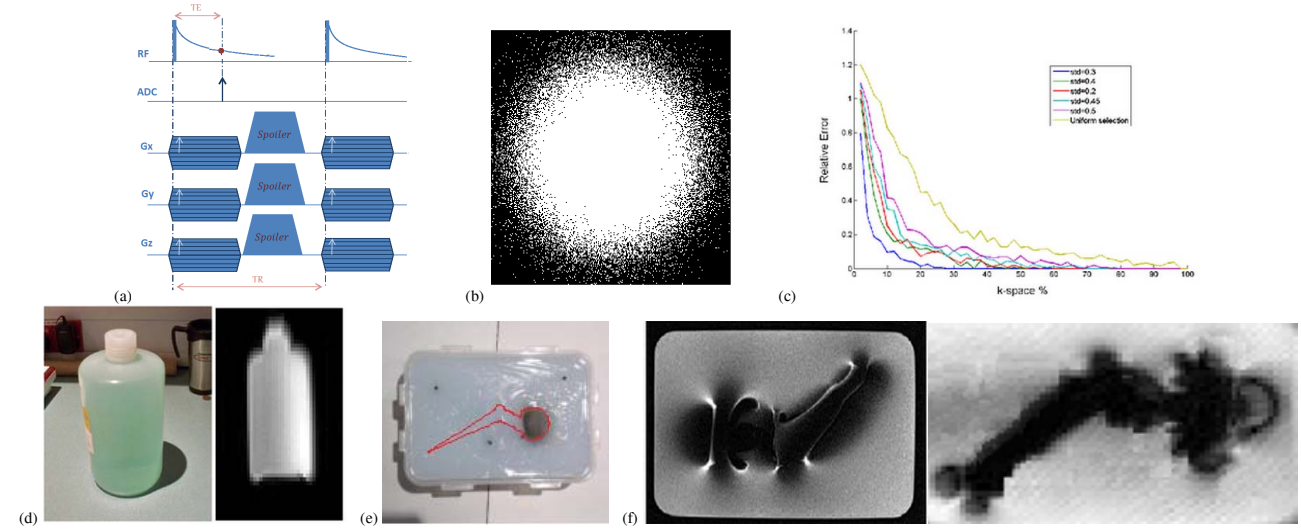

Figure 1. (a) The SPI pulse sequence diagram. (b) A randomised Gaussian 2D acquisition filter with a reduction factor of 2 (i.e. 50% of data) and std=0.3. (c) Plot showing the relative error against percentage of data for different standard deviations of the Gaussian filter. (d) Bottle phantom and corresponding image taken at 64*64*64 matrix size. (e) Agar gel phantom showing the approximate outline of the embedded hip implant . (f) Images from (left) Spin-Echo sequence and (right) a 64*64*64 SPI acquired in 3min 45secs.

Results

Comparison of the errors from simulated data sets pointed to an optimum acquisition filter with a standard deviation of 0.3 and a reduction factor of 4 (see Fig 1c). It was also found that the FOV decreased in size as TE increased, due to the increasing of the phase encoding moment with time. Analysis of the bottle phantom data led us to select an optimum TE/TR of 1.3ms/2ms, and the requirement for a short sequence, permitting a 128*128*128 matrix acquisition in around 17 minutes. Scans with a reduction factor of 4 (i.e. 25% of the full acquisition) were found to give on average a 4% decrease in SNR.

Discussion

This work proposes that a phase-encoding only 3D SPI sequence can be employed in reasonable scan time for the purpose of metal artefact reduction using Compressed Sensing and a randomised, Gaussian filtered 2D acquisition matrix. It was found that a matrix size of 128*128*128 with a 200mm FOV gave a pixel size of 1.56m, and although some artefact remained it was much reduced in size when compared with a spin echo sequence. It seems reasonable that a reduction factor of 6 or more would give a potential scan time of less than 10 minutes, suitable for clinical use. Further work is being undertaken to tackle the remaining artefact, implement a rectangular FOV to better match the expected anatomy, and integrate parallel imaging, allowing lower scan times and leading towards *in-vivo* assessment of the sequence.

References

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