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Autocorrelation Image Reconstruction: Improving the SNR of MR Images by processing raw data

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INTRODUCTION

The purpose of the work presented here is to improve the quality of MR images, by taking advantage of the special characteristics of the MRI signal. It is well recognized that MR images can sometimes be noisy (1). This is particularly true of images obtained in low field strength magnets (2), with long echo times or with fast imaging techniques.

Conventionally, one copes with this problem, using averaging (2). The idea is that, since the signal is statistically coherent (and the noise is not), N acquisitions will result into an improvement of the overall Signal to Noise Ratio (SNR) of the image by a factor of $\sqrt{N}$. Thus, by choosing an appropriate value for N one can raise the SNR to an acceptable level. At the same time, averaging results into an N-fold increase of the total time of the experiment, which not only indicates an increased cost per image but also introduces other potential problems such as, for example, displacement artifacts.

The noisy images may be processed using conventional techniques, but with poor results since these techniques fail to take into account the special characteristics of the MRI signal. The proposed technique interacts with the signal before the reconstruction step, that is directly with the raw FIDs.

THEORY

The autocorrelation $r_s(\tau)$ of any signal s(t) is defined by (3)

$$r_s(\tau) = \int_S s(t)\, s^*(t-\tau)\, dt$$

It has been proven that the autocorrelation of the MRI signal has the following characteristics

a) it retains all the useful information about the proton density distribution,

b) it practically eliminates the so-called phase error (4) of the NMR experiments,

c) it improves the overall SNR of the reconstructed MR image.

Taking into acount the above, it is proposed here to Fourier transform the autocorrelation of the raw data, instead of the data themselves.

The autocorrelation sequence $r_x[k,l]$ of a two dimensional data set $x[m,n]$ ($0 \le m < M$, $0 \le n < N$) may be computed by (3)

$$r_x[k,l] = \frac{1}{M\,N} \sum_{m=0}^{M-1-k} \sum_{n=0}^{N-1-l} x^*[m,n]\,x[m+k,n+l]$$

EXPERIMENTAL RESULTS

We applied the algorithm to images with varying Signal to Noise levels. The technique showed very good improvement of the image quality for SNRs up to -10 db. However, for very poor images (SNRs below -20 db) the image quality deminishes rapidly. There seems to exist a critical threshold below which the estimation is very ill-conditioned. Nevertheless, such SNRs are rather unusual in practical MRI. On the other hand the technique does not offer any advantage in almost noise free images, as it was expected.

On the whole, the responce seems to be very promising for the noise levels usually encountered in the MRI signals (with none or very little averaging)

CONCLUSION

The inherent characteristics of the signals encountered in MRS and MRI and of the autocorrelation function have been found to match well and thus result into an algorithm that can improve the quality of images and spectrographs by a) eliminating the phase noise and b) improving the overall SNR.

The algorithm is expected to be more useful in low-field, long echo time NMR experiments where it can lead to a significant reduction of the number of repetitions required for averaging.

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