Parallel Imaging in Time-Resolved Contrast Enhanced MR Angiography Using Maximum a Posteriori Estimation

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INTRODUCTION:

The original SENSE reconstruction algorithm for parallel imaging [1] has recently seen several important enhancements like regularization techniques [2] and the use of prior information [3] to obtain more efficient spatial-temporal packing in dynamic MRI. In this paper we present a new reconstruction technique for time-resolved contrast-enhanced MR angiography which exploits the correlation structure of angiograms. CEMRA has proved to be quite challenging in terms of phased array acceleration because the angiograms are produced by a subtraction of pre-contrast images from post-contract images, and this leads to extreme sensitivity to noise. Standard SENSE reconstruction is usually quite unsatisfactory due to excessive noise amplification problems if the system is ill-conditioned, which is usually the case.

One must therefore eschew classical least-squares based SENSE reconstruction for CEMRA in favour of some sort of Bayesian approach. To this end we propose a stochastic model for image prior. This model is then used to derive an optimal and efficient reconstruction method based on the theory of Maximum a Posteriori (MAP) estimation. It is well-known that the MAP estimate for Gaussian additive noise and Gaussian, stationary priors reduces to the Wiener estimate, which has been known to the MR community through the kt_BLAST and kt-SENSE techniques [3]. Unlike earlier work we apply Wiener filtering in the spatial domain.

PROPOSED METHOD:

Let the Cartesian SENSE reconstruction problem for each frame in the dynamic sequence be represented by

$$y = Ex \qquad (1)$$

where x is the desired MR image frame in vector form, y is the vector representing the output from all the coils, and E is the system matrix containing sensitivity encoding terms. We propose a Wiener-type estimate for each frame in the sequence, as follows

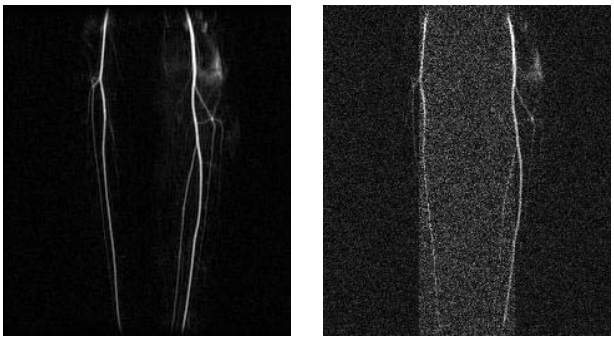
$$\hat{x} = \mu_x + ER_x(ER_xE^H + R_n)^{-1}(y - \mu_y) \qquad (2)$$

where R_x, R_n are signal and noise covariance matrices respectively, and the frames have means μ_x and μ_y.

Estimates of the prior parameters R_x and R_n are obtained directly from available parallel data, hence no training overhead is incurred. In particular, there is no need to perform a low resolution training scan that is required for the recently proposed kt-SENSE approach.

RESULTS:

The objective of our preliminary studies was to evaluate the attractiveness and viability of the MAP approach for accelerated imaging in MR angiography. We selected several 2D projection cases from the trifurcation region. Not only is this an important MRA application, but is also a prime example of situations where traditional SENSE does not fare well due to noise amplification, as shown in the example below. Figure 1(a) shows the original unaccelerated angiogram obtained from the MRA sequence. Fig 1(b) shows the angiogram produced from a 4x accelerated scan, reconstructed with SENSE. Fig 1(c) shows the result of our MAP-based technique. The SENSE output looks quite noisy, but only because the displayed image was obtained from mask subtraction, which amplifies even small noise artifacts. In contrast the proposed MAP reconstruction does not suffer from this problem – in fact shows little loss of quality compared to the unaccelerated angiogram.



(a) Unaccelerated (b) SENSE reconstructed

(c) MAP reconstructed

Figure 1: Simulation of parallel reconstruction in MRA of the trifurcation with 6 coils, accelerated 4 times.

REFERENCES:

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