Application of acceleration methods to Qmap and Synthetic MR imaging

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Target Audience: Physicists with an interest in synthetic MR imaging

Introduction: SyntheticMR is a promising new imaging technique that synthesizes a variety of FSE based contrasts from spin parameter maps generated from a single sequence, called QMAP [1]. While the sequence is very efficient in acquiring a range of saturation delay and spin echo times, an acceleration factor of 2 is required to achieve clinically acceptable acquisition time of about 6 minutes. Potential may exist to shorten the sequence further by utilizing the correlation between the various contrast images of the same slice. In this study, we evaluate compressed sensing [2] and kat-ARC [3] correlation techniques for accelerating QMAP to observe the potential impact of noise and artifacts on the resulting images.

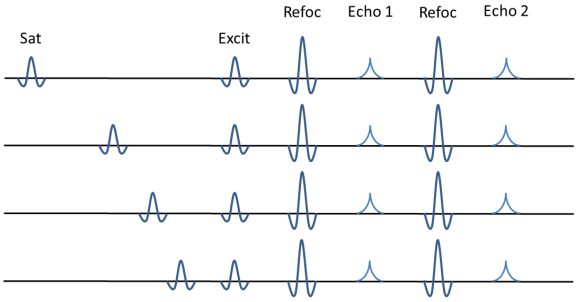

Figure 1. QMAP produces 8 images from 4 delay times and two echo times for simultaneous T1, T2, and PD mapping. Note the actual sequence interleaves saturation pulses and FSE trains of different slices to maximize efficiency [1].

Methods: Base sequence: The QMAP sequence is a saturation delay 2D FSE sequence acquired at 8 saturation delay times and 2 spin echo times, providing a matrix of 16 different tissue contrast images. The saturation pulses and FSE trains are interleaved to maximize scan efficiency. Spin parameters can then be extracted by fitting a T1 to the different delay times and T2 to the different echo times, and scaling the curves to determine PD. Coronal QMAP images of a T2 phantom were acquired on a 3.0T 60cm scanner (MR750, GE Healthcare, Waukesha, WI) and 12-channel HNU coil. Scan parameters were: TR = 4200, TE = 23 and 89, ETL = 10, bandwidth = ±22.73 kHz, acquisition matrix = 320x206, FOV = 24x19.6 cm, slice thickness = 4, slice spacing = 1. To evaluate acceleration techniques, the acquisition was performed with full sampling of four delay times, with a total scan time of close to 12 minutes (the standard protocol achieves ~6 minute scan time by using ASSET with an acceleration factor of 2). Compressed sensing: Since the acquisition is 2D, the center 32 lines of each kspace slice were fully sampled, and the outer lines were randomly undersampled at a variable density by a factor of 2.4, to produce an overall acceleration of 2.0. A conjugate gradient minimization was performed on the total variation of the images and square of the data error in k-space [2]. kat-ARC: The image set was split into two groups by the two echo times, with 4 delay times in each group. Each group was then reconstructed with outer acceleration factors of 2 and 3 [3], with the calibration region set to the central 31 lines and a coherent variable density sampling pattern applied to the outer regions.

All methods were applied on a coil-by-coil basis before complex coil combination for phase sensitive parameter fitting. All reconstructed images were fitted using an evaluation version of SyMRI (SyntheticMR, Linköping, Sweden) to produce T1 and T2 maps, as well as synthetic T1 and T2 weighted images. All maps and images of the accelerated and un-accelerated data sets were compared and observed for noise and artifacts.

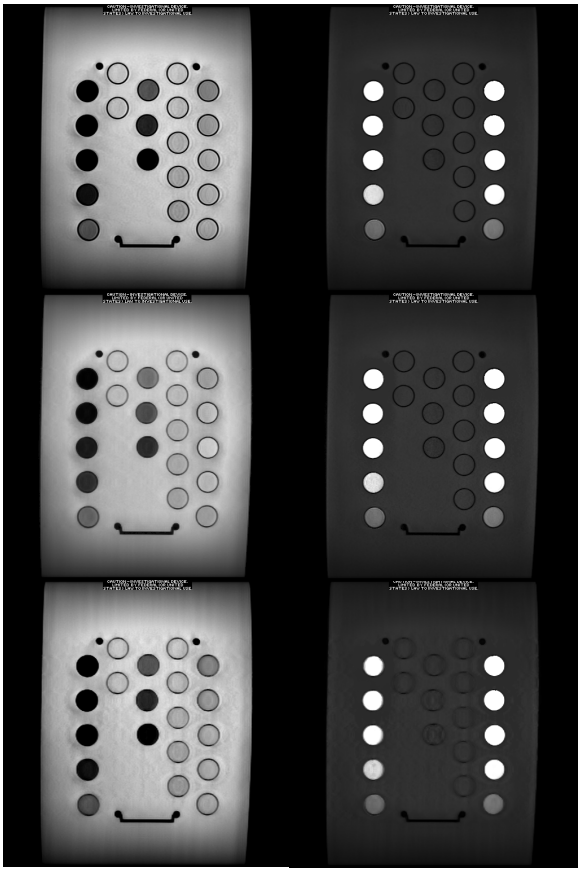

Figure 2. T2 (left) and T1 (right) weighted images generated from the full unaccelerated acquisition (top), kt-ARC with outer acceleration factor of 3 (middle) and CS reconstruction with acceleration of 2 (bottom).

Results and Discussion: Figure 2 shows T1 and T2 weighted images resulting from the CS and kt-ARC reconstructions. Generally the CS reconstruction resulted in low spatial frequency artifacts, while kt-ARC resulted in very little increase in noise or residual aliasing artifacts but a slight loss of DC fidelity. This translated to similar artifacts and patterns of error in the T1 and T2 maps. Subjectively, relative changes observed in the T1 weighted and T2 weighted were less obvious than the quantitative maps. PD maps were not evaluated, since it is expected that estimated absolute PD values are heavily dependent on the absolute coil sensitivities as well as the methods used for complex coil combination.

Conclusions: The artifact and noise characteristics of images synthesized from accelerated reconstructions are very similar to those expected of the underlying acceleration methods. It is therefore possible to accelerate QMAP further by compressing information along the parameter mapping dimensions.

References: [1] Warntjes JB et al, Magn Reson Med 2008, 60:320-9. [2] Lustig M et al, Magn Reson Med 2007, 58:1182-95. [3] Lai P, JCMR 2014, 16 suppl:W3.