Comparison of GRAPPA, SPIRiT and ESPIRiT for the Acceleration of Model-based PRF Temperature Mapping

Yuxin Hu[1], Feiyu Chen[1], Dan Zhu[1], Chenguang Peng[2], Shi Wang[2], and Kui Ying[2]

[1]*Department of Biomedical Engineering, Tsinghua University, Beijing, China,* [2]*Department of Engineering Physics, Tsinghua University, Beijing, China*

Target audience: Radiologists and MR scientists working on MR thermometry and/or fast imaging algorithms.

Purpose: Model-based proton resonance frequency shift (PRF) [1] MR thermometry uses fat frequency as the internal reference, which reduces the temperature quantification errors and is less sensitive to inter-frame motion. However, this method is relatively slow, compared with traditional PRF method[2], which calculates relative temperature change based on phase difference. Thus, in this research, we attempted to combine parallel imaging with model-based PRF to accelerate the acquisition of temperature measurement. The purpose of this work is to evaluate the feasibility of accelerated model-based PRF method with current parallel imaging methods, including GRAPPA[3], SPIRiT[4] and ESPIRiT[5], and compare the temperature accuracy of these methods.

Methods: In this research, the temperature measurement using model-based PRF is divided into two steps: (1) GRAPPA, SPIRiT and ESPIRiT were performed respectively on the artificially down-sampled multi-channel 16-echo kspace of each temporal frame at a reduction factor of 4 and 6 and use 16 ACS lines; (2) The temperature map of each frame was calculated from the reconstructed complex images, based on the frequency difference of fat and water solved from a multi-echo signal T2* decay model[1]. In order to test these acceleration methods on an actual tissue, we performed an MR temperature measurement on an *ex-vivo* goose liver. At the beginning of our experiment, the goose liver was heated to about 60°C and then put into the scanner. A cooling down process was scanned in a Philips 3 Tesla system (Philips, Best, the Netherlands) and the temperature maps were calculated based on a fully-sampled dataset. The fully-sampled k-space data was acquired with the following imaging parameters: TR = 69ms, first TE = 2.1ms, ΔTE = 1.8ms, flip angle = 40°, BW = 1446.1Hz, acquisition matrix size = 100×100, FOV = 180mm × 180mm, slice thickness = 6mm. The scan time for one frame is 9.4 seconds. We then performed an artificial under-sampling in ky and time direction using 16 ACS lines and an outside acceleration factor of 4 and 6. The accelerated temperature maps were calculated and then compared with the fully-sampled references.

Results: Accelerated temperature maps using GRAPPA, SPIRiT and ESPIRiT are shown in Figure 1. The inner part of the tissue is hotter than edges, as we monitored a cooling down process during the scan. The edges of the tissue show smaller temperature error than inner part. ESPIRiT shows the best temperature map among all the methods. GRAPPA and SPIRiT are similar in temperature maps and error maps at a reduction factor of 4, while SPIRiT is much better than GRAPPA when the reduction factor is 6. Figure 2 demonstrates again that ESPIRiT results in the most accurate temperature measurements than other methods.

Discussion: The comparison of temperature maps shown in Figure 1 indicates that ESPIRiT can keep accurate magnitude and phase information at a reduction factor of 4, which is more accurate than GRAPPA and SPIRiT. According to Table 1, the root-mean-square error (RMSE) of ESPIRIT is about 0.2℃ lower than GRAPPA and SPIRiT at a reduction factor of 4.

Conclusion: We validate the feasibility of currently-used parallel imaging methods for the reconstruction of temperature maps using model-based PRF methods. All of GRAPPA, SPIRiT and ESPIRiT result in temperature errors lower than 2℃ and ESPIRiT has the best temperature accuracy with a value of 1.55℃ at a reduction factor of 4.

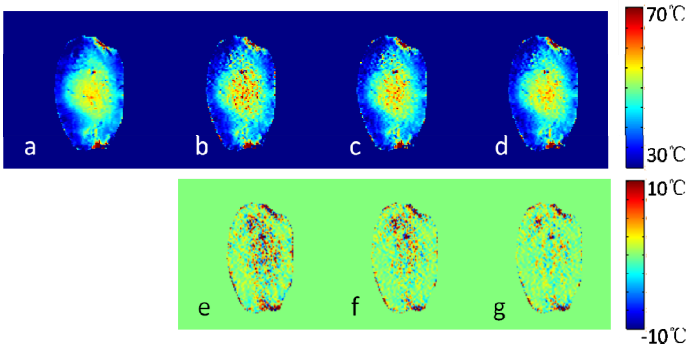

Fig.1 *Comparison of temperature maps reconstructed by GRAPPA(b), SPIRiT(c), and ESPIRiT(d) at a reduction factor of 6 and fully-sampled images(a).*

Table 1 Temperature Root-Mean-Square Error (RMSE) of GRAPPA, SPIRiT and ESPIRiT

Reduction Factor	RMSE /℃	GRAPPA	SPIRiT	ESPIRiT
4	a 10*10 pixel in the center	1.79	1.80	1.55
	four 5*5 pixel ROIs near edges	1.09	1.12	1.02
6	a 10*10 pixel in the center	6.53	3.84	2.48
	four 5*5 pixel ROIs near edges	3.06	2.63	1.95

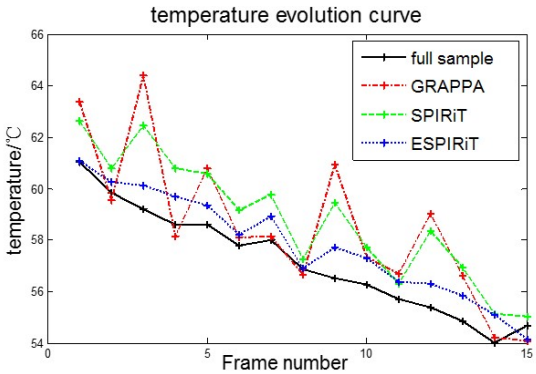

Fig.2 *The temperature evolution curves of three different reconstruction methods (GRAPPA (red line), SPIRiT (green line) and ESPIRiT (blue line)) for the under-sampled data compared with fully-sampled data (black line) at a reduction factor of 6*

References: [1] Pan X et al. MRM, 2010. [2] Li C et al. MRM, 2009. [3] Griswold M A et al. MRM, 2002. [4] Lustig M et al. MRM, 2010. [5] Uecker M et al. MRM, 2013.