A Real Time Approach to Baseline Library Size Recommendations for Hybrid MB+R Thermometry

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Purpose:

PRF shift thermometry is widely accepted as an effective method for temperature monitoring during MR-guided focused ultrasound (MRgFUS) treatments. The Hybrid Mulit-baseline/Referenceless Algorithm (Hybrid MB+R) produces improved temperature estimation compared to single baseline PRF methods [1]. The multi-baseline portion [2] of the Hybrid algorithm requires some number of pre-treatment images to reduce motion artifacts. A previous study used retrospective analysis to give a general recommendation for baseline library size for brain applications, but the results varied across 3 volunteers [3]. The purpose of this study was to present a simple, real-time algorithm for determining when a sufficient baseline library size has been obtained before treatment for use in clinical applications.

Methods:

The proposed method will analyze each baseline image as it is acquired, and indicate to the user when enough baselines have been acquired to stop scanning. Temperature is reconstructed with Hybrid MB+R for a sliding window of the 10 newest images, using all of the previously collected images as the baseline library. Temperature error statistics are calculated for the sliding window, and averaged across voxels in the brain. These statistics are the mean absolute value (L1 error) and the mean temporal standard deviation. Multiple criteria are used to determine when a sufficient number of baseline images have been acquired. If the temperature error is sufficiently small (below τ), baseline acquisition stops. Otherwise, images are collected until the error improves by a sufficient amount ($T < \alpha T_{max}$). If more than N images are collected without sufficient overall improvement, then baseline acquisitions continue until the error is no longer improving (slope of error > β). The stopping criterion should be met *n* times before the acquisition terminates. The parameters used in this study are shown in Fig 1 with a diagram of the decision tree. The real-time algorithm was applied to a dataset of 80 sagittal images collected from 3 healthy volunteers on a GE 3T scanner using a quadrature head coil (TE=12ms, TR=24ms, flip angle=30-40, FOV=20-30cm, BW=12kHz, Matrix Size: 256x128). The recommended baseline library sizes calculated by the real-time approach were compared to those recommended in a previous retrospective analysis.

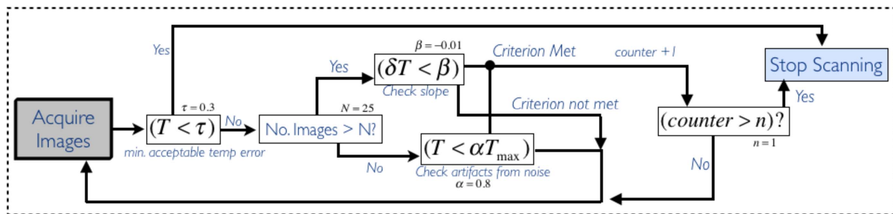

Fig 1. Real-time library size algorithm for hybrid thermometry. Values for stopping threshold parameters are shown in the above flow chart.

Results

Using both the real-time method and previous retrospective analysis, the spatial L1 error and temporal uncertainty decrease for increasing baseline library sizes before stabilizing at larger sizes (Fig. 2). Library size recommendations across volunteers are shown in table 1 for the real-time approach and for retrospective analysis.

Discussion

In this study, the real-time method reconstructs temperature information using a library size that is 10 images less than the total number of images acquired because a sliding window of 10 images was used to calculate temperature statistics. With this difference, the real-time approach gives reliable, conservative recommendations as compared with the retrospective analysis. These results show that sufficient library sizes for hybrid thermometry in the brain can be determined in real-time. This approach will ensure that sufficient baselines are collected to minimize temperature errors during monitoring without wasting scan time by collecting unnecessary baseline images. The threshold parameters used in this study were chosen based on the temperature information gathered from the retrospective analysis. These thresholds may be sufficient for future implementation, but may be adjusted as more datasets are analyzed.

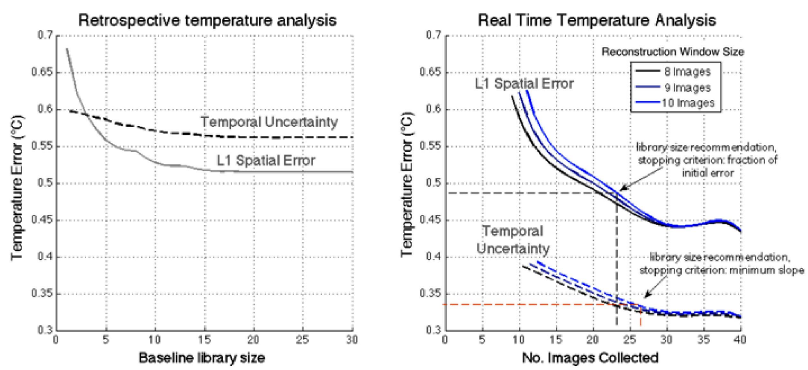

Fig 2. Spatial L1 error and temporal uncertainty across library sizes, retrospective (left) and real-time metric (right). Multiple real-time curves show different sliding window sizes.

		Volunteer		
Metric		1	2	3
Retrospective	Spatial Error (L1)	10	5	13
	Temporal Uncertainty	15	18	16
Real Time	Spatial Error (L1)	23	15	19
	Temporal Uncertainty	26	23	26

Table 1. Library size recommendations using both retrospective and real-time temperature analysis. Temperature estimates were reconstructed using hybrid thermometry.

Conclusion

This study presents a simple, preliminary, real-time temperature processing method for determining pre-treatment baseline library size recommendations for Hybrid MB+R Thermometry. Temperature data collected from 3 volunteer brain scans are analyzed using the real-time method to produce recommendations that are consistent with retrospective analysis. If implemented clinically, this method shows promise as a practical approach to ensuring sufficient baselines are collected pre-treatment to improve temperature estimates, while minimizing the amount of time spent scanning.

Acknowledgements We'd like to thank our grant support NIH P01 CA159992 and General Electric.

References [1] Grissom WA et al. Med Phys. 37:5014-26, 2010. [2] Vigen KK et al. Magn Reson Med 2003; 50:1003-1010. [3] Instrella R et al. ISMRM 2012, p.1578