

A REFERENCELESS THERMOMETRY USING PHASE DIFFERENTIATION MAP

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Introduction Accurate and robust magnetic resonance thermometry (MRT) is critical for real-time MR guided high intensity focused ultrasound (HIFU) therapy. In proton resonance frequency shift (PRFS) thermometry, temperature accuracy can be compromised by motion artifact and magnetic field drift. Referenceless thermometry has been proposed to address this problem. In this method, the baseline phase of the heated region is chosen by polynomial extrapolation from unheated region [1], and 2D phase unwrapping is prerequisite for the model fitting. Some of work has been proposed to avoid unwrapping by complex field estimation [2] or phase gradient model [3]. In this abstract, we proposed a new method to solve the zero-th order term ambiguity in [3] based on phase differentiation estimation. Phantom and ex-vivo studies were performed to evaluate the performance of the proposed method.

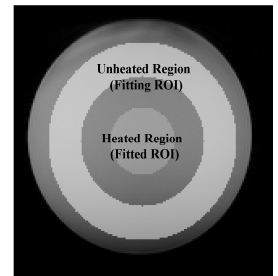


Fig.1 Fitting and fitted ROI in phantom

Background Phase map is modeled by $\varphi(x, y) = \sum_{n=0}^N \sum_{m=0}^{n-1} C_n(m)x^{n-m}y^m$ in referenceless method, where N is

polynomial order, (x, y) is the spatial coordinate. The coefficients $\{C_n(m)\}$ are found by fitting the unheated region using weighted least square criterion. Phase unwrapping would precede the fitting process. We propose to fit the phase differentiation map defined by complex subtraction $\frac{\partial \varphi(x, y)}{\partial x} = \text{angle}(I(x, y) \times I^*(x-1, y))$ to avoid phase unwrapping. Phase differentiation map of heated region is extrapolated from unheated region through polynomial fitting instead, and then it is numerically integrated to recover the baseline phase map using the outer boundary of heated region as initial values. This approach addresses the issue of zero-th order term ambiguity in [3].

Order	3	4	5	6	7
MAX	10.964	1.940	2.575	3.607	3.712
	3.893	3.120	2.604	2.832	2.736
STD	0.629	0.593	1.014	1.453	1.375
	0.842	0.738	0.483	0.495	0.704
MEAN	0.517	0.487	0.862	1.245	1.144
	0.702	0.063	0.068	0.069	0.056

Table I. Factor of polynomial order to standard referenceless method (dark column) and our method (white column). Unit is Celsius degree.

Phantom experiment To test the proposed method, a room temperature phantom experiment (Fig. 1) was conducted on a 3.0T system (Siemens TIM Trio, Erlangen). 3D EPI sequence with the following imaging parameters was used: TR/TE=25/10ms, flip angle=15°, resolution = 1.5 mm isotropic, matrix size = 160 * 160, EPI factor = 9. We investigated the criteria of choosing best polynomial order for both methods over 40 measurements.

Ex-vivo bovine liver experiment The experiment was conducted on a 1.5T system (Siemens Symphony, Erlangen) with an MR compatible HIFU system (Haifu Technology, Chongqing). FLASH with the following imaging parameters was used for temperature imaging during ablation: TR/TE = 21ms/14.3ms, parallel imaging with acceleration factor of 2, PF = 6/8, flip angle = 25°, resolution = 1.67*1.67*4mm³, matrix size = 128*192. The HIFU energy was delivered for 3 times in bursts during a period of ~200s.

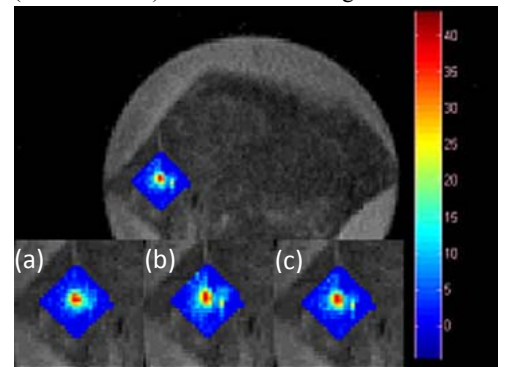


Fig. 2 Temperature map of ex-vivo bovine liver heated by HIFU. (a) reference method; (b) referenceless method; (c) our method

Results Table I shows how polynomial order is related to maximal absolute error (MAX), mean error (MEAN) and standard deviation (STD) of heated region in referenceless and our method through room temperature experiment. The proposed method showed less sensitivity on the polynomial order and comparable performance in error compared to standard referenceless method. Fig.2 shows the temperature map of ex-vivo bovine liver at $t = 142s$ by the reference method (a), referenceless method (b) and the new method (c). Fig. 3 shows the temperature change of the hottest spot in the bovine liver after temporal Gaussian filtering for all three methods.

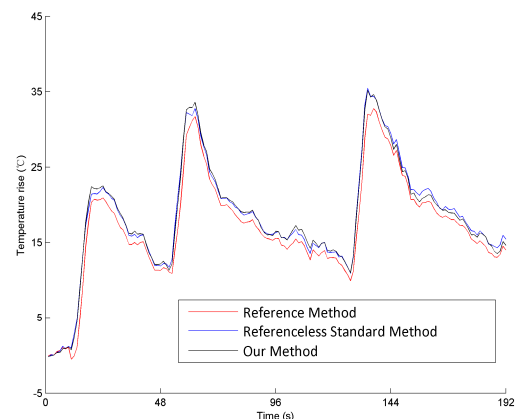


Fig.3 Hottest spot temperature change calculated by three methods. Polynomial order = 4.

Conclusion A new referenceless method based on phase differentiation map estimation is proposed to avoid phase unwrapping. Phantom and ex-vivo studies show that the proposed method is less sensitive to polynomial order, computationally more efficient, and its accuracy is comparable to that of the standard method.

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Reference [1] Rieke, et al MRM 51: 1223-1231. [2] Kuroda, et al MRM 56: 835-843. [3] Langley, et al. ISMRM 2010 p. 5221