Phantom study for boundary artifact reduction in MREPT

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Target audience: Researchers interested in electrical property mapping

Purpose: Magnetic resonance electrical properties tomography (MREPT) is a technique which estimates conductivity and permittivity by measuring B1 information[1−3]. Previous MREPT assumed that electrical properties are locally homogeneous which leads to so-called 'Boundary Artifact' [4]. Recently, several boundary artifact reduction studies were introduced[5,6]. The proposed method[5] in ref(5) reduces boundary artifact by iteratively estimating the electrical field over inhomogeneous regions. However, this method was verified just for simulation data without any noise added. To verify the practical applicability of this method, the iterative boundary artifact reduction algorithm is implemented for a phantom experiment.

Method

Iterative Boundary Reduction Algorithm (Fig. 1): At the initial processing, an initial admittivity map (τ^0) was reconstructed using conventional MREPT method. After this step, an initial artifact free mask (Ω^0) is chosen from the τ^0. For the extraction of Ω^0, a histogram-based method[7] was applied. In each iterative step, the admittivity value (τ^n) outside the artifact-free region is updated from the ${E_z}^n$ and ${E_+}^n$ estimates. After updating the admittivity, the region with small changes is included to the artifact free mask (Ω^n).

$$ {E_z}^n = \frac{2}{\tau^n}\left(-i\frac{\partial H^+}{\partial x} - \frac{\partial H^+}{\partial y}\right) \quad (1) $$

$$ {E_+}^n = \frac{2}{\tau^n}\left(-i\frac{\partial H^+}{\partial z}\right) \quad (2) $$

$$ \tau^{n+1} = 2\frac{\left(-i\frac{\partial H^+}{\partial x} - \frac{\partial H^+}{\partial y}\right){E_z}^n + i\frac{\partial H^+}{\partial z}{E_+}^n}{|{E_z}^n|^2 + |{E_+}^n|^2} \quad (3) $$

$$ \Omega^{n+1} = \Omega^n \cup \{v: \|\tau^{n+1}(v) - \tau^n(v)\| < \varepsilon\} \quad (4) $$

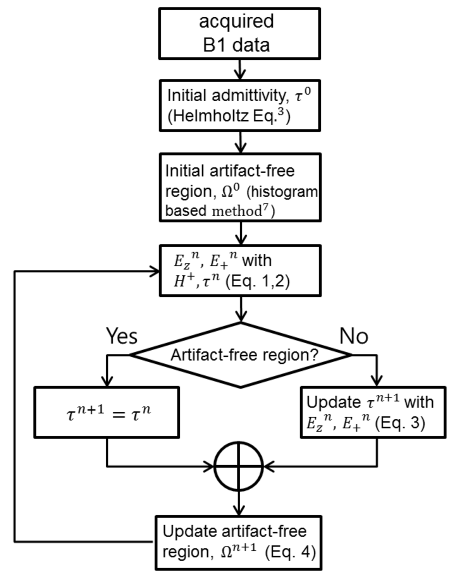

Fig 1. Flow diagram of iterative process

Experiment design: A cylindrical phantom was made with 11cm diameter and 6cm height as shown fig.2. The center region was filled with agar-saline gel (1.4 gr/l Agar, 0.2 gr/l NaCl, 0.3 gr/l $CuSO_4$). The background was filled with saline (0.5 gr/l NaCl, 0.2 gr/l $CuSO_4$). Experiment was performed in a 3T clinical scanner (Siemens Tim Trio) using 2D spin echo (Flip angle = $60^\circ / 120^\circ$, TR/TE = 650/13ms, voxel size = 1x1x1mm^3 and 8 averages). H^+ magnitude was obtained by the double angle method (DAM)[8] and H^+ phase was retrieved from a half of the spin echo phase. For denoising, H^+ data was Gaussian filtered before the processing to increase the stability of the iteration.

Result & discussion: Figure 2 shows the reconstructed conductivity map using the Helmholtz equation[3] without and with Gaussian filter and the proposed method. By comparing the conductivity estimates in fig. 2 (a-c), it can be seen that the boundary artifacts are strongly reduced using our method (also seen in the line plot of Fig 3) and that the noise of the conductivity map is lower than other methods and. However, a slight bump can be seen in the middle region which is probably due to the error propagation during the iterative process.

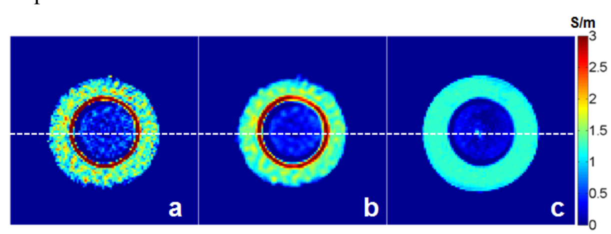

Fig 2. Reconstructed conductivity values: (a) conventional MREPT, (b) conventional MREPT w/ Gaussian filter, (c) proposed method. A white dot line is for line plot.

Conclusion: The proposed work well on the practical experiment on phantom even though there were some limitations (a correct initial mask, error propagation etc.), Compared to the previous MREPT method, the boundary artifacts are significantly reduced.

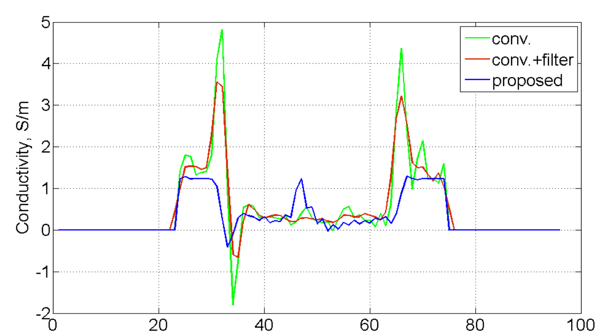

Fig 3. Line plots through the center slice of each methods

Reference: [1] Katscher et al, IEEE TMI, 28:1365-1374 2009, [2] Voigt et al, MRM, 66:456-466, 2011 [3] van Lier et al, MRM, 67:552-561, 2012, [4] Seo et al, IEEE TMI, 31:430-437, 2011, [5] J Lee et al, ISMRM(2013) 4183 [6] Hafalir et al, IEEE TMI, 33:777-793, 2014, [7] Linda et al, “Computer Vision”, 279-325,2001, ISBN 0-13-030796-3, [8] Stollberger et al, MRM, 35:246-251,1996.