Robust Phase Unwrapping Using Grid-fit Method

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Abstract In MRI, field map estimation techniques using 3 point multi-echo acquisitions have been developed for reliable water fat separation. Among the various techniques, Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation (IDEAL) has gained considerable popularity as an iterative method for acquiring high quality water and fat images. A core of IDEAL is to have an initial estimate of field map, to ensure that algorithm will converge to correct solution which is close to the true value. However, due to the worsened B0 inhomogeneity at high field, IDEAL could not adjust for the meaningful field map estimation, particularly for a large field of view. Previously, to improve the robustness of this estimation, a region-growing (RG) technique was developed to take advantage of the 2D linear extrapolation procedure through the seed point set by median value in target object. There are some limitations with this approach, such as the dependence on the initial seed point, like a number, intensity and position of seed point. In this work, we introduce the simplest and robust method called Grid-fit that does not need to considering some parameters relate with accuracy.

Keywords-component; MRI, Grid-fit, Least square fit, Phase unwrapping, 3-space

I. INTRODUCTION

Fat appears bright in MR images acquired by a number of important pulse sequences, including fast spin-echo (FSE)[1], steady-state free precession (SSFP) [2], and spoiled gradient echo (SPGR). The inability to isolate water signal from fat signal may degrade the diagnostic value of these images because bright fat signal can obscure underlying pathology[3]. The 3-point (3-pt) Dixon water-fat decomposition method is based on the frequency shift of fat with respect to water. [4–6]. After Dixon’s original work, Yeung and Kormos [7], Glover and Schneider [8], and Glover [9] showed that it is actually possible to determine \( \phi \) by acquiring an additional image. Such a requirement on the field inhomogeneity is essentially the same as that for the successful fat suppression by the frequency selective methods and, as discussed. Therefore, correct water and fat separation using the Dixon approach has been deemed to rely largely on the success of phase unwrapping [10]. Phase unwrapping is a well-studied but long-standing problem outside the field of MRI. Although many different methods of phase unwrapping have been developed, no general solution is available, particularly in the context of MRI. Mathematically speaking, phase unwrapping can be stated simply as recovering the true phase \( \phi \) from its principal or wrapped value \( \phi^w \):

\[
\phi^w = \phi + k \cdot 2\pi
\]

where \( k \) is an integer and, as explained above, \( \phi^w \) is limited to a range between \( -\pi \) and \( \pi \) is determined from \( \phi \) through a wrapping operator as follows:

\[
\phi^w = W[\phi]
\]

Phase unwrapping is not meaningful for an isolated image pixel because any multiples of \( 2\pi \) can be added to its principal value. Thus, phase unwrapping is in general only considered for an ensemble of pixels for which the true underlying phase is assumed to be spatially continuous or smooth.

Field map estimation is a critical step in all multi-point water-fat decomposition methods. However, it always involves some degree of ambiguity. The IDEAL method [11] avoids the need for phase unwrapping using an iterative field map estimation method. However, an intrinsic ambiguity still exists. Here we describe the behavior of this ambiguity and propose an improvement to the robustness of the field map estimation by using Grid-fit method.

II. PROPOSED METHOD

We propose a more robust and simple phase unwrapping scheme. The key to our method is to begin the iteration at each grid with least-square fitting by using MiP (Median intensity Projection) process at each axis pixels. The steps on the proposed Grid-fit method are:

1. Compute field map by pixel independent method [12],
2. Divide by KxK Grid-regions, that Grid-region size can changeable depend on field map resolution. Sample Grid-region size \( K \) is 6 according to (Fig. 1).
3. Compute MiP value at each axis pixels.
4. Adjust the Least-square fitting by using MiP values.
5. Fill median value in each pixel by fitted values at local grid.

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6. After fit the local grid, adjust the homomorphic filtering [13] at entire Grid-region to enhance the global inhomogeneity.
7. Compute the water/fat map using the field map calculated above.

III. EXPERTMENT

To evaluate the proposed method, experiments based on medical MR imaging were performed, and the method has been applied successfully to 30 image slices. By figure 3 and 4, we can check the successful sample experiment results.

We can track the fast changes in the field map around the sternum. A new algorithm has been developed to estimate the field map associated with fat-water separation. The algorithm is more robust than a region growing algorithm previously described. This provides an improved methodology for fat-water separation in cardiac imaging.

IV. CONCLUSION

In this paper, proposed grid-fit within the image processing algorithm has been used to resolve the limitations in exist phase unwrapping method. It suggested fitting of each grid regions by least square method. It also suggested an effective algorithm to field map estimation the each grid regions using image processing method. This method did not stick to fundamental unwrapping method, but focused on fitting the grid region that intensity correction by grid-fit processing, considering the least square method and homomorphic filtering. The results have confirmed that the meaningful region, which have been fitted through a local and global grid-fit region, that is, the method in which the water and fat region separated through grid-fit were used was more accurate than the conventional one in which the difference of pixel information was used. However, when the grid-fit result has considerable number and size of grid, the accuracy depend on this conditions. This limitation should be complemented by further research on estimation improvement. This paper aimed to verify the possibility phase unwrapping improvement in image processing by adopting the MRI. Further research needs to be conducted to help in resolving the general limitations through the appropriate combination of MR technique and image processing.

REFERENCES