Consistent region-growing based Dixon water and fat separation for images with disconnected objects

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Introduction: Successful water and fat separation in a Dixon technique [1] requires reliable and consistent correction of phase errors that are caused by the magnetic field inhomogeneity. Among different phase correction algorithms that have been published, region growing does not require a priori assumption on the spatial distribution of the field inhomogeneity and has been successful in many applications [2,3]. In a typical region growing scheme, the phase information is successively propagated from one pixel to its neighboring pixels under a general assumption that the magnetic field inhomogeneity is spatially smooth and does not have large discontinuities between the neighboring pixels. A potential problem with region growing is when objects are separated by signal voids. While using a cluster of pixels (e.g. within a boxcar) rather than a single pixel can help region growing overcome small separation between the objects [3], gaps that are well above the boxcar size will essentially break down the information "bridge" and result in region growing failures. As a consequence, the water and fat separation for the disconnected objects within an image will become inconsistent (see Fig. 1). In this work, we demonstrate that modification of a previously-published region-growing algorithm can be used to achieve consistent water and fat separation even when objects are disconnected with large gaps.

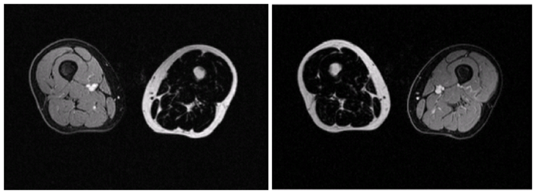

Fig.1 Mis-assignment of water and fat within a pair of separated images.

Methods: Our method for dealing with disconnected objects consists of two processing steps. According to Ref [3], the region growing starts from a well-behaved pixel and proceeds in a sequence that is determined by the pre-calculated phase gradient maps. Pixels with smaller phase gradients relative to the seed pixels are processed before the pixels with larger phase gradients. This is designed to increase the robustness of the region growing by processing the high-quality pixels (with smaller phase gradients) before the low-quality pixels (with larger phase gradients). The time sequence of the region growing can be monitored and recorded as a quality index. The 1st step in our method is to automatically segment the disconnected objects into sub-images using the quality index from the region growing. Because the pixels within an object are in general better-behaved than the pixels in the background, the quality index are expected to display distinct minima (see arrows in Fig. 2), each corresponding to the processing of an object and separated by higher quality index that represent the processing of the background pixels in between. Fig. 2 shows the quality index from the actual region growing of the image in Fig. 1 and confirms our expectation. Based on the distinct feature, we can easily segment (e.g., by detecting and marking the mid-point between the two minima) the two objects into sub-images (one of them is shown in Fig.3). After the segmentation, each water-only and fat-only image pair becomes four separate sub-images (designated as W1, W2, F1, and F2).

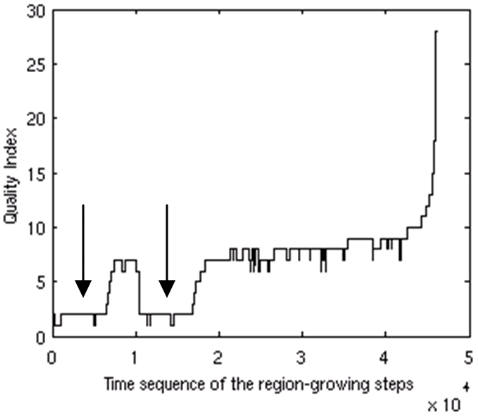

Fig.2 Quality Index from the region-growing of image in Fig.1.

The second step in our method is to recombine the segmented sub-images (e.g., W1 with W2 and F1 with F2, or W1 with F2 and W2 with F1) so that within each image, the water and fat assignment is consistent. In order to achieve this goal, we start with the center slice by applying a statistical method that can correctly identify water and fat based on their asymmetric chemical shift spectra [4]. For all other slices, the identification is based on a method that successively correlates the neighboring slices (starting from the center slice) based on the phase coherence between the slices [5].

We implemented the proposed method in Matlab and evaluated its effectiveness in a total of 13 different patient datasets. Each dataset corresponds to a 3D acquisition of the lower legs in axial plane using a dual-echo fast spoiled gradient echo sequence [6]. Excluding 4 boundary slices from each 3D dataset, a total of 1106 slices were included in the analysis.

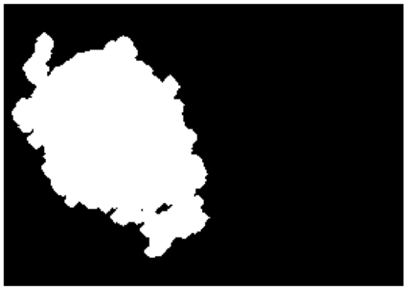

Fig.3 A segmentation of the image in Fig.1 using the mid-point of the high quality index region between the two minima.

Results: Without the proposed method, the region growing was unpredictable when going from one leg to the other leg through the background pixels in the gap. As a result, a total of 203 images or 18.4% were found to contain incorrect water and fat assignment (such as shown in Fig. 1). With the proposed method, the number of images with mis-assigned water and fat decreased to only 6 or 0.5%. The 6 failed images all corresponded to locations near the edge of the 3D acquisition and resulted from an infrequent failure in the 1st segmentation step of the proposed method.

Discussion: Consistent phase correction by region growing for images containing disconnected objects is difficult to achieve. As a result, water and fat separation within an image can be inconsistent and in practice may cause distraction to a radiologist's reading. By exploiting the quality index from an existing region growing scheme, we demonstrated that consistent water and fat separation is possible. Our proposed method consists of two simple steps and incurs minimal amount of increase in the processing time. We expect that the very small number of failures (~0.5%) found in our initial testing can be reduced with future optimization in the automatic segmentation step.

Reference: [1] Dixon WT. Radiology 1984;153 (1):189-194. [2] Xiang QS et al. J Magn Reson Imaging 1997;7 (6):1002-1015. [3] Ma J. Magn Reson Med 2004;52 (2):415-419. [4] Moiz A et al. Magn Reson Imaging 2009; (in press). [5] Ma J et al. Magn Reson Imaging 2005;23 (10):977-982. [6] Ma J, et al. J Magn Reson Imaging 2006;23 (1):36-41.