

Water Fat Identification for Symmetrically Acquired Dixon Method on Non-connected Body Regions

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Introduction Water-fat separation technique, also known as Dixon technique, is widely used as a fat suppression method. Dixon technique generates water images and fat images with a single scan. One problem for this symmetrically acquired Dixon technique is non-connective object imaging. In those cases, phase information is inconsistent due to the gaps between different body parts, causing a separation failure of intermingled contrast. Several works have been published for water/fat identification, such as partially-opposed-phase [1] and histogram analysis [2][3]. In this work, an alternative histogram-based recognition method is proposed. It is also extended to address the problem of non-connective object imaging.

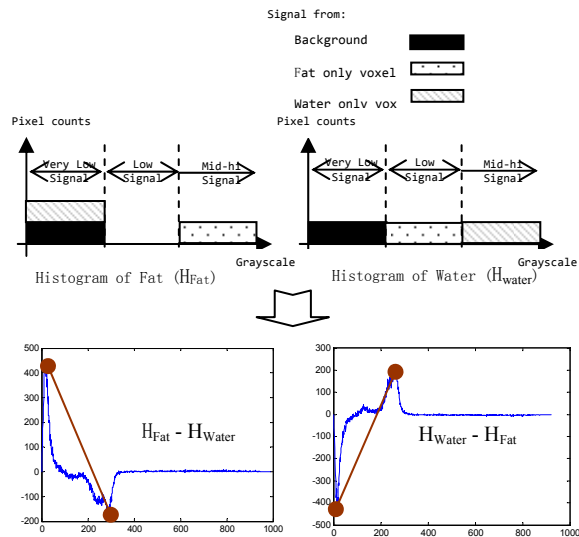


Fig 1 Due to spectral distribution, Water image and Fat image would have different patterns in histogram. A histogram subtraction can be used to identify this pattern, and afterwards, identify the property of the image.

neurology and soft-tissues.

Visual inspection is used to verify the results. With all test cases, intermingling between tissues is successfully corrected. Water/fat recognition also worked well in most body parts except for the breast. In breast imaging, artifacts from the heart contribute to separation failure in the thorax, which leads to unstable recognition.

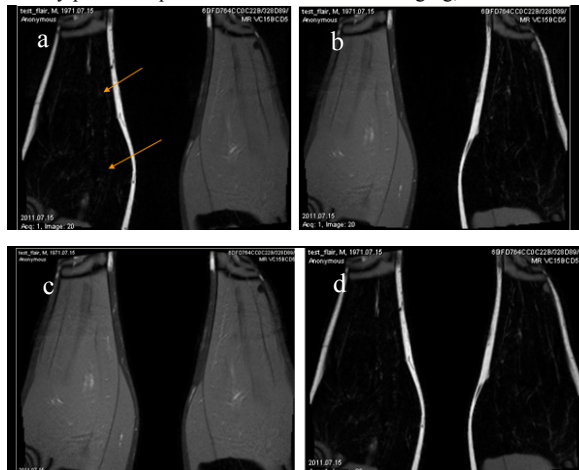


Fig 2 (a, b) In the original Dixon images, a water/fat intermingling happens between two calves. (c, d) The image are adjusted after histogram based correction. The method is robust enough with existence of minor artifacts at corner.

However, it does not possess the intrinsic phase information for water/fat for archiving and inline composing for whole body exams.

Reference: [1] Xiang QS. MRM 2006;56(3):572–84. [2] Ahmada M, Liu Y etc.al JMRI 28 (2010) 427–433 [3] T. Romu, O. Dahlqvist Leinhard etc.al Proc. ISMRM. 19 (2011) 2711 [4] Eggers. H. MRM 65 (2011) 96 - 107

Methods The Dixon separation is performed on a 2-Point method with echoes positioned at 0° and 180° . For any single object in the imaging volume, phase information is consistent in both in-plane and through-plane direction, as 3D region-growing is used. Here, water/fat images at the same slice position are denoted as I_A and I_B .

To correct signal intermingling between body parts, following method is implemented:

1. In the DICOM image series, a 3D image mask is first created on the in-phase image ($I_A + I_B$) with Otsu's method. Morphological image operations, such as image open and image fill, are then performed to remove noises and holes.
2. An image erode is subsequently applied until each area of the mask becomes a single point; those points are labeled with numbers; the labeled points are re-expanded back into distinctive areas with a region growing algorithm, thereby labeling each non-connected tissue with a mask of unique label k .
3. For each volume k , the histograms of the water & fat images (H_{Ak} , H_{Bk}), as well as $H_{Ak} - H_{Bk}$, are calculated.
4. A labeled volume with the largest number of voxels is set as the reference (k_r).
5. For each k , the dot product of vectors ($H_{Ak} - H_{Bk}$) and ($H_{Akr} - H_{Bkr}$) is calculated.
6. If the dot product is negative, the voxels are swapped in volume k between I_A and I_B .
7. Steps 5 and 6 are repeated for all labeled volumes

Image property identification is also done after the correction of non-connected parts. In the subtracted histogram $H_{Akr} - H_{Bkr}$, the highest and lowest peaks are connected. If the slope of the connecting line is positive, then I_A is water image and I_B is fat image. Otherwise, I_A is water and I_B is fat.

Results The algorithm is implemented on MATLAB (MathWorks Inc, Natick, MA, USA). DICOM images from 50 sets are used to test the intermingle-correction algorithm. Those images are acquired across different field strengths (0.35T, 1.5T, 3T, Siemens AG, Erlangen, Germany), different contrasts (T1w, T2w and PDw) and different sequence types (GRE and TSE). Examined body parts include the thighs, calves, and feet. To test the method's robustness, two sets of images with minor separation failure are also tested. (Fig. 2)

In addition, a second set of images is acquired to test the water/fat identification algorithm. The test set is also extended to images of other body parts often examined by MRI in orthopedics,

Discussion In most commercially available Dixon methods, water and fat signals are considered as single peaks in the frequency domain. The single peak assumption is true for water. However, there are multiple peaks for fat spectrum, the major peak being used for Dixon water/fat decomposition. Signals from other fat peaks are divided into both fat and water images according their spectral distances from their respective major fat or single water peaks. Therefore, a water-only voxel will have no signal in a fat image, but a fat-only voxel will leave non-zero signal intensity on water image.

By assuming that any body region contains both fat-only voxels and water-only voxels, we can design an image identity recognition method based on an image histogram. In the histogram, background noise will always have the lowest signal intensity, as will a pure water voxel in a fat image. As described above, fat signal will have low signal intensity in water image. Fat and water voxels will have mid-to-high signal intensity in the fat and water images, respectively. Fat-water-mixture tissue will always have mid-to-high signal intensity in both images.

By subtracting the fat image histogram from the water image histogram, we will have a fixed pattern, which shows a positive peak on very low signal and a negative peak in low signal. On the other hand, a subtraction of water by fat will lead to a pattern of opposite sign. (Fig 1) Based on this observation, an assumption is made that for every image there should be at least one region that is pure water or pure fat. Empirically, this assumption can be true for all known MR applications. With this assumption, a water/fat classification can be achieved by examining these patterns.

Conclusion Symmetrically acquired Dixon technique provides the optimal SNR and maximum water/fat angular difference [4], which increases the reliability of Dixon algorithm. Thus, an automatic intermingle correction and annotation would be beneficial