Novel Variable Voxel Intensity Correction Scheme and Application to Breast Imaging

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Introduction. High-density surface coil arrays have been used for attaining highly accelerated, high-resolution images for brain, breast and cardiac MRI studies [1,2]. Due to the layout and size of the coil elements, these arrays usually exhibit sensitivity variations across the field of view. Several intensity correction schemes have been investigated in literature, and many of these algorithms significantly change the spatial noise profile [3,4]. Especially, in cases with large coil sensitivity variations, these corrections can obscure the overall image quality. In this study, we introduce a novel variable voxel size intensity correction method that reduces intensity variations across the image while keeping the desired noise profile. This is a new approach for intensity correction as it involves lowering spatial resolution in low sensitivity areas in order to gain SNR. The algorithm is retrospective so it does not fully recover the potential SNR, but the SNR gain is adequate for intensity correction.

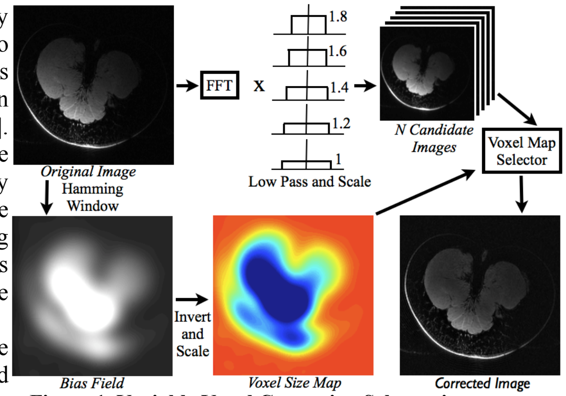

Figure 1. Variable Voxel Correction Schematic.

Methods. We demonstrate the process for this algorithm in a grapefruit phantom (Figure 1). We assumed that the coil intensity profile is a slowly varying spatial function and approximated this bias field using a hamming window low-pass filter on the original image data. We normalized this bias field and created a "voxel size" map where larger voxel sizes correspond to regions of low intensity of the bias field. For this example, we also threshold this map to ensure that no correction would be applied (voxel size = 1x) for regions of the bias field with intensities greater than 50% of the maximum intensity. We passed the original dataset individually through *N* scaled low-pass filters of varying bandwidths to achieve the desired resolution in the voxel size map. In the final corrected dataset, we chose the appropriate dataset for each voxel based on the voxel size map. We have made this tool publicly available as a plug-in (Variable_Voxel) for an open source image viewing software, Osirix. We have implemented the variable voxel correction as a 2D technique, but it can be easily extended to 3D. The algorithm is not computationally intensive, as it requires only $N+2$ FFTs.

For *in vivo* breast imaging, we compare this novel technique to two commercially available techniques: PURE (Phased array UnifoRmity Enhancement) and SCIC (Surface Coil Intensity Correction) [GE Healthcare]. PURE corrects field inhomogeneities using a low-resolution proton density weighted calibration scan. SCIC utilizes statistics from the actual image for inhomogeneity correction and does not require a calibration scan.

We scanned two subjects with suspicious lesions and three healthy volunteers, utilizing a 3D spoiled gradient recalled echo (SPGR) sequence with a water-only RF excitation. We performed all imaging experiments on a 3.0T GE MR750 scanner using a custom-fitted 16-channel receive-only breast array. We used the following parameters: axial scan plane, 0.8 x 0.8 x 0.6 mm^3 resolution and 6:51 scan time (no parallel imaging). We windowed all images to the same level relative to the maximum intensity in each image.

Results. The results from one volunteer are shown in Figure 2. Each technique shows improved signal uniformity in the breasts. Using the correction techniques, the glandular structures at the posterior of the breast become more iso-intense with the anterior of the breast. However, the PURE algorithm shows noise amplification at the background and between the breasts (see zoomed portion), while the variable voxel technique minimizes this added noise at the expense of spatial resolution in these areas. The SCIC image is less noisy when compared to PURE, but SCIC has poorer visualization of some areas of the chest wall (see arrow) in comparison to the other two techniques. Figure 2e) shows the increase in voxel volume with reference to the original image.

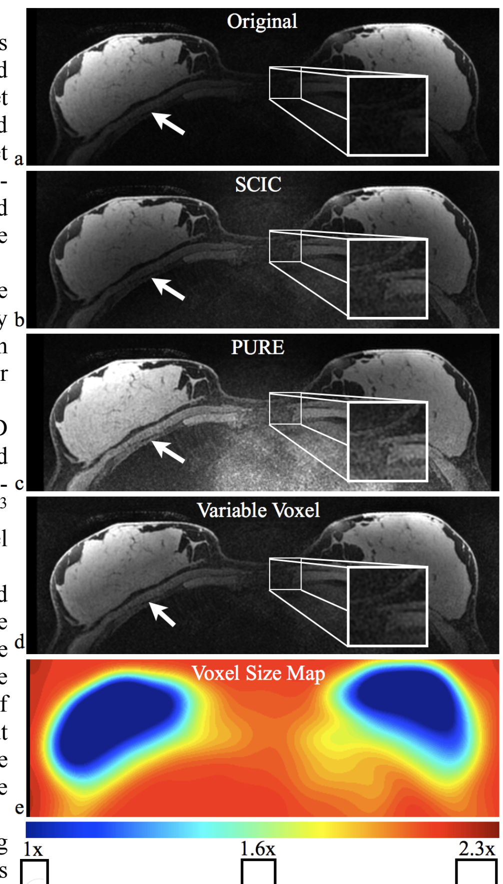

Figure 2. T_1W Axial Images of Healthy Volunteer. We windowed images a) - d) at the same level relative to the brightest voxel in each image. SCIC shows subpar visualization of the chest wall in some areas (see arrow), and there is noticeable noise amplification between the breasts using PURE (see zoomed-in portion). The variable voxel approach provides clear visualization of the chest wall and breast, while minimizes the noise at the expense of reduced spatial resolution in peripheral areas.

Discussion. We have demonstrated the variable voxel correction method as a tool for reducing intensity variations across surface coil images. The correction algorithm is conservative in terms of increases in voxel volume, and we threshold the voxel size map to minimize the loss of detail in the breast. We acknowledge that averaging voxels in post-processing results in less SNR gain (square-root of the final voxel size divided by the original voxel size) than acquiring the image with the intended voxel size. Other alternatives may be used for the voxel size map. Further studies need to be performed to evaluate the utility of this algorithm in a clinical setting.

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References. [1] Wiggins et al. MRM 2006; 16:216. [2] Wintersperger et al. JMRI 2006; 23:222. [3] Brey et al. Med. Phys. 1987; 15:241. [4] Lin et al. Hum Brain Map 2003; 19:96.