Model-free spatial intensity non-uniformity correction algorithm for MR images

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Purpose

MRI images can contain intensity inhomogeneity in space because of various reasons. Recent progress in MRI technologies such as multi reception/transmission of RF and ultra-high-field MRI systems has made this problem even more serious. Although many types of algorithms [1-3] have been proposed and evaluated to deal with the problem, so far there has been no perfect solution. Our goal is to develop a robust algorithm to correct intensity inhomogeneity of MRI signals without relying on additional scans.

Method

For each voxel in a 2D or 3D dataset, we first defined a small local region, with the voxel being in the center of the region, then searched for some statistical value in the region, and then assigned this value to the voxel. In general, this statistical value was the maximum signal intensity in the local region, which works satisfactorily for the data that does not contain any sharp intensity peak such as the signal around a blood vessel. In the presence of sharp intensity peaks, this statistical value could be lowered to the 90 percentile of the voxel values. After this value was determined for all voxels, a map generated using these statistical values was smoothed with spatial averaging kernel. The corrected image was obtained by dividing the original inhomogeneous image by the smoothed image as a denominator. The test data was acquired with a 4 Tesla whole-body MRI scanner (Agilent Technologies, Santa Clara, CA, USA). Other intensity correction algorithms, N3[1], SPM8[2] and the image division method[3] with the additional scan were also tested for the comparison.

Results

Sets of anatomical images (obtained using a T1-weighted 3D MPRAGE pulse sequence) before and after the correction are shown in the Fig. 1 (top). The matrix size was 256x256x180 and the voxel resolution was isotropic 1 mm^3. The original images were acquired with 16 receive coils and the sum-of-squares were calculated to unify images from individual coils. The local region for each voxel (i.e., center voxel) in this example was defined by the radius from the center voxel (r<7 mm). For all voxels, 90 percentiles of maximum intensity values were taken from respective local regions. The smoothing kernel size was 8 mm in radius. Then the signal outside of the head was removed with appropriate spatial masking. As can be seen in the Fig. 1 (top-right), the intensity inhomogeneity was well corrected. The intensity profile along the green line on the image was shown in the Fig. 1 (bottom). Then we carefully chose the white matter voxels conservatively and calculated the signal's standard deviation (SD) over the selected voxels. The ratio between the SD and the average was shown in percentage in Fig. 2. It shows that our method gave the most flattened white matter images. We have also applied this algorithm to other types of MRI data, e.g., T2*-weighted images and MR venograms, and have obtained equally satisfactory results.

Summary

We have demonstrated that our newly proposed algorithm is very robust and corrects MRI images with inhomogeneous intensity satisfactorily. A big advantage is that the algorithm doesn't require any additional scans or information other than original MRI images themselves. The algorithm can be applied to correcting images of any dimensions (i.e., 1D, 2D or 3D). The proposed algorithm can also be easily applied to other types of medical and non-medical images.

References

[1] J. G. Sled et al., IEEE Trans. on Medical Imaging 1998, 17(1): 87–97
[2] J. Ashburner and K. Friston, NeuroImage 1998, 7(4):S107
[3] Van de Moortele PF et al., NeuroImage 2009, 46(2):432-46

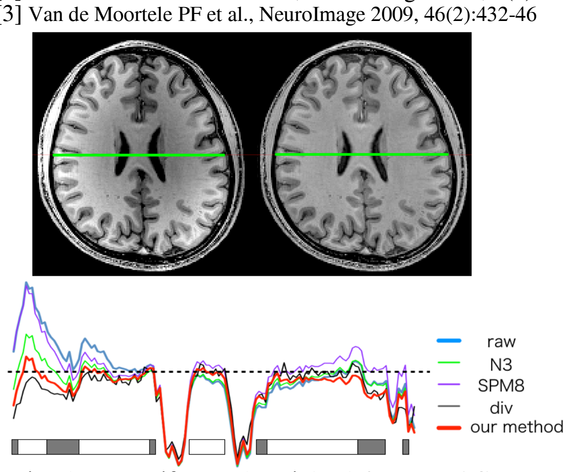

Fig. 1 Non-uniform T1 weighted 3D MPRAGE image (top-left) was corrected with our algorithm (top-right). The intensity profiles along the green line on the image was shown in the bottom. The results corrected by the other algorithm were overlaid. The bottom bars indicate the gray and

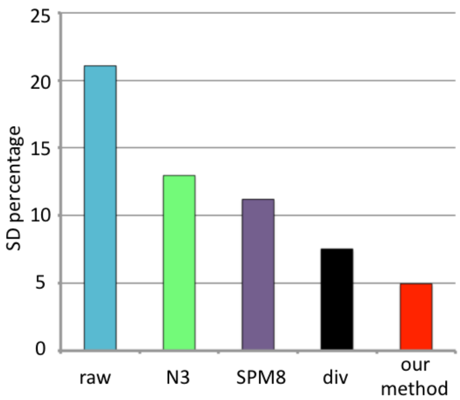

Fig. 2 The intensity flatness of the white matter cortex was evaluated. The white matter cortex volumes were carefully selected and the SD over the voxels was calculated for the results.