Optimization of the Homomorphic Filter for Bias Field Correction

V. Jellus[1], B. Kiefer[1]

[1]Siemens Medical Solutions, Erlangen, Germany

Introduction

Radiofrequency field inhomogeneity in magnetic resonance imaging is a desired feature connected with the use of surface coils, which increases signal to noise ratio and makes parallel imaging possible in many different implementations, e.g., SENSE or GRAPPA. As a consequence the intensity of the reconstructed images is also inhomogeneous. Many techniques have been developed for reducing this unwanted influence. Some of them use *a priori* information on the geometry of the receiving coils, other ones use adjustment measurements comparing low resolution images from the body coil, which is supposed to be homogeneous enough, with the images from the surface coils. The resulting information is used to normalize the full resolution images. All these techniques can compensate only for RF. field inhomogeneity of the receiving coils. This is usually sufficient for systems working at 1.5T and lower. Currently, with the more common use of systems working at 3T and higher, the homogeneity of the transmitter RF. field is of increasing importance. It can be impaired by dielectric resonances to unacceptable levels. Measure of the influence is dependent on many parameters like geometry of the sample and its conductivity, sequence parameters and so on. This inhomogeneity generally cannot be compensated by calibration techniques. There are some other techniques which can handle transmitter RF. field inhomogeneity mostly based on the information inherent in the image itself. One of them is the homomorphic filter [1,2]. It is based on the fact that influence of the inhomogeneity is multiplicative and inhomogeneity has only low frequency components. Thus it can be easily filtered out by low pass filter from the spectrum of the logarithm of the image. One of the problems when used in MRI is that the MR image can involve areas with very low or zero signal intensity. This causes false information for the homomorphic filter and insufficient homogeneity of the resulting image. The technique presented here can decrease this problem by replacing background noise by artificial signal.

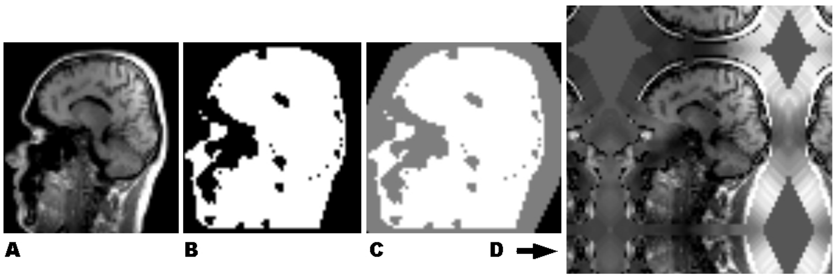

Fig.1 Creation of the artificial input image for homomorphic filter: **A** original image with low resolution, **B** mask created by thresholding and erosion, **C** mask with marked pixels (grey color), that have to be replaced, **D** resulting input image for homomorphic filter after calculation of marked pixels and after mirroring along borders.

Material and Methods

The new technique can be split into the following steps: 1) Decreasing image resolution – this increases signal to noise ratio and improves performance. 2) Detecting areas with low signal intensity by thresholding and removing isolated pixels. 3) Removal of pixels with partial volume effect using erosion. 4) Replacing pixel values in detected areas by mean value of N neighbour pixels ($N \sim 10 – 100$) that have signal intensity high enough. This can be done for all detected pixels or only to such within some distance from the object. 5) Mirroring some part of the image to the outside to decrease problem with sharp signal changes at borders. 6) Application of standard homomorphic filter on this new artificial low resolution image. 7) Ratio of the filtered image and the input artificial image gives the correction function. 8) Interpolation of the correction function from the central part with low resolution (corresponding to the unmirrored image) to full resolution and multiplication with the high resolution image. The result is the corrected image. The new technique has been implemented both in a two dim. and three dim. version. The three dim. version is used not only for 3D measurements but also for multi slice measurements where number of slices is greater than a few (typically four).

Results

The modified homomorphic filter has been tested on the 3T Siemens Magnetom Trio and on the 1.5T Siemens Magnetom Avanto for many body regions and different applications. It has been found that different anatomical regions and applications require different parameters for creation of the artificial image and for homomorphic filter itself. Fig.2 shows some examples of the filter use.

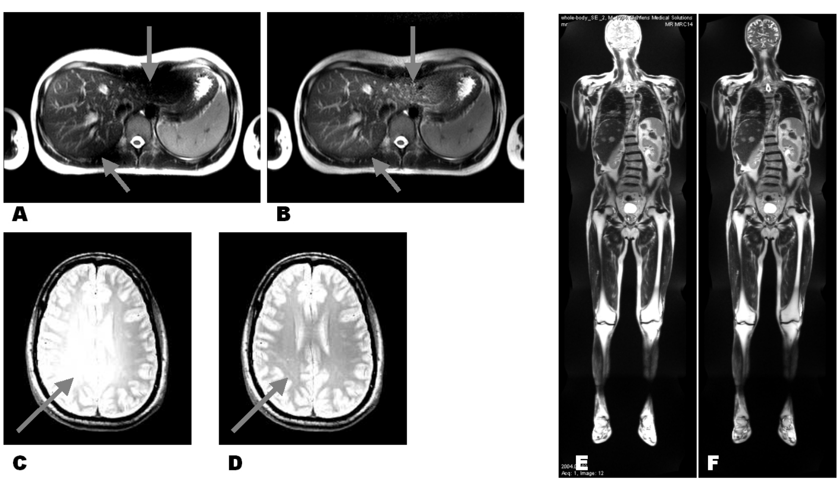

Fig.2 Examples for the use of the modified homomorphic filter. 3T abdomen image: **A** original and **B** normalized, 3T head image: **C** original and **D** normalized, 1.5T composed whole body image acquired at 5 table positions with matrix coils: **E** original and **F** normalized. The original 3T images were already normalized by standard techniques before the application of the homomorphic filter . This is not necessary, but it shows the limits of standard approaches.

Conclusion

Our modification of the homomorphic filter is more robust than standard implementations, especially for images involving areas with low signal intensity. Although originally developed for addressing problems with dielectric resonances at 3T and higher field strengths, some other applications have been found, where it can increase image quality (whole body measurements using different coils for separate regions and some others). It can be combined with some other measures for decreasing dielectric resonances like with the use of dielectric pads [3]. Although the modified homomorphic filter cannot be considered as a general purpose tool, it can improve image quality in many situations.

References

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