

# New Calculation Method of Pixel Shift Map on PSF Mapping Technique: A Study on 7T MRI

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## INTRODUCTION

A prominent EPI artifact is geometric distortion due to strong magnetic field inhomogeneity and susceptibility. A number of different approaches have been proposed for the distortion correction and one of them is the point spread function (PSF) mapping method[1-3]. Previous PSF mapping method, which was implemented by Zaitsev *et al.*[3] used GE (Gradient Echo) StdDev (standard deviation) image as a base and produced a “mask” to extrapolate pixel shift map. In the case of human in-vivo imaging, the flow artifacts occur along phase encoding direction. Especially in the case of long TE at higher magnetic field imaging, flow artifacts strongly contaminate the acquired image. B1 field inhomogeneity also affects the result of mask calculation. These artifacts could cause errors in the result of mask. And the mask image result will be affected by setting of parameters. A mask can be used to extrapolate the pixel shift map. If the mask has erroneous artifact, the extrapolated shift map will eventually be affected by the error as well, and therefore, the distortion correction will be erroneous as well. Figure.1(b) shows a GE StdDev image which used for mask calculation, this image, however, contains flow artifact and intensity inhomogeneity. Then we applied two different threshold values and get two mask images (Fig.1(d)). With these two threshold values, two masks will be obtained and the flow artifact as well as setting of the parameters (i.e. threshold value) can affect the result of mask. And the extrapolated shift map(Fig.1(f)) which resulting shift maps with extrapolation eventually have error. Consequently corrected images(Fig.1(g)) will also have errors induced by mask errors and flow artifacts.

## MATERIALS AND METHODS

PSF and EPI data were acquired at 7 Tesla MRI. A new mask calculation method we proposed is strictly based on calculation using a 2D PSF data based, not based on the GE StdDev image as previously used. This technique, therefore, not threshold setting dependant and can be free from the arbitrary settings and the errors such as flow artifacts. Thus, we can implement automatic mask procedure. Moreover, if we use 2D PSF data based mask, the extrapolation procedure is not required. The new proposed mask method starts from y-s plane 2D PSF data shown in Fig. 2(a). Before the differentiation an anisotropic diffusion filter was applied. The filtered 2D PSF data, shown in Fig.2.(b) is differentiated and peak to peak detection to set the width of the mask. The differential result along the red solid line of Fig.2(b) is shown in Fig.2(d) displaying the positive maximum as well as negative maximum values. These min-max values are used to eliminate the flow artifact, signal intensity of such flow artifact dependant lines are usually smaller than that of main line. Maximum to negative maximum value is set as width of 2D PSF mask (between red dot lines). This result of the proposed method using differentiation technique is shown in Fig. 2(c). Doing this along the y-direction and every frequency encoding step generates whole 3D PSF mask. As mentioned, the benefit of using the s-direction differentiation is to select main 2D PSF signal without ghost that occur by flow. Along the s-direction, the main 2D PSF signal is larger than the flow induced ghost signal. So, 2D PSF data always have positive and negative maximum value around the border of main signal. Then we can eliminate flow artifacts using the proposed mask method. In the low signal area like the both end of 2D PSF data, set the fixed width mask along diagonal direction.

## RESULTS AND DISCUSSION

Fig.3 demonstrates the result of human in-vivo brain image with a size 1.4mm isotropic voxel for the comparison of two approaches, i.e., image based mask with extrapolation and the new proposed mask. In Fig.3(b) shows a set of original distorted EPI images (Matrix = 160x160, Partial TR = 3000 ms, TE = 39 ms) while Fig. 3(a) is GE StdDev image. This GE StdDev image has flow artifact along phase direction. The images in Fig. 3(c-d) are the raw shift map and corrected images by application of the GE StdDev image based mask and extrapolation, respectively. Fig. 3(e-f) images are the raw shift map and corrected images i.e. 2D PSF data based mask without extrapolation, respectively. As shown, there are flow artifacts induced by the CSF in the shift maps (see black arrows in Fig.3(c)) and as seen in Fig. 3(d), large flow dependant artifacts are visible. Shift maps based on proposed mask is shown in Fig.3(e) and resulting images corrected by the new proposed shift maps are shown in Fig.3(f). As shown complete elimination of the artifact are seen when correction was made by the proposed mask method.

## CONCLUSION

This method is capable of making automatic mask calculation procedure, along with the advantage of eliminating flow induced ghost artifact all together.

**REFERENCES** [1] Robson MD, et al., *MRM*, 1997; **38**:733-740 [2] Stevick JW, et al., *MRM*, 2008; **59**:598-606 [3] M. Zaitsev, et al., *MRM*, 2004; **52**:1156-1166

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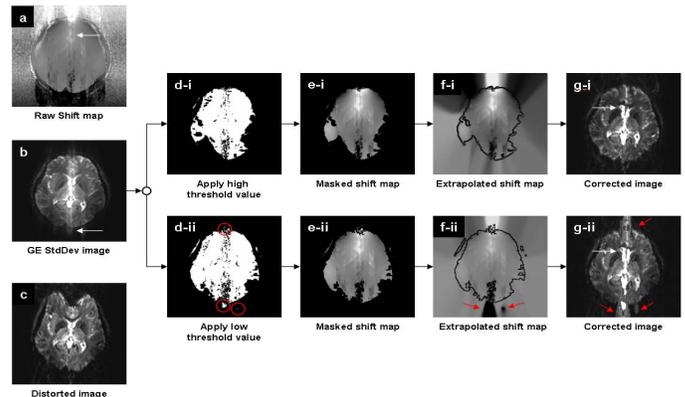


Fig.1. Results of PSF geometric distortion corrected image affected by mask results. (a) Raw pixel shift map. Flow artifact exists in the object region (see the white arrow). (b) GE StdDev image. (c) Uncorrected EPI image. (d) Calculated mask images with different threshold values. (e) Masked shift map. (f) Extrapolated shift maps, these images have errors outside brain (see red arrows in (f-ii)). Mask boundaries are drawn with black bold line. (g) Geometric distortion corrected image. There are errors induced by mask miscalculation (red arrows in (g-ii)) and flow artifacts (white arrows in both (g-i) and (g-ii)).

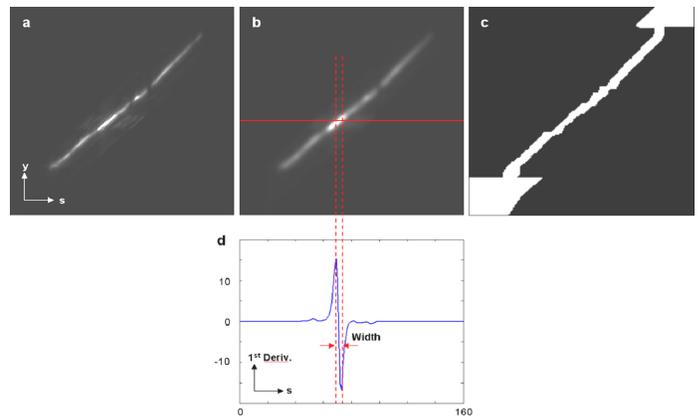


Fig.2. Procedure of proposed mask calculation method based on 2D PSF data. (a) s-y plane 2D PSF data, picked from the transformed 3D k-space. (b) Filtered 2D PSF image. (c) 2D PSF mask image (d) 1<sup>st</sup> derivative plot along red bold line in (b).

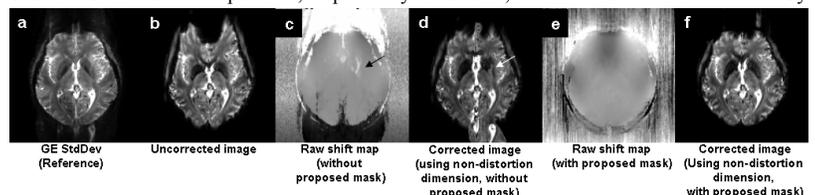


Fig.3. Results of distortion correction using proposed mask method. (a) GE StdDev image. This image is based on image base mask. (b) Uncorrected EPI images. (c) Raw shift map calculated without applying proposed mask. Flow artifacts exist in the raw shift map (see black arrows). (d) Distortion correction image used raw shift map shown in (c). Before correction, raw shift map was extrapolated with image based mask. (e) Raw shift map calculated by proposed mask method. Flow artifacts are eliminated by proposed mask. (f) Distortion correction image used raw shift map shown in (e). Correction is applied along non-distortion direction.