Multi-stational Whole-body MR Imaging with Geometric and Intensity Distortion Correction

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Introduction

Whole body MR imaging has become very popular in recent years. There are two types of the techniques for the whole body MR imaging, continuous moving table (CMT) imaging [1] and multi-stational (MS) imaging [2]. In MS imaging, coronal or sagittal images are acquired at different stations in the head to feet (HF) direction, while stepping the table motion, and then the images are joined together to formulate a whole image. MS imaging has some advantages, compared to CMT imaging, that all of the conventional pulse sequences can be used and that the conventional table of MRI equipment does not need to be improved.

However, in MS imaging, the images are not smoothly joined together if the images are not acquired in small field of view (FOV). This is because MR images have geometric and intensity distortions on the periphery of large FOV. These distortions are mainly caused by inhomogeneity of the coil sensitivity distribution, magnetic field inhomogeneity, and non-linearity of the magnetic field gradients.

In this study, we propose a method for obtaining whole body images by smoothly joining MS images. Both geometric and intensity distortions are corrected using image intensity values, not hardware distortion information. Images acquired in large FOV are smoothly joined together using this method and the imaging time can be shortened because the number of stations is reduced. More than 300 sets of MS images of human bodies, obtained by various pulse sequences, were tested to evaluate the proposed method, and subsequently we were able to obtain good results from all of the images.

Method

Coronal or sagittal images are acquired at different stations, such that two adjacent images overlap about 10% of the FOV. Geometric and intensity distortions are corrected using intensity values of the overlapping areas of the two images to be joined together. Let $I_A(x,y)$ and $I_B(x,y)$ denote the intensity values of images A and B that are to be joined and $s_A(x,y)$ and $s_B(x,y)$ denote the intensity values in the overlapping areas of images A and B. Figure 1 is a flow chart for the correction process. **Step 1:** Intensity values of image B are changed so that the overlapping areas are approximately equal in intensity levels by the following equation: $s_B{}^c(x,y) = \bar{s}_A(x,y)/\bar{s}_B(x,y)\cdot s_B(x,y)$, where $\bar{s}$ is a mean value of s. **Step 2:** Spatial resolution of s_A and $s_B{}^c$ are reduced to 1/4 and the resulting images are denoted as $s_A{}^s(x,y)$ and $s_B{}^{cs}(x,y)$. The optical flow velocity vector field $\mathbf{v}_{AB}(x,y)$ is then calculated from $s_A{}^s$ and $s_B{}^{cs}$ using the spatio-temporal derivative method. In the calculation of the optical flow vectors, the two images are considered a movie with two frames ($s_A{}^s$ is the first frame and $s_B{}^{cs}$ is the second.) such that the interval between $s_A{}^s$ and $s_B{}^{cs}$ is a unit of time or one second. Each optical flow vector describes a distortion vector from $s_A{}^s$ toward $s_B{}^{cs}$ at each pixel of $s_A{}^s$. By employing the same method, $\mathbf{v}_{BA}$, a distortion vector from $s_B{}^{cs}$ toward $s_A{}^s$, is acquired. Image warp maps (Fig. 2) are then built from vector fields $\mathbf{v}_{AB}$ and $\mathbf{v}_{BA}$ by homogeneous function interpolation and s_A and s_B are spatially transformed to $s_A{}^w$ and $s_B{}^w$ by the maps. **Step 3:** $s_A{}^w$ and $s_B{}^w$ are composed using equation $s_{AB} = \sqrt{(w_A s_A{}^w)^2 + (w_B s_B{}^w)^2}$ where w_A and w_B decrease from one to zero toward the edge of the FOV in the HF direction and are determined so that $\bar{s}_{AB}$ is approximately equal to the mean value of the intensity in the regions adjacent to s_{AB}. **Step 4:** Uneven intensity that remains in the HF direction is corrected using the interpolation curve described by the mean intensity values of each station image.

Results and Discussion

More than 300 sets of MS images of human bodies were composed using the proposed method. The images were multi-sliced images obtained on a 0.7T open system, by pulse sequences of spin-echo (SE), gradient echo, fast SE (FSE), and short inversion time inversion recovery, and MIP images obtained by contrast-enhanced (CE) MR angiography. In these images, the FOV was from 320 to 420 mm and the overlapping length was from 20 to 150 mm. All of the MS images were well composed with the correction of the geometric and intensity distortions. The processing time was about one second per slice on a Windows PC with a 3-GHz Xeon CPU.

Figure 3 shows one of the MS FSE images and one of the MS CE-MRA images, both of which are composed from four separate station images. In the MS FSE image that was obtained with a FOV of 320 mm in each station image and an overlapping length of 20 mm, white marks are located at the boundaries of the overlapping areas. It is difficult to indicate where the overlapping areas are in the resulting images, if there are no marks located.

Conclusion

We have described a method for the correction of geometric and intensity distortions in MS image composition. We used the optical flow method to build an image warp map and correct the geometric distortions. The resulting images show that smoothly joined whole body images can be obtained by MS imaging with the proposed method.

References

[1] Kruger DG, et al., MRM, **47**, 224, 2002.
[2] Meaney JFM, et al., Radiology, **211**, 59, 1999.

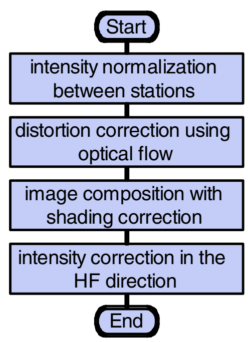

Fig. 1: Flow chart for proposed image joining method.

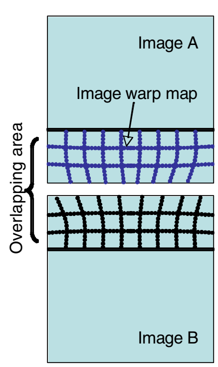

Fig. 2: Distortion correction using image warp maps in overlapping areas.

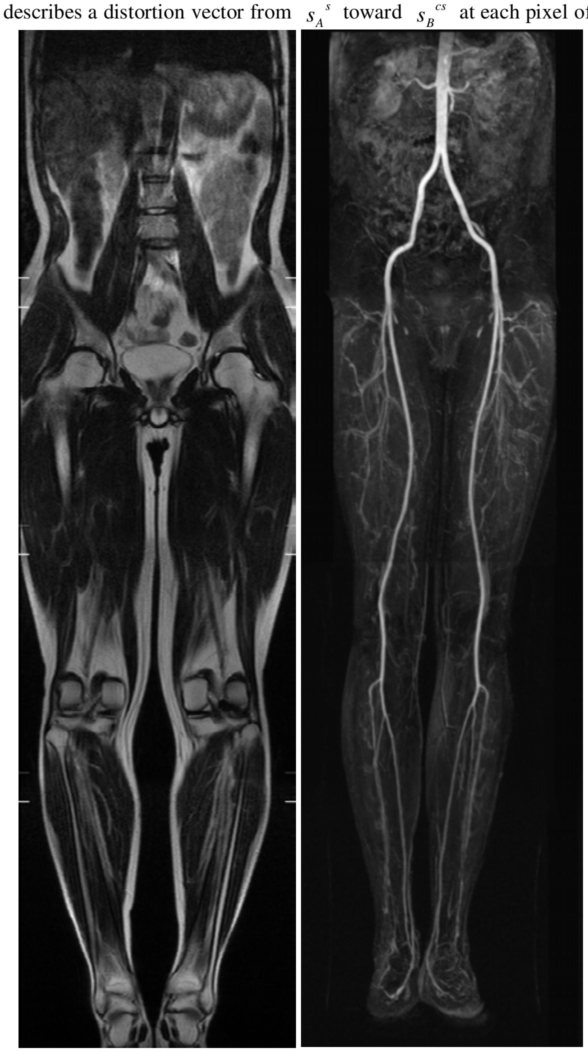

Fig. 3: MS images joined using proposed method: FSE (left) and CE-MRA (right).