Stability Evaluation of Geometric Distortion Correction in Multi-station Whole-body MR Imaging

Y. Taniguchi[1], H. Nagao[2], T. Abe[2], T. Takahashi[2], and H. Ochi[1]
[1]Central Research Laboratory, Hitachi, Ltd., Kokubunji, Tokyo, Japan, [2]R&D Center, Hitachi Medical Corporation, Kashiwa, Chiba, Japan

Introduction

Whole body MR imaging has become very popular in recent years. There are two types of techniques for whole body MR imaging: continuously moving table (CMT) imaging [1] and multi-station (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 form a whole image. MS imaging has some advantages over CMT imaging in that all of the conventional pulse sequences can be used, and the conventional MRI table does not need to be improved.

To smoothly join the images in MS imaging, both the geometric and intensity distortions of the images need to be corrected because MR images have these distortions at the periphery of the field of view (FOV). A method to correct these distortions has been presented in which MS images with variations in contrast that were obtained by different sequences can be joined [3]. In this method, optical flow is calculated in the overlapping areas of two images to be joined in order to correct geometric distortions occurring due to hardware and subjects. Image intensity values are used to calculate the optical flow. Therefore, if the intensity distortion is large in each station image, the optical flow will not be obtained with high accuracy, and the images may not be joined together smoothly.

In this study, we evaluated the stability of geometric distortion correction in the presence of intensity distortion. Artificial intensity distortions are added to each station image, and the results of the distortion correction are visually evaluated. We evaluated 180 MS images. Consequently, the geometric distortion correction was confirmed to be stable enough so that the rate of joining error occurrence is only 2 or 3% even if the intensity attenuation is 40% at the corners of the FOV of each station image.

Method

Figure 1 is a flow chart for the geometric and intensity distortion correction process [3]. In this process, the image intensity levels are first normalized between stations, which improves the accuracy of the correction of geometric distortion in the next step. However, local intensity distortion in each station image is not corrected by this first step. Local intensity distortion is mainly intensity attenuation at the corners of the image. Thus, intensity attenuations like this are artificially added to each station image in order to evaluate how stable the geometric distortion correction is with respect to intensity distortion. The distributions of the two types of intensity attenuations that were evaluated are shown in Fig. 2: first and second order attenuation, in each of which the intensity attenuation is at a maximum at the corners of the FOV. The rates of attenuation were 20%, 40%, and 60%. Intensity attenuation with the rate of 40% is shown in Fig. 2.

Many MS images of various image contrasts were evaluated with the attenuations added. These images were multi-sliced images obtained on a 0.7 T open system, by pulse sequences of spin-echo (SE), gradient echo (GrE), fast SE (FSE), and short inversion time inversion recovery (STIR) FSE, and MIP images obtained by contrast-enhanced MR angiography. In these images, the FOV was from 320 to 420 mm, the overlapping length was from 20 to 145 mm, and the number of stations varied from four to seven. The number of evaluated MS images was 180 (18 sets of 10-slice MS images). Each of these MS images was joined together after the intensity attenuations were added. The joined images were evaluated visually. If any one of the structures was not well connected, the image was considered to have a joining error.

Results and Discussion

The rates of the joining error occurrence are listed in Table 1. The error rates increased to 8 or 12% when the intensity attenuation was very high, such as 60%. However, if the intensity attenuation was up to 40%, joining error hardly occurred, so that the error rate was less than a few percent. Therefore, we confirmed from this result that the correction method for geometric distortion is sufficiently stable even in the presence of intensity distortion.

Two images with joining error are shown in Fig. 3, where the artificial intensity attenuations are of the second order with a rate of 60%. A STIR-FSE MS image is at the left in the figure, and a GrE image is at the right, where ellipses indicate unconnected structures. If an error occurs in the correction of geometrical distortion, some structures will be slightly misaligned, like these images in Fig. 3. Figure 4 shows the same slices as in Fig. 3, but these images are joined together without the artificial intensity attenuation for comparison. These MS images were composed from five separate station images in which white marks are located at the boundaries of the overlapping areas. The MS STIR-FSE image was obtained with a FOV of 320 mm in each station image and an overlapping length of 45 mm. The MS GrE image was obtained with a FOV of 320 mm in each station image and an overlapping length of 70 mm. It would be difficult to see where the overlapping areas were in the resulting images, if no marks were visible.

Conclusion

We have described the stability of our joining method in the presence of intensity distortion in MS image composition. We used the optical flow method to correct the geometric distortions, and the results show that the method is sufficiently robust. This method only uses image intensity values in its correction process. Therefore, it is not necessary to use hardware distortion information, and distortion due to both hardware and subjects can be corrected.

References

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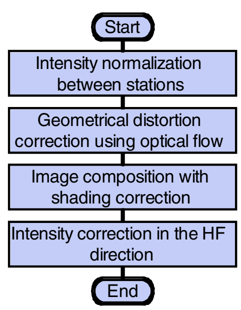

Fig. 1: Flow chart for the image joining method.

Table 1: Joining error rate in accordance with intensity attenuation at the corners of FOV.

intensity attenuation	joining error rate 1st order	2nd order
20%	0.6%	0.6%
40%	2%	3%
60%	8%	12%

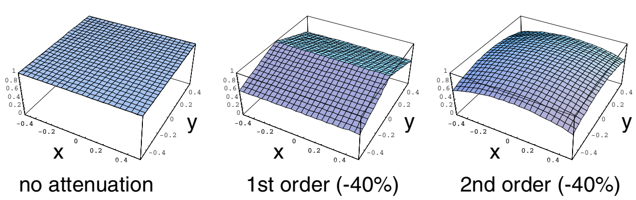

Fig. 2: Distribution of the intensity attenuation artificially added to each station image to evaluate the robustness of the spatial distortion correction. The body axis was parallel to y.

Fig. 3: Joining errors arising from the intensity attenuation of the second order with the rate of 60%: STIR-FSE (left) and GrE. (right).

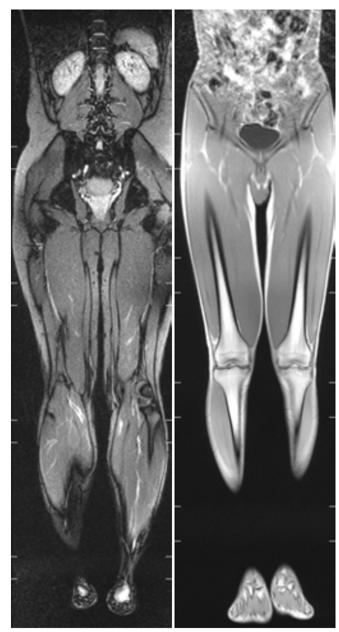

Fig. 4: Joined images without the artificial intensity attenuation: STIR-FSE (left) and GrE (right), same as Fig. 3.