Image Fusion Techniques for Integrated MR-Endoscope system

M. Matsumoto[1], Y. Shoji[1], Y. Matsuoka[2], E. Kumamoto[3], K. Kuroda[2,4], and T. Kaihara[1]

[1]Graduate School of Engineering, Kobe University, Kobe, Hyogo, Japan, [2]Molecular Imaging Research Group, Institute of Biomedical Research and Innovation, Kobe, Hyogo, Japan,

[3]Information Science and Technology Center, Kobe University, Kobe, Hyogo, Japan, [4]Graduate School of General Science and Technology, Tokai University, Hiratsuka, Kanagawa, Japan

Introduction The integrated Magnetic Resonance (MR) endoscope is a hybrid imaging modality developed for minimally invasive diagnostic and surgical procedures on digestive organs with high resolution inner structure visualization [1]. In this study, we have developed prototype image fusion software system for MR-endoscope. It is important in the image fusion to give the same distortion as the endoscope lens to the MR image. The distortion processing decided to be done to the MR image by using the Zhang's camera calibration algorithm [2]. In addition, tracking of the MR-endoscope is important for navigation and image fusion between the endoscope and MR views. Because of the limited duct capacity in the endoscope, it is preferable to use wireless type of markers, some of which have been proposed with tuned resonance circuits coupled capacitively or inductively with the catheter tracking [3]. In this study, we have developed that are capacitively coupled resonance coils used with a Gadlinium-absorbed gels for signal intensity enchancement. Since the three dimensional position and orientation of the endoscope tip in the MR coordinate system can be determined with three or more coils, automatic image fusion between the MR images and the optical endoscopic picturescan be expected.

Methods Endoscope image of porcine stomach are acquired in vivo and in vitro. MR images are obtained using inner coil which was specially developed for porcine stomach. Fast Spin Echo (FSE) with TR/TE, 300/14.4 ms; ET, 6; slice thickness, 5 mm; field of view, 80 * 80mm^2; spatial matrix, 256 * 128; and read out band width, 15.6kHz.. To match the position and orientation of MR images to endoscope image, affine coordinate transformation was applied to MR images. The optical distortion in the endoscope picture was numerically given to the MR images by approximating the distortion with a fifth-order, two-dimensional deformation function in Zhang's camera calibration algorithm [2]. First, the lens parameters were estimated by taking picture of the chessboard pattern with the endoscope, and using Zhang's algorithm. The size and the optical axis point of the object image were set by manual operation. The distortion processing was applied to the object image with estimated lens parameter. The distortion was visually confirmed by fusion it to the endoscope image.

The developed tracking marker had resonant circuit that was capacitively coupled. Three coils (5 turns) with diameter of 2 mm put together on resonance frequency 63.865MHz made for trial purpose were made, and they were installed in an arbitrary position of an acrylic pipe that imitated the endoscope. Aquacoke (Sumitomo Seika Chemicals Co., Ltd.) swelled gadolinium was put and fixed on the coils (Figure.1). An experimental coil was arranged between bags that enclosed water that likened to the stomach wall. Axial, coronal, and sagittal images were aquired by a 1.5T-MRI (Signa Twin Speed,Excite 11,GE Healthcare) with Fast Spoiled Gradient Recalled Echo (FSPGR) of following conditions; TR/TE, 20/1.3ms; slice thickness, 30, 60, 100mm; field of view, 300 * 300mm^2; spatial matrix, 256 * 128; flip Angle, 2 or 10degrees; and read out band width, 31.25kHz.

Results Figure 2 shows the developed image fusion software. Figure.3 shows a fusion image of distored images and endoscope image. (a) shows chessboard pattern image and (b) shows MR volume image of porcine stomach in vitro. Gap between distorted pattern and endoscope image (red arrow in Figure 3(a) and (b)) was very small. Figure 4 shows the MR images of marker coils (30mm in the slice thickness; axial plane). The marker coils had high luminance on the images. The marker coils were indicated by red arrows in Figure 4. Table.1 shows Contrast-to-Noise-Ratio (CNR) of the signal strength of coil and water in each image.

Discussion The developed fusion software enables to provide less contradiction fusion images of the endoscope image and the MR image. However, when the optical axis points of each image were not adjusted, misalign was occurred in fusion image. Therefore, it is important to match coordinate of endoscope with MR coordinate system correctly using tracking technique with resonance marker coils. As shown in Figure 4, the developed marker coils were projected on the MR image in high intensity. As shown in Table 1, CNRs had high values when the flip angle was small, and CNRs became small as the slice thickness becomes thick. As a result, a small flip angle and a thin slice were effective to constraint the water signal. However, the contrast of the marker coils in this experiment was considered insufficient for detecting the markers in vivo because there were many organs which have high intensity. Therefore, more sophisticated coils will be necessary to improve visibility in the future. The markers of Aquacoke swelled gadolinium put on inner coil which shown on right fusion image in Figure 2 is also used to do adjacent MR images and endoscope image. For real time tracking and fusion MR images and endoscope images for navigation, it is issue in the future to develop rapid determination of the position and orientation of endoscope and rapid generating of the fusion images.

References

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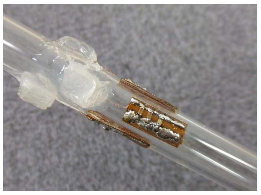

Figure 1. Test-made wireless, 5-turn marker coils of 2mm diameter, inside of which gadolinium-absorbed gel blocks are installed.

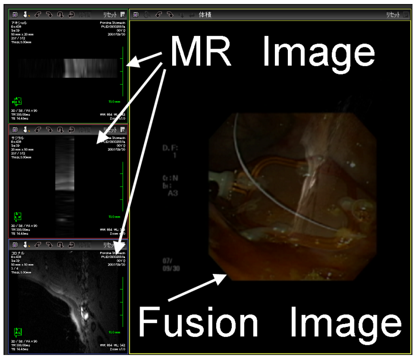

Figure 2. Prototype image fusion software for superimposing MR images on the optical endoscopic video images.

Table 1. CNR of the markers versus water in the phantom

Slice	FA	Coil	Water	CNR
30mm	2deg	57.09	32.75	6.76
	10deg	104.84	113.05	-2.42
60mm	2deg	38.03	32.60	3.39
	10deg	42.52	120.90	-46.11
100mm	2deg	20.78	32.95	-12.17
	10deg	33.13	109.75	-76.62

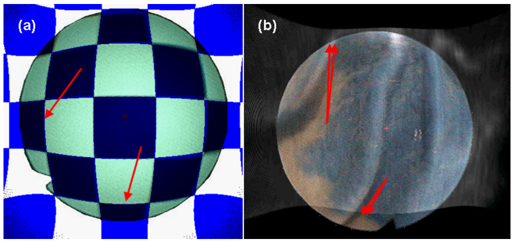

Figure 3. Numerical deformations of chessboard pattern (a) and MR volume image of a porcine stomach sample in vitro (b) superimposed with the corresponding scope views.

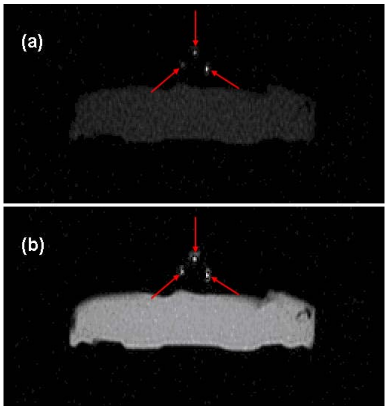

Figure 4. Appearance of the markers in the axial images of 30mm thickness with flip angles of 2 degrees (a), and 10 degrees (b) .

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