Multi Planar Reconstruction Technique for MR-endoscope System based on Scope Tip Tracking with Gradient Field Sensor

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PURPOSE An integrated MR-endoscope system can perform MR imaging during inspection and surgery with an MR-compatible flexible endoscope. Our system includes software to navigate scope location and orientation inside an MR bore and to present MR images simultaneously with the scope view. A bird's-eye view is also provided for globally viewing the target region[1, 2]. The accelerometer-based handy and effective remote control device to manipulate the software view helps endoscopists execute smooth, safe and precise endoscopy and endoscopic surgeries resulting in shortening the procedures and decreasing unnecessary stress on patients[3]. To further improve the usability, we developed the technique of real-time multi-planar reconstruction (R-MPR) using the endoscope tip as a user interface.

METHODS A tracking system (EndoScout, Robin Medical, Inc., USA) installed onto a 1.5T MR scanner (Signa EXCITE TwinSpeed, ver1.1, GE Healthcare, USA) was used to detect the location and orientation of an endoscope tip with a gradient filed sensor in the MR bore. R-MPR provides the orthogonal planes (sagittal, coronal and axial planes), and oblique planes by using real-time tracking data. In this demonstration, the log data of tracking was used. MR images of porcine stomach were acquired with T2-weighted spin echo with the following conditions: TR/TE, 3000/102ms; FOV, 24 x 24cm; slice thickness, 5mm; acquisition matrix, 256 x 256; echo train length, 20; and number of slices, 43.

First, the volume data was reconstructed by isotropic voxelization of MR images in its pixel spacing, 0.9375mm. The voxel data consisted of pixel values and location in the MR coordinate system, each pixel value was determined by linear interpolation, and the location was calculated by using pixel spacing and location of the original MR image.

Next, the orthogonal and oblique planes were reconstructed using the location, $P(x_p, y_p, z_p)$, and orientation, $\mathbf{V_t}$ and $\mathbf{V}_n$, of the endoscope tip from the generated volume data. In the orthogonal plane, the voxel closest to the location $P(x_p, y_p, z_p)$ was selected. In the each plane, all voxel data that were "$i = i_p$", "$j = j_p$" or "$k = k_p$" were detected and create the images shown in Figure 1. In oblique planes, the vertical and horizontal planes against the endoscope were reconstructed as shown in Figure 2. Location of image center in the MR coordinate system was calculated using endoscope location, normal vector, and offset. Image orientation was calculated using endoscope orientation. In the vertical plane, it was possible to rotate the image around the normal vector as a rotation axis. The index of the nearest voxel data was determined for each pixel location and the pixel value was detected. All planes were updated according to endoscope location and orientation.

The tracking data were embedded to the endoscope images as shown in Figure 3. Tracking data consisted of location P, orientation $\mathbf{V_t}$, $\mathbf{V}_n$, and status code. Each pixel had 8bits RGB channel. Therefore, the location and orientation data were divided to integers and fractions, each of which was represented by the 16 radix and stored in the specified RGB pixels. For example, $44 = 12 + 2 * 16 + 0 * 16^2 + 0 * 16^3$. Tracking status code was stored in one pixel. One tracking datum was stored in the 23 pixels. In restoration, that pixel value was converted to decimal numbers, and the integer portion adds the fractional portion.

RESULTS and DISCUSSION Figure 4 shows a three-dimensional image created with the volume data of porcine stomach, the orthogonal images, and the oblique planes reconstructed according to tracking data. Image matrix of each image was 256 x 256 and pixel size was 0.9375mm x 0.9375mm in the orthogonal planes or 0.5mm x 0.5mm in the oblique planes. These planes were updated depending on the tracking data. Pixels embedded the tracking data in a log file didn't flicker in playing images.

CONCLUSION The sagittal, axial, coronal, and oblique planes were reconstructed depending on the tracking data, that is, the scope tip location and orientation. Thus, smooth presentation of the desired region could be possible with the manipulation of the endoscope as the user interface. The developed technique to show the MR images by synchronizing the endoscope location would facilitate an intuitive operation for endoscopists. This technique with the MR-endoscope system would contribute easy and safe procedures for the endoscopy and endoscopic surgeries during MRI, and it would result in improving the reliance of them. Further, it is possible to smoothly synchronize the endoscope images and the MR images via the tracking data that is embedded in endoscope images following the operation. For the next step, the animal examination to evaluate the feasibility for this technique should be conducted.

REFERENCES

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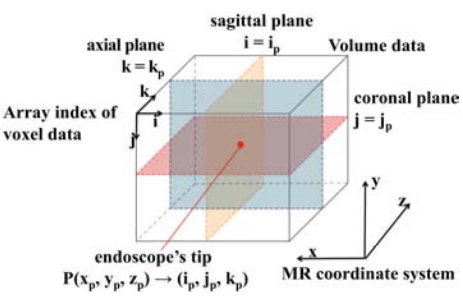


Figure 1 Reconstruction of Sagittal, coronal and axial plane by using the endoscope tip.

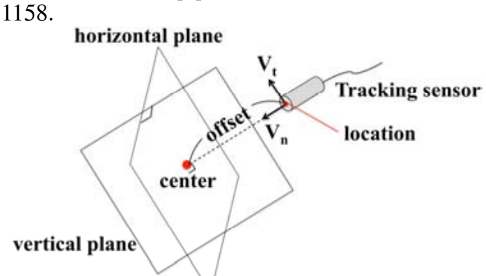


Figure 2 View of horizontal and vertical planes. The tangent and normal vector are acquired by the tracking system.

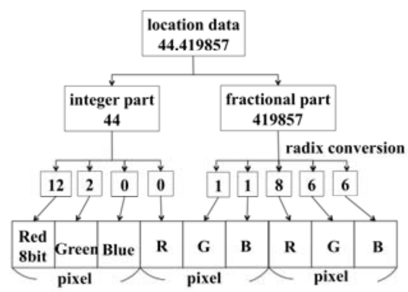
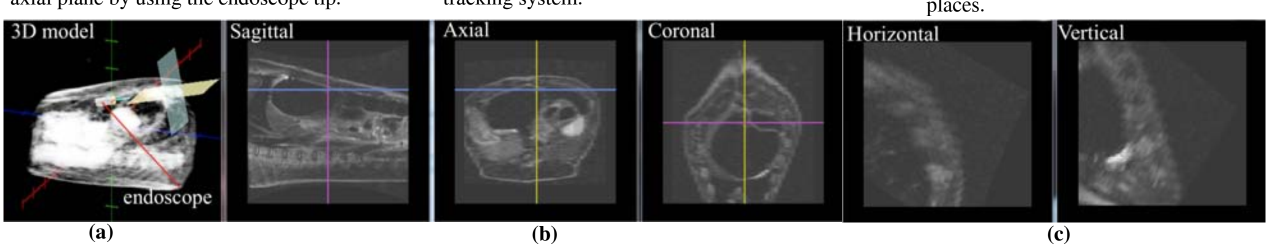


Figure 3 Example of embedding the location data to pixels. Location and orientation data are six decimal places.



(a) (b) (c)

Figure 4 Demonstration of multi planar reconstruction using the tracking data. The volume data were created by the MR images of porcine stomach. Tracking data were off line data. (a) 3-demensional model and the location of the endoscope. Yellow plane shows the location of vertical plane, and blue shows the location of horizontal. (b) Sagittal, axial and coronal plane. Blue line displays the location of coronal plane. Purple line displays the location of axial. Yellow line displays the location of sagittal. Cross points are the location of the endoscope tip in each image. (c) Horizontal and vertical plane.