Enhancement of MRI angiogram with modified MIP method

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Abstract

We have developed a 3-D image processing and display technique that include image resampling, modification of MIP, and fusion of MIP image and volumetric rendered image. This technique facilitates the visualization of the three-dimensional spatial relationship between vasculature and surrounding organs by overlapping the MIP image on the volumetric rendered image of the organ.

We applied this technique to a MR brain image data to produce an MRI angiogram that is overlapped with 3-D volume rendered image of brain. MIP technique was used to visualize the vasculature of brain, and volume rendering was used to visualize the other structures of brain. The two images are fused after adjustment of contrast and brightness levels of each image in such a way that both the vasculature and brain structure are well visualized either by selecting the maximum value of each image or by assigning different color table to each image.

The resultant image with this technique visualizes both the brain structure and vasculature simultaneously, allowing the physicians to inspect their relationship more easily. The presented technique will be useful for surgical planning for neurosurgery.

1. Introduction

MIP is a useful method that visualizes the vascular structure with the three-dimensional data set obtained with MRI or spiral CT scan. Because of the non-invasiveness of MRI, MR brain angio study is widely used either for the diagnosis of brain disease or pre-inspection of surgical trajectory in neurosurgery.

However, the MIP images visualizes the vascular structure exclusively and does not provide information of the surrounding organ. It has been sometimes necessary to inspect multiple MIP images projected at different angles in correlation with slice images in order to grasp the 3D nature of vascular structure from the MIP images. Therefore, it has been desirable to obtain MIP images with surrounding organ images overlapped as a visual aid for the understanding of the topological relationship between vasculature and the surrounding organs.

In this paper, we present a 3D display technique that combines the MIP and volumetric rendering technique to visualize the vasculature and surrounding organs simultaneously that provides better perception of 3D nature of vasculature.

2. Methods

2.1 Data Acquisition

We obtained a three dimensional data set from MRI scanner(Horizon, GE). The data set consists of two volumes of brain of the same patient ; MRA scan data(TR 52, TE 2, 1mm thickness, and 512 x 512 matrix), and standard T2 weighted axial slices(TR 4000, TE 98, 5 mm thickness, and 256x256 matrix). The image data were transferred to the PACS acquisition server via DICOM protocol, and then moved to a PC for the subsequent data processing.

We used a personal computer that has Intel Pentium Pro 200 MHz CPU and 64MB RAM, and Microsoft Windows NT 4.0 operating system. We wrote a program for the data processing and volume rendering with Microsoft Visual C++ 4.2 language.

2.2 Data Preparation

In order to facilitate the tracing procedure in both the MIP and volumetric rendering, we manipulated the data set so that the two volume data have same resolution and become isometric (have equal spatial resolution in all three dimensional directions).

First, we sub-sampled the MRA data set to 256x256 resolution to make the two volumes have same resolutions. And then, the volume data with axial slice images were interpolated in Z direction to produce 4 extra intermediate slices by using the bilinear interpolation method. Thus the slice spacing of the two data sets became identical[1]. We did not attempt to interpolate the MRA data because the field of view of data set was 250 mm, which make almost same spacing in Z direction as the that of X and Y direction.

After interpolation of slices, the centers of the two volumes were aligned. The centers of the two volumes are approximately the same in general. However, misalignment of the centers may result in disagreement of the position of organs in the two rendered images.

2.3 Volume Rendering

We used the shear-warp rendering[2] technique in volumetric rendering of the T2 weighted MRI data set. Shear-warp rendering is a ray-tracing techniques which follows a ray's path to find the pixel value, and is known as one of the most efficient volumetric rendering technique. The shear-warp rendering can produce rotated sequence of images centered at the center of the data set.

Maximum intensity projection method also tracks the path of the ray to find out the maximum of the values on the path. Since the two methods use the same sets of rays when viewed from the same direction, they can be easily integrated, as is explained in 2.4.

As an alternative to volume rendering, surface rendering may be used to visualize the shape of the organs[3]. However, surface rendering involves severe manual procedures for extracting the surfaces. On the contrary, volume rendering only requires specifying opacity transfer functions which represent density and gradient magnitude ranges of visible voxels.

Shear-warp rendering requires that the input data should be a run-length encoded, classified volume. So we converted the data set to a classified volume by specifying an opacity transfer function so that the desired portion of the volume may be visible. In some cases, the desired organ may share the same range of density and gradient magnitude with other structures.

To visualize only the desired organ, other organs should be erased manually in the 2 dimensional slices. To avoid this manual intervention, we plan to use some method to exclude some portions of the volume during rendering in the future work. As of now, the manual erasure of undesired organs is obviously inconvenient. However, the amount of work involved is less than that of specifying the boundaries for surface rendering, since the erasure may not as accurate as the specification of boundaries.

2.4 Maximum Intensity Projection

Maximum intensity projection(MIP) produces an X-ray like image by projecting the maximum of the intensities along the path of a ray. To enable producing an image viewed from the same direction as the volume rendered image, MIP is implemented by modifying the intermediate image composition stage of shear-warp rendering software.

In addition to the standard MIP, two variations were also evaluated. MIP samples voxel values at each slice along the path of a ray, and takes the maximum of the sample values as the pixel value. Normally, MIP performs nearest neighbor sampling. First variation takes bilinearly interpolated samples on a slice, and the second one takes the maximum of the four neighboring voxels.

Theoretically thinking, bilinear-interpolation is expected to perform best. However the resampling process seems to lower the maximum intensity particularly at the terminal of fine vessels. Maximum-of-the-four-neighbors generally tends to highlight the vessels by thickening the high intensity regions. However, it appears to enhance high intensity noises also.

2.5 Fusion of the 3-D Displays.

Once two image sequences are obtained, each image in a sequence is fused with corresponding one in the other sequence. MIP images are first enhanced by adjusting intensity level and contrast, and the intensity of volume rendered image is optionally lowered to avoid interfering the MIP image.

We tried two image fusion methods: with the first method, the maximum value among the two images are taken as the resultant image ; and the second method is overlapping colored intensity of the MIP image on the gray scale volume rendered image.

3. Experimental Results

Figure 1 (a) and (b) show the results of MIP and volume rendering, respectively. Figure 2 (a) and (b) show the result of the two fusion methods. Before fusing two images, the contrast of the volume rendered image is reduced to emphasize MIP results. On the contrary, the contrast of the MIP image is enhanced to suppress undesirable background. Since volume rendered image becomes to have low-contrast and low-intensity, directly taking the maximum of the two image, as shown in Figure 2 (a) shows a satisfactory result.

All important vessels are visible in the fused image, and the spatial relationship with the the other brain structures can be easily understood with the aid of volume rendered image. Figure 4 shows more enhanced view. The vessels are displayed in red color, and the volume rendered image remains the same.

4. Conclusions

We have developed a 3-D image processing and display technique that include image resampling, modification of MIP, and fusion of MIP image and volumetric rendered image. This technique has been applied to a MR brain image to produce an angiogram overlapped with 3-D volume rendered image of brain. The resultant image with this technique visualizes both the brain structure and vasculature simultaneously, allowing the physicians to inspect their relationship more easily. The presented technique will be useful for surgical planning for neurosurgery.

5. References

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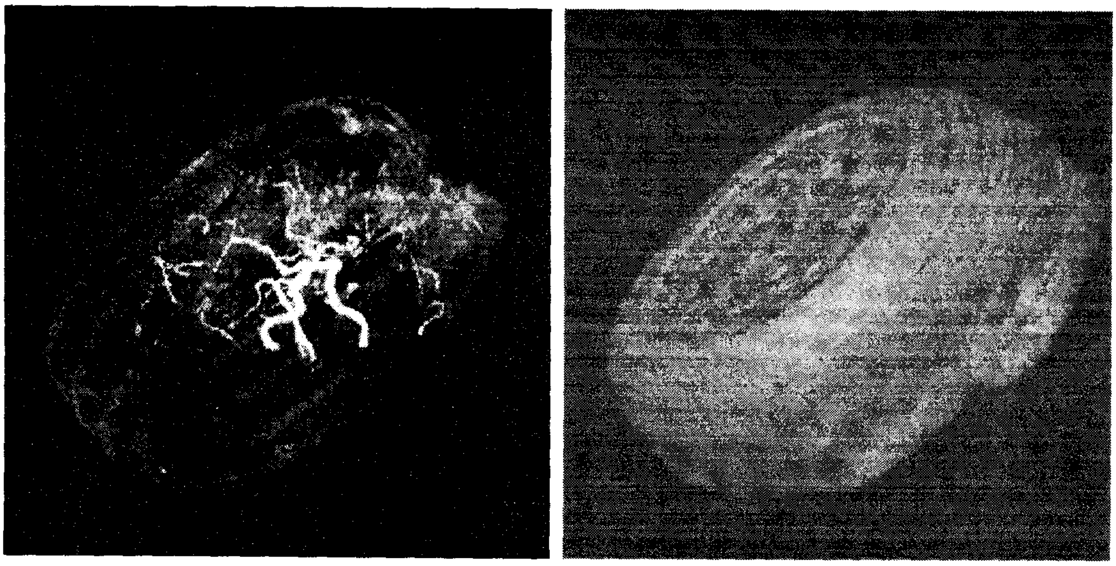

Figure 1. The results of each rendering technique ; (a) MIP image, (b) volume rendered image.

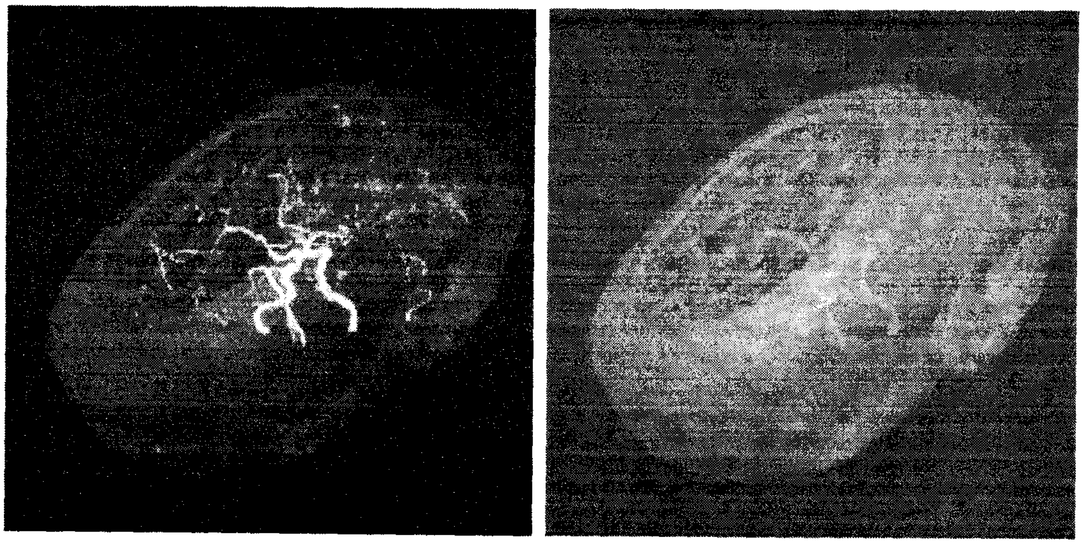

Figure 2. The results of two fusion methods ; (a) maximum of the two images,
(b) overlapping of colored MIP on the gray scale volume rendered image.