An Image Registration Method for Head CTA and MRA Images Using Mutual Inforamtion on Volumes of Interest

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Abstract—**Image registration is an important and a fundamental task in computer vision and image processing field. For example, to make a surgical plan for head operation, the surgeons should gain more detailed information from CT angiography (CTA) and MR angiography (MRA) images. And the abnormalities can be easily detected from the fusion image which is obtained from two different modalities. One of the multiple modal image registration methods is matching the CTA and MRA, by which the image of head vascular could be enhanced. In general, the procedure for fusion is completed manually. It is time-consuming and subjective. Particularly the anatomical knowledge is required as well. Therefore, the development of automatic registration methods is expected in medical fields. In this paper, we propose a method for high accurate registration, which concentrates the structure of head vascular. We use 2-D projection images and restrict volume of interests to improve the processing affection. In experiments, we performed our proposed method for registration on five sets of CTA and MRA images and a better result from our previous method is obtained.**

Keywords-component; Medical image; Image registration; Volume of interest; Mutual infomation

I. INTRODUCTION

Various medical equipment have been developed to analyze abnormalities and to cure patient's disease fast. Especially, such as computed tomography (CT), ultrasound (US) and magnetic resonance imaging (MRI) have been introduced into medical fields. These equipment can screen the patient's internal organs noninvasively. And more detailed information of the interested regions is possible to be provided immediately. Recently, many new techniques such as the registration of positron emission tomography (PET) and CT images are introduced. Radiologist can easily detect abnormalities using those different modality images. However, it might spend a lot of time for visual screening than past. Therefore many related image processing techniques have been proposed in medical fields for extracting the abnormal regions on visual screening.

Image registration is one of the most important problems and fundamental tasks in medical image analysis. It is a process that superposes two or more images of one object taken in different time or by different equipment. Medical doctor can analyze and detect the abnormality and register the image according to the expert knowledge. In medical image-processing fields, some image registration techniques are proposed to find a geometrical transformation that matching the landmark points of one image to their corresponding points on the reference image. There are two types of registration methods: obtaining the objects from same modality or different modalities. In recent years, multi-modal image registration techniques are proposed for analyzing medical images obtained from different modality. Especially, CT and MR imaging of head for diagnosis and surgical planning indicates that physicians and surgeons could gain important information from these modalities. In general, in order to register two images, physicians segment the volumes of interest from each set of slices manually. However, manual segmentation of the object area may require several hours for analyzing. The registration accuracy depends on the ability of physicians. Consequently, automatic registration methods are still expected.

There are many automatic or semi-automatic registration techniques. Fitzpatrick et al. [1] proposed a volume image registration using template matching. Ding et al. [2] proposed an image registration method by use of template matching. There is a registration method with similar level of the voxel as in [3]. Furthermore, many related registration methods with mutual information of CT and MR image were proposed in [4-8]. Also Maes et al. [9] proposed an image registration method by use of maximization of MI (mutual information). The method employed the multi direction set method (Powell's method) [10] calculated transformation parameters for image registration in 3-D. It cost a long processing time for registration. The other methods require processing time for registration or manual operation, too. To overcome these problems, we propose a semi-automatic image registration technique by using the structure of a blood vessel and volume of interests (VOIs) to reduce the processing time and amounts of manual works.

II. METHODS

In this paper, we propose a new multi-modal image registration method for three-dimensional CTA and MRA imaging of head. In our method, a target image is translated and rotated to overlap a reference image in order to achieve a higher accuracy of registration. Here, we explain main step of

our proposed method. Firstly, we perform a preprocessing step to normalize the image size and to transform the target image roughly. Then initial registration is performed using center of gravity on two images with projection images. In this step we try to reduce the processing time and prevent falling into a local minimum of final registration using the 3-D information which is obtained blood vessels area. As the last step, final registration based on the structure of a blood vessel and MI (Mutual Information) is performed to transform the target image for precisely superposing onto the reference image. In this point, final registration step is different to our previous method in [12]. The details of each step are shown as follows.

A. Preprocessing

Firstly, we remove unnecessary regions on computation, such as bed area which remained on CTA image. Furthermore, initial registration is performed by using center of gravity which is obtained two images. We assume that $f(x,y)$ where x and y are bounded positive integers. The $(i+j)^{\text{th}}$ order moment m_{ij} of $f(x,y)$ is defined by,

$$m_{ij} = \sum_{(x,y) \in R} x^i y^j f(x,y) \qquad (1)$$

where R is a region of interest. Then, the centroid denoted by (x_c, y_c),

$$(x_c, y_c) = \left(\frac{m_{10}}{m_{00}}, \frac{m_{01}}{m_{00}} \right). \qquad (2)$$

The target image is superposed onto reference image by transformed onto the x-y coordinates of the derived center of gravity. In the next stage, the MIP (Maximum Intensity Projection) images are used for next registration which is obtained from 3-D CTA and MRA images by projecting in the axial viewpoint to reduce the computational times as shown in Figure 1. The MIP technique is a method for the 3-D data which projects the voxels in the visualization plane with maximum intensity that fall in the way of parallel rays traced from the viewpoint to the plane of projection.

B. Image Registration of Projected Images

In order to obtain high accuracy of registration, we introduce an initial registration processing with 2-D projection images. At first, we create three MIP images from a CTA and MRA image, respectively. The three MIP images are made from axial, sagittal and coronal viewpoint in each image (Figure 2). Then, the images which are made same viewpoint are operated registration with maximizing the mutual information.

Mutual information is a quantity that measures the mutual dependence of two variables. From two images A and B, mutual information $I(A,B)$ is defined as follows [9].

$$I(A,B) = \sum p_{A,B}(a,b) \log \frac{p_{A,B}(a,b)}{p_A(a) \times p_B(b)} \qquad (3)$$

The interpretation of this equation form is measuring the distance between the joint distribution of image pixel values $p_{A,B}(a,b)$, and the joint distribution in case of independence of
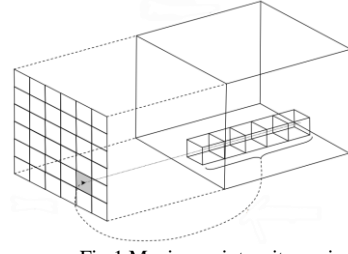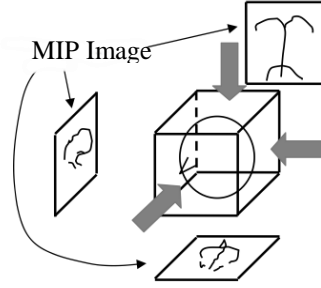

Fig.1 Maximum intensity projection

MIP Image

Fig.2 MIP images

the image, $p_A(a)$, and $p_B(b)$. In this paper, the target image is transformed until getting the maximum of mutual information.

C. Final Registration

Some miss-registration areas are still remained after the rough image registration obtained in the previous steps. Here, we refine the miss-registration regions based on the structure of blood vessels and maximize the mutual information. In general, blood vessel regions are appears with high density on the CTA and MRA image. To detect a feature on the two images, we segment the blood vessels region. The blood vessel regions are enhanced by three-dimensional line enhanced filter [11] which is used to improve the precision of the blood vessels.

Assume that the pixel in a 2-D image is denoted by, $f(x,y)$, and its four second derivatives are represented by f_{xx}, f_{yy}, f_{xy} and f_{yx}, where $f_{xy}=f_{yx}$. Then we can construct the Hessian matrix $\mathbf{H}$ of the pixel $f(x,y)$ in the original 2-D image,

$$\mathbf{H} = \begin{vmatrix} f_{xx} & f_{xy} \\ f_{yx} & f_{yy} \end{vmatrix} \qquad (4)$$

Two eigenvalues, λ_1 and λ_2 can be compute form the Hessian matrix $\mathbf{H}$ [13]. The circular objects and elongated objects are enhanced under the conditions of λ_1 and λ_2. Also the algorithm of the multi-scale selective enhancement filters can be found in [14]. In this study, as a final step to detect vessel areas from the two image set we used dot enhancement filter from three types of selective enhancement filter.

Then, the registration based on maximizing the mutual information value is performed on these images. However, the long processing time is required. In this paper, we set VOIs manually that contain enhanced blood vessels to reduce the processing time as shown in Figure 3. Finally, the mutual information values on the each VOI are performed to calculate best matched region.

Fig.3 Manual set of VOIS

III. EXPERIMENTAL RESULTS

Our new technique was applied to obtained real images from two different modalities, which were obtained from CT and MR. We performed five pairs of human head images. The computer is applied with 3.16[GHz] CPU and 3[GB] capacity of memory. The details of CT and MR images are shown in Table 1. Table 2 and Table 3 show the accuracy of registration and the processing time of our new proposed method and comparing the methods proposed in [9-12] separately. From the Table2, MI value of our new method is less than our previous method [12].
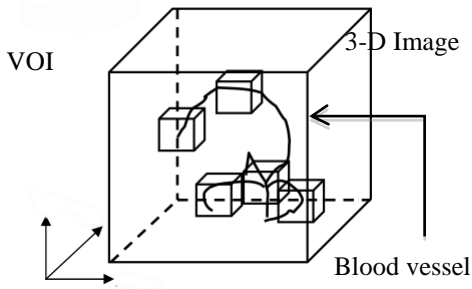
TABLE I.   IMAGE SOUCES.

	CTA	**MRA**
Pixel size	512X512	512X512
Number of slice	110	172-178
Pixel spacing [mm]	0.683	0.5469
Slice thickness [mm]	2.0	1.0

TABLE II.   EXPERIMENTAL RESULTS OF THE MUTUAL INFORMATION

Case	**Original Registration**	**Conventional Method [9]**	**Our Previous Method[12]**	**Our New Method**
1	0.1238	0.3351	0.3363	0.3103
2	0.1211	0.3117	0.3036	0.3034
3	0.1529	0.3921	0.3734	0.3617
4	0.1584	0.3228	0.3102	0.2953
5	0.1522	0.3822	0.3702	0.3749
Ave.	0.1417	0.3488	0.3388	0.3291

TABLE III.   EXPERIMENTAL RESULTS OF THE COMPUTATIONAL TIME. (SECONDS)

Case	**Conventional Method [9]**	**Our Previous Method[12]**	**Our New Method**
1	4184.3	716.9	236.1
2	2822.7	780.6	246.5
3	3930.7	562.7	227.9
4	2362.3	1777.4	225.0
5	3690.4	820.4	232.8
Ave.	3398.1	931.6	233.7
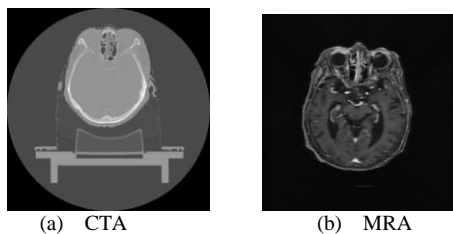
(a) CTA   (b) MRA
(1)   Original Images
Figure 4. Experimental Result: Red color shows CTA, green color shows MRA images, respectively.(Cont.)

(2) Conventional Method [9]

(3) Our Previous Method [12]

(a) Axial View (b) Coronal View (c) Sagittal View (d) Enlarged in (c)
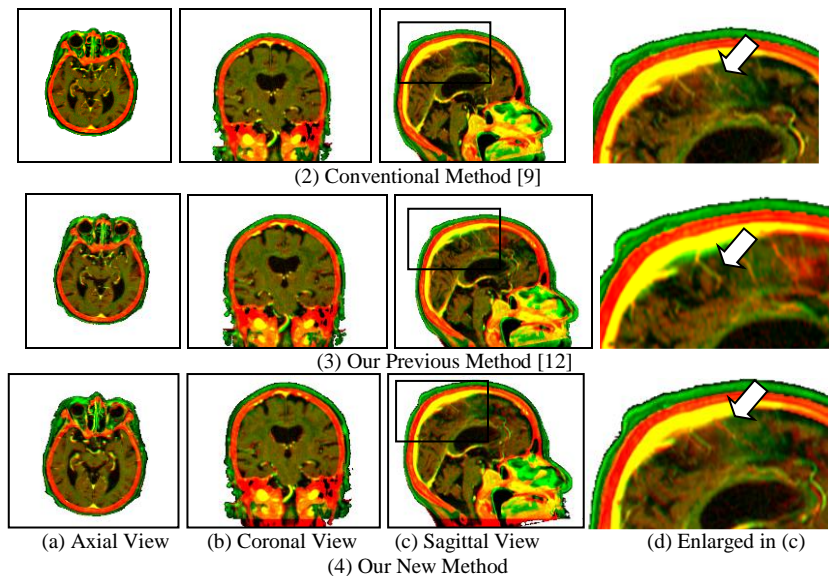
(4) Our New Method

Figure 4. Experimental Result: Red color shows CTA, green color shows MRA images, respectively. From the enlarged image in (d), our new methods obtained high accuracy of registration performance with almost same image between the conventional method and our new method.

IV. DISCUSSION AND CONCLUSIONS

In this paper, we proposed a new technique for CTA and MRA images registration. The primary purpose of this study is to increase the accuracy of registration and reduce the processing time. But according to Table 2, mutual information results of our new method are less than our previous method in [12]. In conventional method and our previous method, we use all CTA and MRA data to compute the mutual information. In this method, we use VOIs. The information of VOIs is less than the whole image data. Therefore, the mutual information of our new method is less than the previous one. However, from the Figure 4, there is an improvement of our new method from our previous method. At the result, the processing time is shorted by 7% comparing the accuracy of previous method. In the future, we improve our registration method and adopt our algorithms to the medical fields.

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