International Journal of Innovative
Computing, Information and Control
Volume **5**, Number **11(B)**, November **2009**

ICIC International ©2009 ISSN 1349-4198
pp. **4249–4254**

AN IMAGE REGISTRATION METHOD FOR HEAD CT AND MR IMAGING BASED ON OPTIMAL RETRIEVAL

Yutaro Yamamura[1], Hyoungseop Kim[1], Joo Kooi Tan[1]
Seiji Ishikawa[1] and Akiyoshi Yamamoto[2]

[1]Department of Control Engineering
Kyushu Institute of Technology
1-1, Sensui, Tobata, Kitakyushu 804-8550, Japan
kim@cntl.kyutech.ac.jp

[2]Kyouaikai Tobata Kyouritsu Hospital, Japan

Received October 2008; revised February 2009

Abstract. *Image registration is an important problem and a fundamental task in computer vision and image processing field. Recently, many image registration techniques are introduced such as PET with CT image and abnormalities can be easily detected by using image information. One of the multi modal images, CT and MR imaging of the head for diagnosis and surgical planning indicates that physicians and surgeons gain important information from these modalities. In radiotherapy planning, manual registration techniques are performed on MR and CT images of the brain. In general, physicians segment the volumes of interest (VOIs) from each set of slices on the MR and CT images manually. However, manual registration of the object may require several hours for analysis based on anatomical knowledge. In this paper, we describes a new method for automatic registration of head images which is obtained CT and MRI by using an optimal retrieval on neighbor VOIs in several extracted data and maximization of mutual information. In the experimental results, we can reduce the computational times. The primary objective of this study is to increase accuracy of the registration and reduce the computational processing time.*

Keywords: Image registration, Mutual information, CT, MRI

1. **Introduction.** During the last decades, various imaging equipments such as computed tomography (CT), ultrasound (US) and magnetic resonance imaging (MRI), have been introduced into medical fields. Especially, high resolution helical CT (HRCT) is one of the most useful diagnosis systems because it provides a high resolution image to medical doctors as a clear image. Radiologist can easily detect abnormalities by use of the clear images. However, they should spend a lot of time for visual screening than the past. Accordingly, many related image processing techniques have been proposed into medical fields for extraction of abnormal area [1-3].

Image registration is the most important problem and a fundamental task in medical image analysis, computer vision, etc. It is the process of superposing two or more images of the same image taken at different times. Medical doctor can analyze and detect the abnormality and register the image by use of human expert knowledge employing their anatomical knowledge even if it is a complex and difficult problem. In the medical image processing field, some image registration techniques are proposed to find a geometrical transformation that relates the points of an image to their corresponding points of another image. There are two types of the registration method which obtains same modality or different modality. In recent years, multi-modal image registration techniques are proposed for analyzing which obtained the different modal images. Especially, CT and

MR imaging of the head for diagnosis and surgical planning indicates that physicians and surgeons gain important information from these modalities. In general, in order to register the two images physicians segment the volumes of interest from each set of slices manually. It is, however, manual segmentation of the object area may require several hours for analyzing. Therefore, manual segmentation and registration method cannot be applied for clinical application in the head CT and MR images.

In order to register the two types of images, many automatic and/or semi-automatic image registration methods have been proposed. Fitzpatrick *et al.* [4] propose a visual assessment of accuracy of retrospective registration techniques. Ding *et al.* [5] propose the volume image registration by template matching. There is a registration method with similar level of the voxel [6]. Furthermore, many related registration methods with mutual information of CT and MR image are proposed [7-11]. Maes *et al.* [12] proposed an image registration method by use of maximization of mutual information. The method employed the multi direction set method (Powell's method) [13] to request transformation parameters for image registration in 3-D. It is, however, the method needed long processing time for registration. The other methods require processing time for registration or manual operation, too. To overcome this problem, we propose an automatic image registration technique.

We have already proposed a method for reducing the computational time in order to register two images which are obtained by MDCT and MRI of head employing maximization of mutual information [14]. In [14], we created six projection images from a 3-D volume data set on each modality image for reducing the calculation time. A registration technique which is obtained by projection is proposed for a 3-D and 2-D image registration, too [15-18]. However, there are still remained some registration errors and also required the computational times. Consequentially, we have proposed a method [19] that improves the method [14]. This method used extracted edge information by use of a wavelet transform. We could get higher accuracy by using the method [19] than using the method [14]. However, image registration accuracy was not improved in several cases. It was because that information is lacked by using projection.

In this paper, we propose a new method for automatic image registration of head images based on optimal retrieval on neighbor VOIs from CT and MR imaging to get high accuracy than our previous method [19] which is obtained volume image. In the literature [19], 2-D edge information based on wavelet transformation was introduced for image registration. In this new method, we use 3-D information based on volume data. Also, we improve the algorithm in [12] by use of a selected volume of interest. The primary objective of this study is to increase accuracy of the registration and reduce the processing time. This paper is organized as follows. The image processing methods for registration of two images are presented in Section 2. Some experimental results employing proposed method are illustrated in Section 3. Finally, some discussions and conclusion are given in Section 4.

2. **Methods.**

In this paper, we develop a new multi-modal image registration method based on a maximization of mutual information from a set of CT and MR imaging of head. When the image is superposes onto another one, several image preprocessing techniques are needed for achieving a higher accuracy of registration.

In order to achieve the multi-modal image registration, it is required to normalize the image size. It is because the images obtained from different modality usually do not have same image size. The first step starts to resample the input two images which are obtained different modalities. In general, two image sets which are obtained CT and MRI have different pixel spacing, slice thickness. It is because we adjust each image sets

including pixel spacing and slice thickness in the early stage. In the next step, initial image registration is performed by using center of gravity of each image. In the third step, one or some VOIs obtained on the image set for registration are selected. Finally, the registration is performed employing maximization of mutual information from the extracted VOIs. The details of each technique are shown as follows.

2.1. **Preprocessing and initial registration.** In general, the images obtained from the different modalities may have different image size, pixel spacing and a number of slices. In the image preprocessing step, image size and pixel spacing are normalized and image noise is reduced for registration. In order to align the multi-modal images, center of gravity of CT and MR images is calculated for initial registration. In this paper, we assume that the MR image as a target image and CT image as a reference image. In this step, we calculate the center of gravity on multi-modal images.

The target image is transformed onto the $x - y$ coordinates of the center of image. The reference image is transformed onto the same coordinates, too. It must be the same coordinates as an initial position for registration. In our method, initial 2-D images for initial registration are selected the range of 4[cm] from the parietal region.

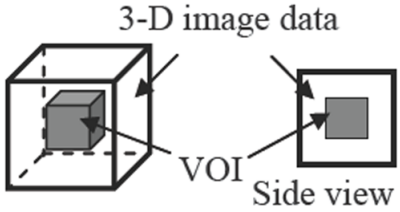

FIGURE 1. A VOI of center of image

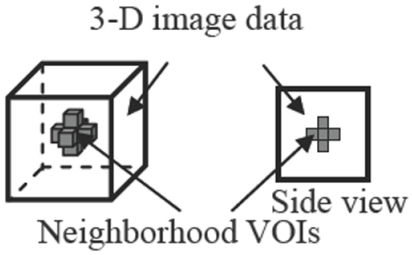

FIGURE 2. Neighborhood VOIs

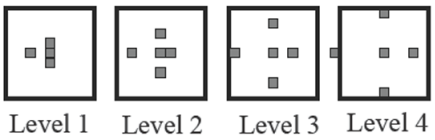

FIGURE 3. Levels of neighborhoods far from center of image (side view)

2.2. **Extracting of ROI.** In order to reduce the computational time, we reduce data for image registration. In this section, we introduce the method of extracting a VOI. In our study, we use data that are in the vicinity of center of image (Figure 1). In this paper, the size of VOI extracted from the target image of 10% of original image size. The reference

images are 14% of the target images on the VOIs. Then, we extract the VOIs which have six neighborhoods (Figure 2). In this paper, we moved those six neighborhoods on the VOIs far from the center of image slightly (Figure 3). Finally, we measured the change of mutual information which has best matched position.

2.3. **Final registration.** Final registration is performed by use of the mutual information on extracted VOIs. The mutual information is a quantity that measures the mutual dependence of the two variables. The mutual information tries to find the transformation that best matches between two images. It is widely used for registration which obtained multi-modal image in medical image processing field. In this section, we explain the maximization of mutual information technique.

From the two images A and B, mutual information $I(A, B)$ can be defined as follows [12].

$$I(A, B) = \sum p_{A,B}(a, b) \log \frac{p_{A,B}(a, b)}{p_A(a) \cdot p_B(b)} \tag{1}$$

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 the image, $p_A(a)$, and $p_B(b)$. In this paper, the target image is transformed for maximization of mutual information. When the mutual information is calculated, the intensity of pixel is converted from 0 to 255 by linear transformation. In this paper, the amount of the movement of the target image is described by optimization that uses multi-dimensional direction set method (Powell method [13]) of which the index is mutual information. This method can be used to 3-D data. But it needs computational time. Thus, the calculation cost is reduced by using extracted VOIs of the target and reference image.

Image registration is performed on the extracted VOIs by using a method which is described in Section 2.2. The parameters of movement are obtained by registration of the target and reference images of VOIs. A head can be considered to be a rigid body. Then, the parameters of movement are same as the parameter obtained by registration of VOIs.

3. **Experimental Results.** Our new technique was applied to real images which obtained the two different modalities – CT and MR images of five human head images. In our experiment, we use 2GB RAM and a 3GHz CPU. The parameters of CT and MR image are shown in Table 1. In this paper, the images which has 512×512 [pixels] in each slice were converted into 384×384 [pixels] to reduce the processing time.

Table 2 shows accuracy of registration and the achieved computational time of the method by use of method in [12] which is performed previous our method in [19] and the proposed new our registration method based on extracted VOIs. Figure 4 shows overlapped two images from the experimental results of data set 1. From the Figure 4, our new method can obtain the satisfactory registration accuracy. On the other hand, it is shown the processing time can be reduced as shown in Table 2.

4. **Discussion and Conclusion.** In this paper, we propose a method to reduce a registration error and processing time by use of optimal retrieval on neighbor VOIs. In Table 2, our new method can obtain higher mutual information than previous our method in level 1. Then, it is understood that our new method get higher accuracy than our previous method. In our previous method in literature [19], we have proposed a method for image registration by use of wavelet transformation. By using the wavelet transformation, the processing times can be reduced than the conventional method based on 3-D image. For higher accuracy for image registration it is still remained a new method. In Table 2, we focus on levels of neighborhoods far from image center. When the level is big order, it

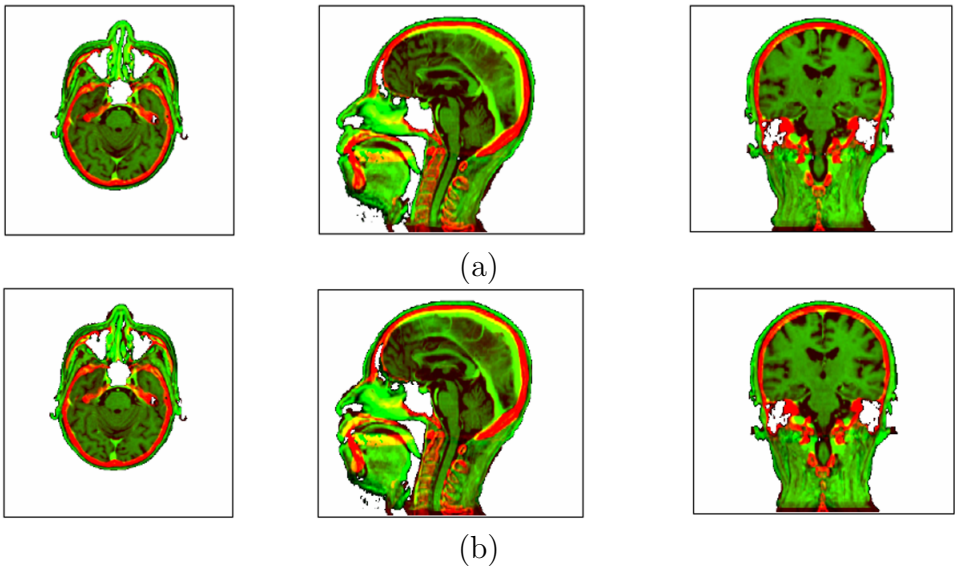

FIGURE 4. Experimental results. (a), (b) show the result of the method of [9] and our new proposed method, respectively. First column images show an axial plane image and middle column images are sagittal plane image, and third column images show the coronal plane images. Red color shows MR images and green color shows CT images, respectively

is understood that accuracy becomes low. We think that using data extracted far from image center causes it. It is thought that image registration between extracted data can't obtain the enough accuracy, because, the influence of the gap of the rotation becomes big far from the image center.

On the other hand, processing time of our new method is less than the previous method and the method of [12]. Especially, when they compared with the method of [12], it is understood to have shortened the processing time to about 1/30. However, in Figure 4, there are scarcely any difference between the method [12] and our new method. Then, it is useful that extracted data are used for image registration. However, it still needs improvement of the algorithms for more reducing the computational time than our previous method. It remains for our future work. The primary objective of this study is to increase accuracy of the registration and reduce the processing time.

TABLE 1. Image sources

	CT image	MR image
Pixel size	512X512	512X512
Number of slice	120	120
Pixel spacing [mm]	0.638	0.6386
Slice thickness [mm]	2	2

REFERENCES

[1] W. Liu, K. Yuan, J. Zou, S. Zhou, W. Chen, S. Jie and P. Xiao, Nonnegative tensor fractorization for brain CT image retrieval, *International Journal of Innovative Computing Information and Control*, vol.4, no.11, pp.2911-2918, 2008.

[2] X. Zhang, K. Xiao, G. Gao and G. Teng, The improvement of a feature-based image mosaics algorithm, *International Journal of Innovative Computing Information and Control*, vol.4, no.10, pp.2759-2764, 2008.

Table 2. Experimental results

			Level in Figure 3				Conventional method [12]	Previous our method [19]
			1	2	3	4		
Mutual information	Case No.	1	0.6149	0.6114	0.5967	0.5343	0.6209	0.6154
		2	0.7013	0.6396	0.6410	0.5383	0.7084	0.6517
		3	0.6056	0.6066	0.5807	0.5797	0.6122	0.6358
		4	0.7808	0.7791	0.7608	0.6708	0.7837	0.7592
		5	0.6998	0.7003	0.6829	0.7040	0.7068	0.7028
	Average		0.6805	0.6674	0.6524	0.6054	0.6864	0.6730
Processing time [s]			63.9	61.9	43.5	44.3	1728.1	511.3

[3] Z. Zhang and Y. Zhao, Multiple description image coding based on frantal, *International Journal of Innovative Computing, Information and Control*, vol.3, no.6(B), pp.1615-1623, 2007.

[4] J. M. Fitzpatrick, D. L. G. Hill, Y. Shyr, J. West, C. Studholme and C. R. Jr. Maurer, Visual assessment of the accuracy of retrospective registration of MR and CT images of the brain, *IEEE Transactions on Medical Imag.*, vol.17, no.4, pp.571-585, 1998.

[5] L. Ding, A. Goshtasby and M. Satter, Volume image registration by template matching, *Image and Vision Computing*, vol.19, no.12, pp.821-832, 2001.

[6] K. J. Friston, J. Ashbuner, C. D. Frith, J.-B. Poline, J. D. Heather and R. S. J. Frackowiak, Spatial registration and normalization of images, *Human Brain Mapping*, vol.3, no.3, pp.165-189, 1995.

[7] A. Roche, G. Malandain, X. Pennec and N. Ayache, The correlation ratio as a new similarity measure for multimodal image registration, *Proc. of the International Conference on Medical Image Computing and Computer-Assisted Intervention*, vol.1496, pp.1115-1124, 1998.

[8] T. Gaens, F. Maes, D. Vandermeulen and P. Suetens, Non-rigid multimodal image Registration using mutual information, *Proc. of the International Conference on Medical Image Computing and Computer-Assisted Intervention*, vol.1496, pp.1099-1106, 1998.

[9] J. Maintz, E. Meijering and M. Viergever, General multimodal elastic registration based on mutual information, *Medical Imaging: Image Processing, Proc. SPIE*, vol.3338, pp.144-154, 1998.

[10] B. Kim, J. Boes, K. A. Frey and M. R. Charles, Mutual information for automated unwarping of rat brain autoradiographs, *Neuro Image*, vol.5, no.1, pp.31-40, 1997.

[11] S. V. Klinski, C. Derz, D. Weese and T. Tolxdorff, Model based image processing using snakes and mutual information, *Medical Imaging: Image Processing, Proc. SPIE*, vol.3979, pp.1053-1064, 2000.

[12] F. Maes, A. Collignon, D. Vandermeulen, G. Marchal and P. Suetens, Multimodality image registration by maximization of mutual information, *IEEE Trans. on Medical Imaging*, vol.16, no.2, pp.187-198, 1997.

[13] W. H. Press, S. A. Teukolsky, W. T. Vetterling and B. P. Flannery, *Numerical Recipes in C*, 2nd Ed., Cambridge Univ. Press, pp.412-419, 1993.

[14] Y. Yamamura, H. Kim and A. Yamamoto, A method for image registration by maximization of mutual information, *Proc. of the SICE-ICASE International Joint Conference*, pp.1469-1472, 2006.

[15] D. B. Russakoff, T. Rohifing and C. R. Jr. Maurer, Fast intensity-based 2D-3D image registration of clinical data using light fields, *Proc. of the 9th IEEE International Conference on Computer Vision*, Nice, France, vol.1, pp.416-422, 2003.

[16] T. Rohlfing and C. R. Jr. Maurer, A novel image similarity measure for registration of 3-D MR images and X-ray projection images, *Proc. of the International Conference on Medical Image Computing and Computer-Assisted Intervention*, pp.469-476, 2002.

[17] C. Florin, J. Williams, A. Khamene and N. Paragios, Registration of 3D angiographic and X-ray images using sequential monte carlo sampling, *Statistics and Computing*, vol.10, pp.197-208, 2000.

[18] D. L. G. Hill, P. G. Batchelor, M. Holden and D. J. Hawkes, Medical image registration, *Physics in Medicine and Biology*, vol.46, R1-R45, 2001.

[19] Y. Yamamura, H. Kim, J. K. Tan, S. Ishikawa and A. Yamamoto, A method for reducing of computational time on multi-modal image registration employing wavelet transformation from a set of head CT and MR imaging, *International Journal of Innovative Computing, Information and Control*, vol.4, no.7, pp.1527-1536, 2008.