A Fast Brain Image Registration Using Axial Transformation

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A Fast Brain Image Registration Using Axial Transformation

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Abstract. The registration process in the medical field has evolved rapidly making the physicians to rely on computer algorithms for processing and diagnosing the diseases. Registration has been used for studying disease growth and treatment responses of the diseases. Brain image registration enables physicians to diagnose diseases like Alzheimer's based on the changes in the internal structure of the brain. One of the main challenges in this topic is the huge computational requirements of the registration processes. In this paper we propose a method for the fast and accurate registration of MR brain images using the shape property of the axial slice of the brain. The algorithm exhibits reduced computational time when compared to a standard existing approach, which makes it useful for real time applications.

Keywords: Axial Transformation, Image Registration, Magnetic Resonance Imaging, Medical Image Registration, Multi-resolution.

1 Introduction

Image Registration is the process of geometrically aligning two images onto a common coordinate system [1]. It calculates the transformation required by one image, to overlay on the other image with maximum similarity. The two images may be taken at different times or using different devices or from different angles. The results of registration help to detect subtle changes between the two images. Registration is the primary step in many medical applications that use 2D or 3D images. It is widely used for monitoring tumour growth, measuring volume of tissues, treatment verification, etc.

The different components in the registration process are as follows [2]:

1. Feature Space: Information used for matching is extracted from the images.
2. Search Space: The transformation capable of aligning the images is defined.
3. Similarity Metric: Defines a method to measure the similarity between the features extracted in the feature space.
4. Search Strategy: Defines how the search for optimal transformation has to be done.

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Classification of the registration process is done based on several criteria; for example, based on the similarity criteria-intensity or feature based; based on the modality used-single or multi; based on mode of operation-automatic or interactive, etc. There have been numerable image registration techniques that have been developed in the past several years. The results of the techniques are different in each case of registration, however, the basic steps such as finding the feature space, search space, determining the search strategy and similarity metric are the same for every registration process. The choice of the algorithm used in each of the steps determines the registration process and its results. Hence, a single method that can be used for all applications does not exist.

In many of the experiments conducted in the area of disease growth and treatment response of the disease, registration techniques have been used to monitor them. Diseases such as Alzheimer's, Epilepsy etc., wherein the progress of the disease and treatment responses cannot be detected by the patients external conditions, registration methods have proved to be helpful.

The brain imaging approaches convey a lot of information depending on its modality. The two modalities in brain imaging are functional and structural. The functional imaging techniques like Positron Emission Tomography (PET) and Single-Photon Emission Computed Tomography (SPECT) gives information about the activity of the cell in the region. Whereas, structural imaging techniques like Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) gives information on the structural aspects, the bones and tissues. In this paper, an approach specific to the registration of axial MRI slices has been proposed. It aims at the reduction of time taken for the registration process. The Paper is organized as follows. Section 2 deals with the review of some of the existing approaches in brain image registration. Section 3 presents the basic theory of our approach. The comparative performance study of the proposed method with the mutual information based registration method is given in Section 4. Finally, the work is concluded in Section 5.

2 Related Works

Some of the important related works in this area are reviewed briefly in the following:

A brief description of some of the general methods used for medical image registration, the issues to be addressed and a few examples of the registration technique used have been illustrated in [3]. The authors also comment on the difficulty of the problem of image registration and the variability/ diversity of possible solutions.

Teverovskiy *et al.,* [4] presents the performance evaluation of the intensity versus feature based method for brain image registration. A mutual information method was used for the evaluation process. The algorithms in ITK package and HAMMER [5] are evaluated based on their performances at both local and global levels. The authors concluded that each of the algorithms differed in their performance aspect over the other at different regions of the brain, i.e. the algorithm performance was specific to the brain regions.

In contrast with using purely feature-based or intensity-based methods, a hybrid method that integrates the merits of both approaches has been proposed in [6] by Xiaolei *et al.,* In this method an entropy based detector is used to select the salient region features initially and then the likelihood of the regions is determined. For a test data of 50 moving images the runtime was calculated in 4 cases based on different artificial transformation parameters. An average from all the 4 cases showcased a computation time of 150 seconds for each 50 images.

A recent work on improving the accuracy and speed of the registration process was done by Kim *et al.,* [7] using a Support Vector Regression (SVR) model. In this work, the SVR first learns the brain image appearances and their corresponding shape deformations with respect to a template, for a set of training samples. The learnt SVR models are then applied to rapidly predict a good initial deformation for a given new subject. To test 50 images of size 256x256x198, HAMMER [5] took 5400 seconds and Diffeomorphic demons [8] took 219 seconds without using the framework. A reduced computation time of 960 seconds for HAMMER and 71 seconds for Diffeomorphic demons was obtained by using the framework.

Jean Francois Mangin, *et al.,* [9] proposed a non-supervised 3D registration of images from different modalities. Initially the discrete representations of the region of interest are extracted from the PET and MR images. The required transformation is found from the shape-independent matching algorithm. The registration process required five minutes on a conventional work station.

A new method using Fast Walsh Hadamard Transform for image registration has been put forth in [10]. Applying Fast Walsh Hadamard transform on images results in detecting the local structures of the image; these are used as the features in this approach. The algorithm was tested on 21 sets of CT-MR image pairs, for bases 1 to 5. The results show a reduced runtime that averages to 3.7 seconds in base 1 and 7 seconds in base 5. Another method [11], using wavelet as the edge detector and mutual information as the similarity metric, aligns the MR and CT images with an increased accuracy and reduced processing time.

In the work by Lepore *et al.,* [12], the fluid image registration method incorporated with multi-resolution is suggested to be used when large anatomical differences are expected. This method was tested on a 2D phantom image which was highly deformed. The commonly used elastic registration completely failed for this test set. The computational time required to calculate the numerical solution of viscous fluid has been significantly reduced.

Raj Shekhar, *et al.,* [13] proposed a high speed registration method for 3D and 4D images using mutual information (MI) as the voxel similarity measure. The long execution time is a major drawback of the MI method. To overcome this, a low-cost hardware was developed to accelerate the process of registration. Results show an acceleration ratio of 16.5 for registering images of size 256^3. The execution time to register MRI to a PET image takes 18-22 minutes for the software, whereas the hardware needs only 80-100 seconds.

The works reviewed above reveals that in general most of the algorithms take huge computational time, thus making the real-time registration process a difficult task. The present work proposes a fast approach for brain image registration.

3 Proposed Method

Our approach is dependent on MR images, particularly images of the axial view. We know that, the axial view of the brain and the skull together resembles the shape of an egg or rather it is oval in shape although not perfect. Using this property, it can be said that the length from the frontal lobe to the occipital lobe will be the longest distance of the line that can be plotted in the axial view as shown in Figure 1. This algorithm aims to align the line joining the farthest points to be parallel to the y-axis.

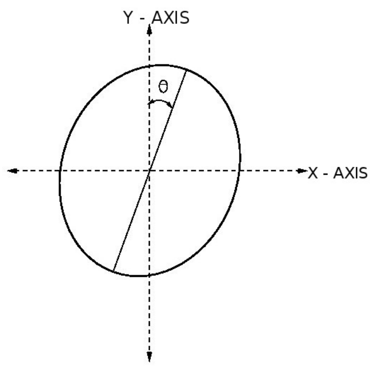


Fig. 1. Axial Slice of the Brain Depicting the Angle of Inclination, θ, Towards the y-axis

Initially an edge detection algorithm is applied to the slice to extract the outermost circumference of the skull. Then using the distance formula, the points on the circumference (x_1,y_1) and (x_2,y_2) that are the farthest from each other are found and a line is plotted between them. The slope of this line towards the y-axis is calculated using the formula (1), for the line joining the points (x_1, y_1) and (x_2, y_2).

$$\theta = tan^{-1}\left[\frac{x_2 - x_1}{y_2 - y_1}\right] . \qquad (1)$$

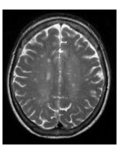
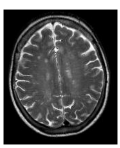
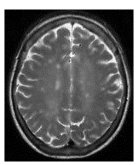
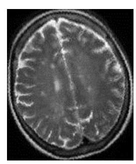
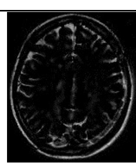
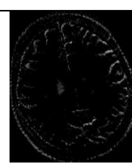
θ gives the angle of rotation required. It has to be noted that, for an MRI image the point of rotation is at the occipital lobe or rather the base of the MRI slice, so therefore a rotation to align the base of the image would be the actual value of the rotation parameter. A bounding box is constructed around the image, which will therefore include only the brain and the skull. Hence the need for translation is completely eliminated. To align two images the corners of the bounding box have to be aligned. A scaling factor is also calculated between the two images and then images are rescaled. A GUI based on wavelet is used for fusing the images.

4 Performance Evaluation and Discussion

A global registration technique that uses mutual information as the similarity metric has been used for comparison in this paper. The method includes a multi-resolution technique to reduce the search space of the algorithm. The two images for registration, the reference image, R, and the float image, F, are given as the input. Different transformations in the search space are applied to the image F and its mutual information is calculated along with the image R. A maximum value of MI results in the correct transformation required for F in order to align itself with R.

Table 1 depicts the performance of both, the existing and the new methods on 1 set of images. It includes the resulting transformation parameters after registration, the MI value of the registered images, the runtime of the algorithm, the fused image and the difference image. Notations used in Table 1 are given in Table 2.

Table 1. Result of Registration Performed on 1 Set of Images

METHOD	EXISTING	PROPOSED
Transformation Parameters	$t_x = 23$ mm $r_x = 8^o$ $t_y = 21$ mm $r_y = 0^o$ $t_z = 0$ mm $r_z = 0^o$	$R_R = 12.4552^o$ $R_F = 14.9314^o$
Mutual Information	0.2437	0.3323
Time (in seconds)	483.06	2.687
Registered Image   R F		
Difference Image		

Evaluation of the proposed method is performed on DICOM images of size 256x256 retrieved from the ADNI database [14]. The images are taken from the same subject at different times. 15 set of MR images were tested with the

Table 2. Notations

t_x - translation w.r.t x-axis	r_x - rotation w.r.t x-axis
t_y - translation w.r.t y-axis	r_y - rotation w.r.t y-axis
t_z - translation w.r.t z-axis	r_z - rotation w.r.t z-axis
R_R - angle of inclination of the reference image w.r.t y-axis	R_F - angle of inclination of the float image w.r.t y-axis

proposed and the existing techniques. The results are tabulated in Table 3. The drastic reduction of computational time with the proposed method makes it suitable for real time applications. The image dependent nature of the method is a major limitation of this method.

Table 3. Comparison of the Proposed Method and the Existing Method

IMAGE SET	MUTUAL INFORMATION VALUE		TIME in seconds	
	EXISTING	PROPOSED	EXISTING	PROPOSED
1	0.2585	0.3097	404.96	1.227
2	0.2665	0.3079	410.14	1.090
3	0.2869	0.3225	401.69	1.100
4	0.2754	0.3247	405.46	1.105
5	0.2777	0.3175	403.59	1.119
6	0.2743	0.3156	411.807	1.152
7	0.2719	0.3165	416.283	1.129
8	0.2721	0.3212	412.802	1.103
9	0.2654	0.3166	403.326	1.139
10	0.2680	0.3022	403.786	1.119
11	0.2794	0.3173	399.566	1.128
12	0.2670	0.2955	399.557	1.108
13	0.2563	0.2856	397.289	1.121
14	0.2505	0.2864	396.941	1.159
15	0.2424	0.2888	399.044	1.154

5 Conclusions

A new algorithm for brain image registration has been proposed in this paper. This method reduces the computational time required for registration of brain images. A reduced runtime makes the registration technique to be used in real time applications. The method proposed here is specific for the axial slice MR brain images.

References

1. Wyawahare, M.V., Patil, P.M., Abhyankar, H.K.: Image Registration Techniques: An Overview. International Journal of Signal Processing, Image Processing and Pattern Recognition 2(3), 1–5 (2009)
2. Brown, L.G.: A Survey of Image Registration Techniques. ACM Computing Surveys 24(4) (1992)
3. Kostelec, P.J., Periaswamy, S.: Image Registration for MRI. Modern Signal Processing 46, 161–184 (2003)
4. Teverovskiy, L., Carmichael, O.T., Aizenstein, H.J., Lazar, N., Liu, Y.: Feature-Based vs. Intensity-based Brain Image Registration: Voxel Level and Structure Level Performance Evaluation. CMU-ML, p. 2 (2006)
5. Shen, D., Davatzikos, C.: HAMMER: Hierarchical Attribute Matching Mechanism for Elastic Registration. IEEE Transactions on Medical Imaging 21, 1421–1439 (2002)
6. Huang, X., Sun, Y., Metaxas, D., Sauer, F., Xu, C.: Hybrid Image Registration Based on Configural Matching of Scale-invariant Salient Region Features. In: Computer Vision and Pattern Recognition Workshop, p. 167 (2004)
7. Kim, M., Wu, G., Yap, P.-T., Shen, D.: A Generalized Learning Based Framework for Fast Brain Image Registration. In: Jiang, T., Navab, N., Pluim, J.P.W., Viergever, M.A. (eds.) MICCAI 2010, Part II. LNCS, vol. 6362, pp. 306–314. Springer, Heidelberg (2010)
8. Vercauteren, T., Pennec, X., Perchant, A., Ayache, N.: Diffeomorphic Demons Efficient Non-parametric Image Registration. NeuroImage 72, S61–S72 (2009)
9. Mangin, J.F., Frouin, V., Bloch, I., Bendriem, B., Lopez-Krahe, J.: Fast Nonsupervised 3-D Registration of PET and MR Images of the Brain. J. Cerebr. Blood Flow Metab. 14(5), 749–762 (1994)
10. Sasikala, D., Neelaveni, R.: Registration of Brain Images Using Fast Walsh HadamardTransform. International Journal of Computer Science and Information Security Publication 8(2), 96–105 (2010)
11. Yamamura, Y., Kim, H., Tan, J., Ishikawa, S., Yamamoto, A.: A Method for Reducing of Computational Time on Image Registration Employing Wavelet Transformation. Control, Automation and Systems, 1286–1291 (2007)
12. Lepore, N., Chou, Y.Y., Lopez, O.L., Aizenstein, H.J., Becker, J.T., Toga, A.W., Thompson, P.M.: Fast 3D Fluid Registration of Brain Magnetic Resonance Images. In: SPIE, vol. 6916, pp. 69160Z–69160Z-8 (2008)
13. Shekhar, R., Zagrodsky, V., Castro-Pareja, C.R., Walimbe, V., Jagadeesh, J.M.: High-speed Registration of Three- and Four-dimensional Medical Images by Using Voxel Similarity. Radiographics 23, 1673–1681 (2003)
14. Alzheimers Disease Neuroimaging Initiative, `http://adni.loni.ucla.edu`