Template-based Affine Registration of Autistic Brain Images

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Abstract: This paper presents a new method for the study of autistic brain image called "Template-based affine registration", based on the transformation of the grid-line from a source image to a target image. By using the locations of grid of both source and target images as the control structure, together with a smart transition of grid computed by bilinear and affine transformations. Besides, the new locations of grid of a target image corresponding to a source image are the best-move of all feature points translated from a source to a target. The template named after the point set extracted from source image, the simple idea is to use the affine transformation for mapping the target point set to the template. The transformation process is used effectively by using the incorporating transition of grid to maintain geometric alignment throughout the process; the proposed method achieves a smooth transformation for image registration.

1 INTRODUCTION

Autism is a neurodevelopmental disorder characterized by marked deficits in communication, social interaction, and interests. Various studies of autism have suggested abnormalities in several brain regions, with an increasing agreement on the abnormal anatomy of the white matter (WM) and the unused brain cells, called gray matter (GM). (Rachid, et al., 2007), (Fisher, 2011). The WM connections between brain regions are important for language and social skills. Normally, as children grow into teenagers, in order to understand and respond to the world, the brain undergoes 2 major changes — the creation of new connections in WM, and the elimination, or "pruning," of GM. Figure 1 shows the region of WM and GM. The brain-imaging scan called a T1-weighted MRI (Magnetic Resonance Imaging), which can map structural changes during brain development (Fisher, 2011). To study how the brains of autism changed over time, the researchers captured the brain images of children with autism before the treatment and they did this again approximately three years later. By doing this twice, the scientists were able to create a detailed picture of how the brain changes. Thus, this new knowledge may help to explain some of the symptoms of autism and could improve future treatment options later on. Unfortunately, only MRI modality does not provide the brain activity analysis, which is essential for understanding how the brain works associated with the difficulties that many autistic children have with — social impairment, communication deficits and repetitive behaviour.

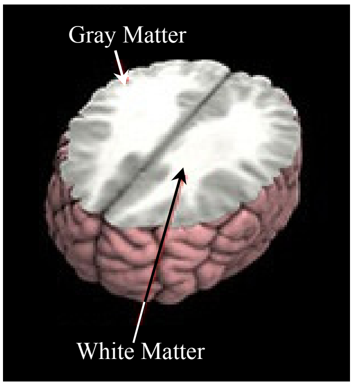

Figure 1: The connections between WM and GM.

A new methodology for analyzing fMRI scans has been proposed by (Wei, et al., 2015). The method called Brain-Wide Association Analysis (BWAS), can analyze over 1 billion pieces of data for creating panoramic views of the whole brain and provides scientists with the 3D model to study the brain connections. The ability to analyze the entire data set from an fMRI scan provided the researchers the opportunity to compile, compare and contrast accurate imaging modalities for both autistic and non-autistic brains. The major drawback of BWAS

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is that the computational cost of the big data analysis should be concerned. A multi-modality of brain imaging methodology has been introduced in (Hughes, 2012). The autistic brain was scanned using three different methods: high-resolution MRI, which captures the structure of the brain; Diffusion Tensor Imaging (DTI), a method to trace the connections between brain regions; and functional MRI, which indicates brain activity. Figure 2 shows the vertical MRI scanning; the future work of (Hughes, 2012) is how to combine the various types of images into one common format.

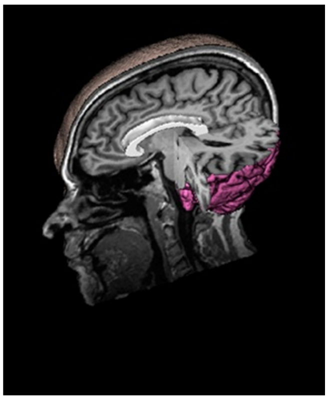

Figure 2: Vertical MRI scanning.

2 PURPOSE OF PROPOSED METHOD

This work aims to study the abnormalities in autistic brain using image processing technique called Image registration. Image registration is the process of aligning the different sets of data of the same object into a common format thus aligning them in order to analyze subtle changes among each other. A fundamental problem in medical image registration is the integration of information from multiple images of the same subject, acquired using the same or different imaging modalities and possibly at different time points (Maes, et al., 2013), i.e., recovering the geometric relationship between corresponding points in multiple images of the same scene.

As mentioned earlier in previous section; the current research trends for analysis the autistic brain image have been focused in 2 major fields:

1. To study the brain activities extraction using fMRI modality, and
2. To study the brain active regions using DTI modality.

The similarities between fMRI and DTI modalities include the study of anomaly in WM and deficits in the size of the corpus callosum (the white crescent in figure 2.). (Lynn, et al., 2014) have been supported the hypothesis that the disruption of the corpus callosum constitutes a major risk factor for developing autism, resulting in the difficulties that many autistic people have with words and social interaction. Unfortunately, to diagnose the symptoms of autism, the doctor need to do it at least twice; the first one concerns the observation of fMRI, the second one the question of how to explain the observed brain active region in DTI.

Therefore, the major contribution of this proposed method is to integrate the fMRI and DTI modalities into a common coordinate system, thus the doctor can take the benefits of both fMRI and DTI by observing the brain images at the same time. This study proposes a new approach of registration for Autistic brain images called Template-based affine registration. The novelty of the method is that the correlation of functional brain image data obtained from different individuals can be achieved by registration of the corresponding anatomical brain images with a fixed template image (Visutsak, 2014). The brain image has been normalized to the new coordinate system, such that after registration process, functional measurements from different individuals can be compared using the new coordinates.

The term “Template” means the point set extracted from source image (in this case; fMRI will be chosen as source image and DTI will be chosen as target image), the goal is to estimate the affine transformation for source and target images using two point sets extracted from these two images. By performing the manual deformation to get source and target image, the point sets of source and target images (as well as the area of WM and corpus callosum included in both images) will be extracted respectively. In order to register two point sets of images, two problems are needed to be solved simultaneously, the first one is to estimate the transformation between two point sets and the second one is to concern with the mapped positions of points using an appropriate transformation.

3 IMAGE REGISTRATION

The general term of image registration can be defined as the evolution of source to target images; this evolution refers to as what the proper mapping function is used to spatially transform two images with respect to their intensities (Visutsak, 2014). Given two images denoted by I_1 and I_2, the mapping between images can be expressed as:

$$I_2(x,y)= g(I_1(f(x,y))) \quad (1)$$

Where, *f()* is the 2D spatial transformation
g() is the 1D intensity transformation

By assuming that the correspondences are known, the goal of image registration is to find such *f()* and *g()*, such that two images are best matched. Figure 3 illustrates the concept of spatial transformation that maps from arbitrary point *P* in fMRI image to homologous point *Q* in DTI image.

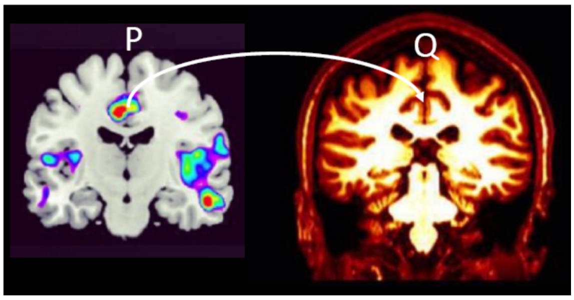

Figure 3: Image registration finds a spatial transform mapping one image into another.

Two images are involved when registration is carried out. One image is taken as source image or fixed image (fMRI), and the other as target image (DTI). Registration is the determination of a one-to-one mapping between the coordinates in fixed image and those in target image, such that points in the two images that correspond to the same anatomical point are mapped to each other (Maurer, 1993). Referring to equation 1, the simple task of image registration is to establish correspondence between features in sets of images, and using a transformation model to infer correspondence away from those features (Crum, 2005).

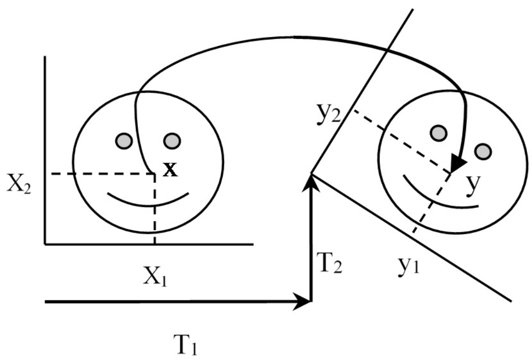

Figure 4: 2D rigid transformation of skull radiographs.

Transformation represents the spatial mapping of points in the floating image to points in the target image (Porawat, 2014). In 2D to 2D image transformation e.g. the transformation of fMRI to DTI, 2 translations (up-down/left-right) and 1 rotation may be needed. Figure 4 shows the parallel projection of skull radiographs, rigid 2D transformation controlled by a rotation Θ and two translation parameters T_1 and T_2, respectively.

This is a Linear mapping from (x_1, x_2) to (y_1, y_2), therefore,

$$y_1 = \cos\Theta.x_1 - \sin\Theta.x_2 + T_1$$
$$y_2 = \sin\Theta.x_1 - \cos\Theta.x_2 + T_2 \quad (2)$$

Equation 2 can be derived into matrix form y =Ax, such that,

$$y_1 = a_{11}.x_1 + a_{12}.x_2 + a_{13}$$
$$y_2 = a_{21}.x_1 + a_{22}.x_2 + a_{23} \quad (3)$$

This is so called the homogeneous coordinate transformation of 2 images. In most cases of affine transformations on images, the rotation around the given location and the scaling with respect to a fixed point are also needed to be considered, the transformation function of these cases are

$$T(x,y).R(\Theta).T(-x,-y),$$
$$T(x,y).S(S_x,S_y).T(-x,-y), \text{ respectively.} \quad (4)$$

There are many well-known techniques for brain image registration, such as surface matching, surface extraction, registration using external landmark points set, and intensity-based registration. Surface matching is a popular choice because of the rigidity of the brain shape. Surface extraction is also successful registration for the multi-modality of CT, MR and PET brain images (Fitzgibbon et al., 2012). External landmarks attached to the brain have also been used to assist the registration (Wirth, et al., 2002). Since the introduction of mutual into medical image registration (Maes et al., 2013), intensity-based registration methods have been widely used (Pluim et al., 2003). The goal of these methods is to choose the transformation types (e.g. rigid, non-rigid, affine), and treat it as an optimization problem with how to find the spatial mapping of images.

4 THE PROPOSED METHOD

The objectives of this study can be summarized as to:

1. Purpose a new method of registration for Autistic brain images called Template-based affine registration.

2. Test the proposed method with brain images data set, and compare the results with the well-known registration methods.

The novel method of brain image registration has been investigated. The method will be applied for image analysis of autistic patients. The new method involves integrating the images to create a composite view, extracting information that would be impossible to obtain from a single brain image.

The method will be started with manually identify landmark points set (around 6-12 points) in fMRI and DTI. There are two major concerns of this selection: 1) the accuracy of the selection should be 1mm at center, and around 2 mm at the edge, 2) all landmark points should be related to the soft tissue structures in GM and WM such as enhancing the brain development after taking some treatments. Figure 5 illustrates the proposed method.

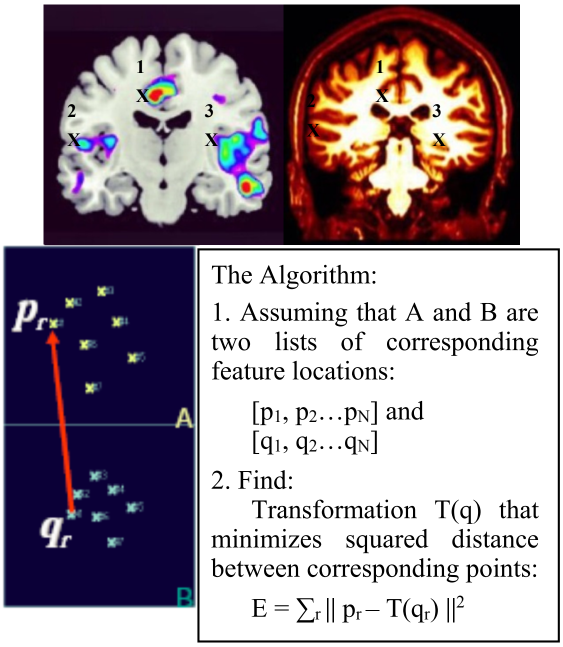

Figure 5: Template-Based affine registration.

Supposing that we have two lists of landmark points of two images:

$$A = [p_1, p_2 \ldots p_N] \text{ and}$$
$$B = [q_1, q_2 \ldots q_N]$$

It is the optimization problem of solving the transformation T(q) that minimizes squared distance between corresponding points in A and B.

E is the extrapolation function for all image pixels:

$$E = \sum_r \| p_r - T(q_r) \|^2 \quad (5)$$

Where one set of points, q, is transformed by T().

5 CONCLUSIONS

This position paper presents a very simple but important matter in image registration. The expected result of this study is useful to register between two multimodal brain images of autism (fMRI and DTI). The expected benefit is the new method of registration for autistic brain images which has many potential applications in clinical diagnosis.

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