AUTOMATIC IMAGE REGISTRATION BASED CONTROL POINTS AND EVALUATION

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Abstract - In this paper, we present a fully automatic image registration method, applied to a pilot study. Image registration plays an important role to the medical image field for the patient prognosis and diagnosis. Particularly image standardization and image correlation could be the most significant studies. Therefore, we have created several feasible two dimensional color training images with the objects having different major axes and sizes. The training images were rotated, translated, scaled and sheared. Consequently, we calculated the registered correction by the minimum squared error(MSE) of the between control points distances and object sizes. Then, we obtained a valuable result (>0.04). It could be useful to biomedical image registration.

Index Terms - Automatic image registration, control points, standardization, color training images, registered correction, minimum squared error

I. INTRODUCTION

Image registration is the process of overlaying images of the same scene taken at different times, depth, from different viewpoints, and by different sensors. It is used in computer vision, medical imaging, military automatic target recognition, and compiling and analyzing images and data from satellites. The registration geometrically aligns two images i.e., original/fixed and moving/reference image. The registration approaches are classified according to their characteristics (feature-based and area based) and according to four basic steps of the image registration procedure: feature detection, feature matching, mapping function design, and image transformation [1].

The field of image registration has continuously developed since the 1990s [2-4]. Image registration is a technique that produces some useful and composite data by extracting complementary information from different imaging modalities. In our previous study [5], a marker-based rigid registration approach was implemented. Using the mesh-warp algorithm, main points are set by active inter-user interactions. The image registration was performed using the linear-interpolation algorithm [6-8]. Peng et al. used a large image dataset of MRI images from the 3D brain registration atlas and presented BrainAligner, which is automatically finding the corresponding landmarks in a subject brain and maps it to the coordinate system of the target brain via a deformable warp [9].

In what follows, Section 2 describes the research materials and methods and comparative evaluation of previously developed software. Section 3 presents the detailed description of our software performance. This section also includes the results of our study. Finally, Section 4 contains concluding remarks evaluating the results of the study as well as suggesting a direction for further studies.

II. MATERIALS AND METHODS

A. Background

Image registration is a geometric method that could be separated into automatic or semi-automatic registration. Generally the algorithms are the mesh-warp based, axis/line based or control points based algorithms. In our study we focus on the fully automatic control points based registration algorithm.

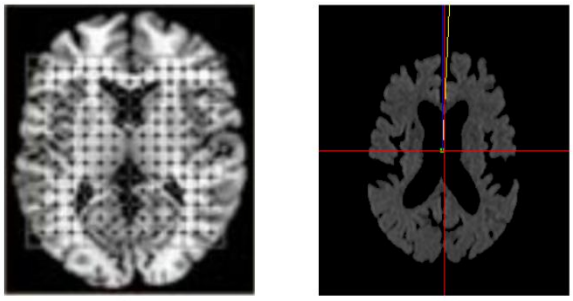


Fig. 1 – Registration methods for the brain MR images; (a) mesh based and (b) line based registration

In the mesh-warp algorithm, which was implemented in our previous study [5], a user sets a 15 x 15 sized mesh grid (Fig. 1 (a)). Each of the 196 mesh points can be moved, i.e., the user can edit the locations whenever he/she wants. Then we accessed the region of interest (ROI) and applied a region growing method (RGM). Another of our image registration methods was the line-based registration [10]. Generally, MR images are not well aligned, and therefore we implemented realignment and rotation correction based on the MR image header data. The orientation position indicated the directionality of the patient by a yellow line. The blue line referred the patient position to the baseline for

easier identification of the orientation position. The red cross represents the center of the image's width and height in Fig.1 (b). The accuracy was 70% for the corrected registration.

B. The Existence Registration Tool

Examples of previously developed software are SPM, Analyzer, Brain Voyager, MRIcro, 3D Slicer, and MNI auto registration package etc. Some software have already developed been and commercialized. SPM, MRIcro, and 3D Slicer can serve as typical examples of medical image processing software that can support brain MR images. The SPM software package is designed to analyze brain imaging data sequences. This software supports fMRI, PET, SPECT, EGG, and MEG data. MRIcro image retrieves and displays brain images effectively. This software provides the region of interest selection function for neuropsychologists. However, this software cannot be used for clinical research because of a lack of image registration function. 3D slicer is a good image visualization software. However, this software does not include a function for image registration and only supports 3D visualization. The functionality of the visualization is excellent, but other processing is very time consuming. We have shown our comparison study for the different software tools in Table I.

Comparison	SPM	MRIcro	3D-Slicer
Requirement data	volume	volume	volume
GUI Convenience	learning	intuitive	intuitive
Speed	slow	fast	slow
ROI	impossible	possible	impossible
Fix error	impossible	possible	impossible
Registration	possible	impossible	impossible
Data accumulation	impossible	impossible	impossible
Variable statistical	possible	impossible	impossible

Table I. Comparison 3 existing software with the functionalities

***C.* Implementation of Our Algorithm**

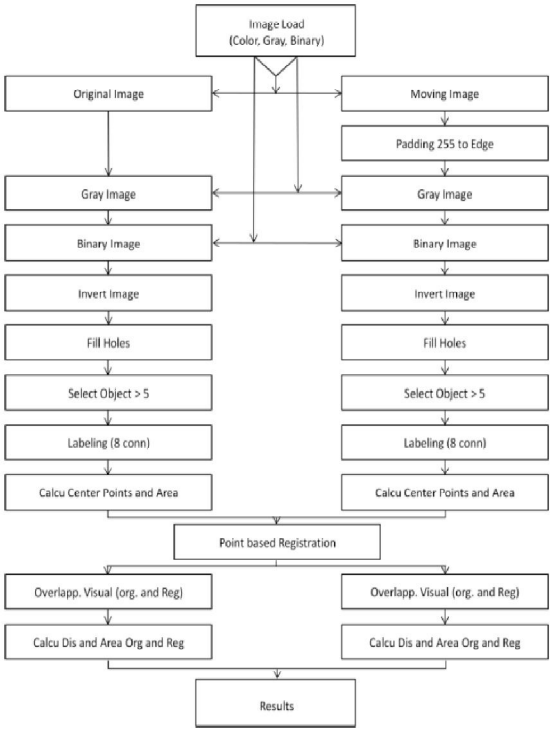


Fig. 2 – Control points based the full automatic image registration process

The whole image registration of our software consists of two parallel parts. The left part is the original image handling, consisting of 11 hierarchical processes. The right part is the moving image handling, consisting of 12 hierarchical processes. Firstly, the image loading should be able to load any type images.If you load a gray or binary image you can skip the converting processes. Then the following processes are Filling holes, Object selection, Labeling and Calculation the center point of each object. Finally the moving image can be registered to the original image. In the evaluation part we calculated the correction of the registration. The calculation is two factors for the distances and areas between the original image and moving image (see in the Fig. 2). The differences were visualized by color mapping.

We have created a 2D ground truth color image(O) (360×480) (e.g., original image) with 9 objects that have different colors, sizes and directions (Fig. 3(a)). The training image set contains 6 Images that are: a translated image (T) by 10 pixels to X-axis and 10 pixels to Y-axis (Fig. 3 (b)), rotated image(R) by 2 degrees to the counter clockwise direction (Fig. 3(c)), scaled image(S) by 1.2 time expansion (Fig. 3(d)), sheared image(SH) by1.2 to Y-axis (Fig. 3(e)), combined RST (Fig. 3(f)), and RSShT transformed images (Fig. 3(g)).

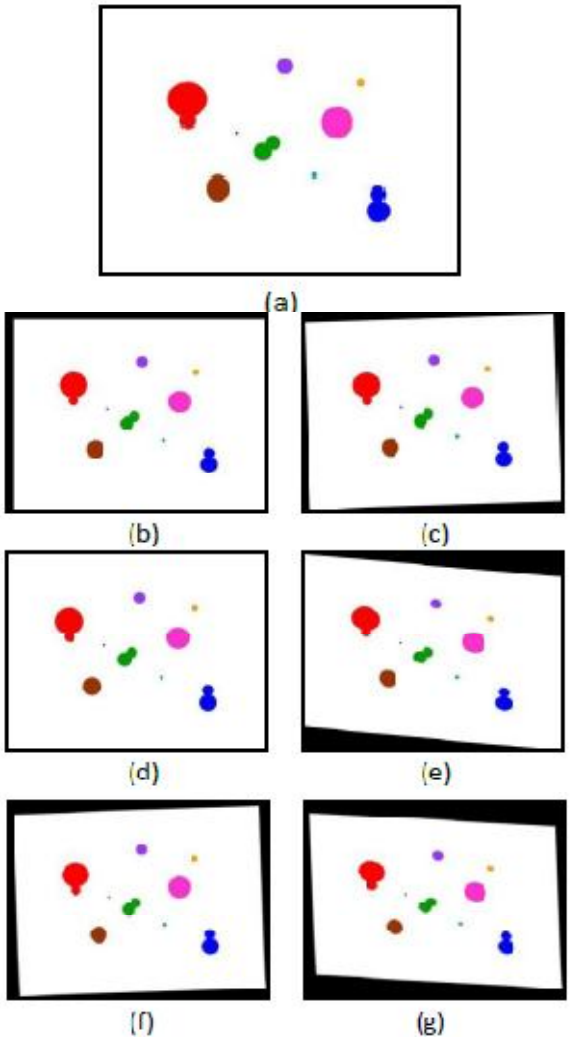


Fig. 3 – Original image (a) and transformed images; translation (b), rotation (c), scale (d), shear (e) RST (f), and RSShT (g).

Fig. 4 shows our implementation for calculating the center points of both the original(O)(360X480) and moving image(RSShT)(463X602). Fig. 4(b) will register to Fig. 4(a) according to the center point.

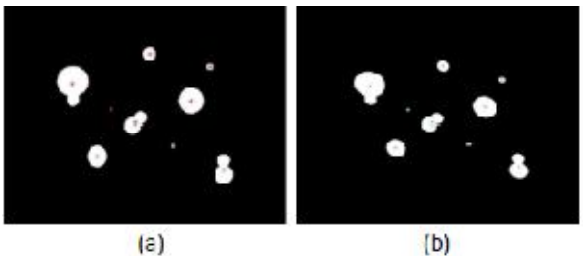


Fig. 4. Center point of each object; (a) original image(O)(360X480) and (b) moving image(RSShT).

III. RESULTS

The results of the image registration are shown in Fig. 5. The left column of Fig. 5 shows the overlapping between the original and moving images and the right column of Fig. 5 shows the overlapping between the original and registered images. The pink color is the object areas of the original image. The green color is the object areas of the moving image and the white is the overlapping of the two object areas. If the final registered image only contains white, it is a perfectly correct registration.

Fig. 5 (a) and (b) are the visualization of the correct registration of the translated image(370X490), (c) and (d) for rotated image(377X493), (e) and (f) for scaled image (432X576), (g) and (h) for sheared image(408X480), (i) and (j) for RST image (463X602) and (k) and (l) for RSShT image(463X602).

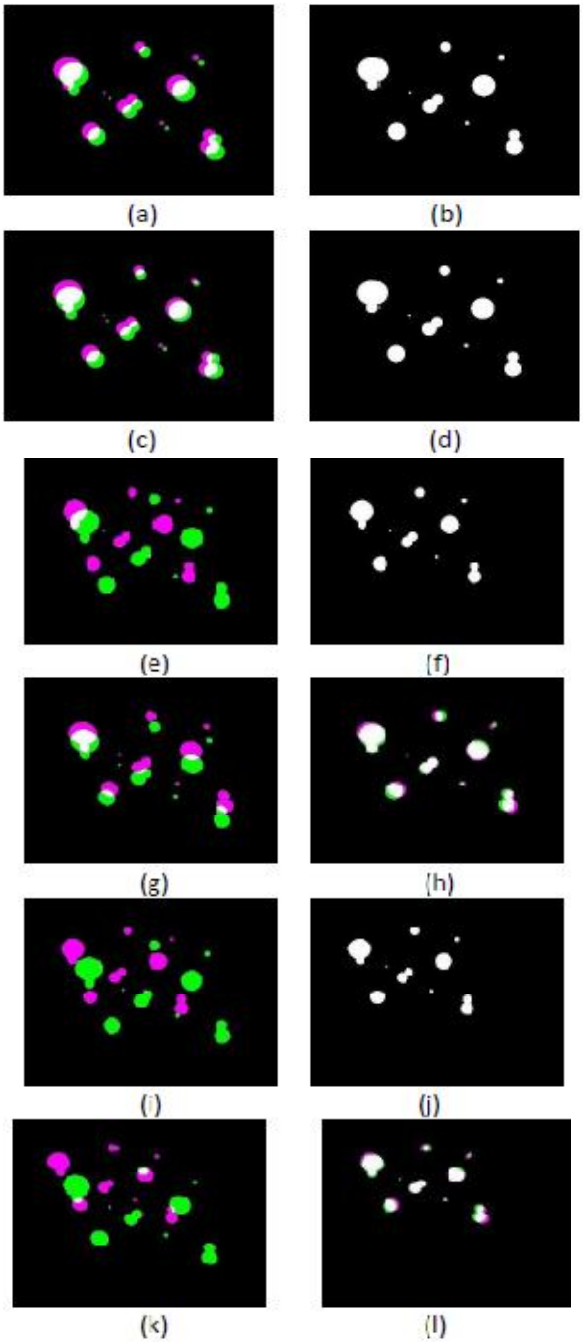


Fig. 5 – Results of the registration of different transformed images and visualization of the comparison between the original, moving and registered images (pink: the object areas of the original image, green: the object areas of the moving image, white: overlapping object areas)

As evaluation of correctly registered images we calculated the error distance between the center points for the original and moving images, i.e., distance of minimum squared error(SMSE) using the equation below. The total ratio (registration image error/moving image error) of the error distance was 0.24 pixels and the average was 0.04 pixels for the 6 transformed images (see Table II).

$$SMSE = \sum_{i,j=1}^{9} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

i: object center point of original image,
j: object center points of moving image

Image Type	Error of Org and Moving Image	Registration Error	Ratio (Reg/Mov)
Rotate	95.542289	1.000911	0.01
Scale	562.814563	1.271013	0.00
Shear	225.712426	40.349075	0.18
Translation	127.384472	0.644118	0.01
RST	793.767566	1.115815	0.00
RSShT	984.220950	40.940398	0.04
SUM	2,789.442266	85.321330	0.24

Table II. Error distances before registration and after registration

Table III shows the area differences before registration and after registration and the ratio of the areas before/after registration. The total ratio was 0.450704 and the average was 0.05 pixels for the 9 objects.

Object No.	Area of Org	Area of Mov	Area of Reg	Diff Org- Mov (a)	Diff Org- Reg (b)	Ratio (a)/(b)
1	2391	3499	2409	1108	18	0,016245
2	901	1326	910	425	9	0,021176
3	16	29	19	13	3	0,230769
4	884	1311	910	427	26	0,060890
5	348	514	352	166	4	0,024096
6	51	77	51	26	0	0,038462
7	1402	2031	1402	629	0	0,001590
8	92	135	92	43	0	0,023256
9	1102	1628	1120	526	18	0,034220
SUM	7187	10550	7265	3363	78	0.450704

Table III. The object areas of the original, moving and registration images and the ratio of the areas

DISCUSSION

Image registration was principally presented as three methods: manual, semi-automatic and full automatic registration. Registration based on manual drawing is highly accurate because the user controls the images directly to match with the standard templates. This process consumes lots of time and the results may vary based on the user. Semi-automatic registration depends on the software programming tools. Maes et al. presented a very powerful criterion for three-dimensional medical image registration, allowing robust and accurate fully automated affine registration of multimodal images in a variety of applications, without the need for segmentation or other preprocessing of the images [11]. The automatic registration could be done quickly because all the processing is done automatically only by inputting the images [12]. This method is very sensitive. That means it may not always produce good results. Our algorithm implementation has obtained valuable and useful results described by calculation of the error distance and the error area. But the right side images in Fig. 5 have shown error colors at Fig. 5(h) and (i). The two images were accessed using the Shear algorithms. For that reason we used only the center points for the registration. Otherwise, we have really good results for the fully automatic registration. However the method was not compared with the other methods. In the future, our method will be applied to protein stained pathological tissue images.

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