RIGID MEDICAL IMAGE REGISTRATION FOR MONOMODAL IMAGES

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Abstract: Image registration is the fundamental task used to match two or more partially overlapping images taken at different times, from different sensors, or from different viewpoints. It is a technique useful in integrating information from different sources. Image registration techniques can be based upon image gray-scale or image features. Feature based registration gives a coarse result. Thus, using some intensity based method, fine or accurate registration is obtained. This paper presents a registration method for medical images based on contour lines of images and mutual information. First of all, a coarse registration is obtained using contour lines of images obtained from canny detector and then fine registration is accomplished using mutual information maximization.

Keywords: Contour line, mutual information, principal axis, registration.

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1. Introduction:

In Image processing, when combining the information content of image, relationship between two or more images is determined. Specific examples of systems where image registration is a significant component include matching a target with a real-time image of a scene for target recognition, monitoring global land usage using satellite images, matching stereo images to recover shape for autonomous navigation, and aligning images from different medical modalities for diagnosis. Image registration, bringing two or more images into a single coordinate system for subsequent analysis, is sometimes called image alignment, is an important step for a great variety of applications such as remote sensing, medical imaging and multi-sensor fusion based target recognition. It is a prerequisite step prior to image fusion or image mosaic. It is very useful in integrating information, finding changes in images taken at different times, inferring three-dimensional information from stereo images, and recognizing model-based objects.

Registration can be performed either manually or automatically [1]. The former refers to human operators manually selecting corresponding features in the images to be registered. In order to get reasonably good registration results, an operator has to choose a considerably large number of feature pairs across the whole images, which is not only tedious but also subject to inconsistency and limited accuracy. Thus, there is a natural need to develop automated techniques that require little or no operator supervision.

The medical image can provide the distinct information of the patient. It can help a doctor in diagnosis of a disease developed in the body of patient. In the application of the medical images, the registration of the medical images is an important technique for that it not only can help a doctor to watch the developing trend of the disease, but also can help a doctor to make an accurate and reasonable treatment scheme about the disease.

Image matching techniques can be based upon image gray-scale or image features. Gray-scale based matching [2] analyzes images as two dimensional signals and uses statistic methods to locate the correlation functions between signals, and then determine their similarity and homonymy points. Feature-based matching [3] extracts two or more features from the images such as point, line and plane, and determine attributes of these features and then matches the images based on these attributes. The common features in normal practices are colors, textures, shapes and spatial locations. It reduces computation by involving only partial pixels. It increases the adaptability to gray-scale changes, morphing and occlusion.

Feature based registration gives a coarse result due to involvement of partial pixels. Thus, using some intensity based method, a fine or accurate registration can be obtained [4][5].

This paper presents a registration method for medical images based on contour lines of images and mutual information. First of all, a coarse registration is obtained using image contour lines obtained from canny detector and then fine registration is accomplished using mutual information maximization.

The paper is organised as follows: Section II presents a method for course registration using feature information and Section III presents a method for fine registration using intensity information of images. Results and discussions are provided in Section IV. Section V concludes the paper.

2. Coarse Registration:

Coarse registration of image is done by using feature based registration method.

A. Contour Line Extraction

The medical images are rigid, and their edge features are clear. So extraction of contour of images is easy. Brain images are taken as an example. Edges in images are areas with strong intensity contrasts. Edge detection significantly reduces the amount of data and filters out useless information, while preserving the important structural properties in an image.

Edge Detection: Contours of couple medical images are extracted by the use of Canny operator. Canny operator, also known as optimal edge detector, can extract an images' edge clearly and accurately even in the noisy environment.

Contour Extraction: And then, contour features of images can be obtained from the edge images which are obtained by Canny operator by using line by line scanning method. Every row of edge image is scanned from the first pixel to the last pixel and only the first and the last non-zero pixel are selected which gives the contour information in the row direction. Similarly for contour information in the column direction, every column of edge image is scanned from the first pixel to the last pixel, and only the first and the last non- zero pixel are selected. Thus, the contour line of a medical image is extracted.

B. Registration Based on Contour Line

Rotation Correction:

Let the pixel coordinate in an images' contour line be $\{(x_i, y_i)\ i = 1, 2, \ldots n\}$, where n denotes total number of pixel in the contour line, then the center coordinate of an image can be calculated by

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad (1)$$
$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$

Where, $(\bar{x}, \bar{y})$ denotes the center coordinate of images i.e. $(\bar{x}_r, \bar{y}_r)$ denotes the center coordinate of reference image and $(\bar{x}_f, \bar{y}_f)$ denotes the center coordinate of float image.

Rotation angle can be calculated by the Principal Axes of the couple medical images. Set the inertia matrix of contour line of images as

$$I = \begin{pmatrix} u_{11} & u_{12} \\ u_{21} & u_{22} \end{pmatrix} \quad (2)$$

Where,

$$u_{11} = \sum_{i=1}^{N} (x_i - \bar{x})^2$$

$$u_{22} = \sum_{i=1}^{N} (y_i - \bar{y})^2$$

$$u_{12} = \sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})$$

Based on the inertia matrix in (2), the long axes and the short axes of the couple medical images can be obtained as they are the two eigenvectors of the inertia matrices. Then, the included angles of the two long axes and the two short axes can be obtained respectively as

$$\begin{aligned} \theta_1 &= Cos^{-1}(V_r(1,2)*V_f(1,2)+V_r(2,2)*V_f(2,2)) \\ \theta_2 &= Cos^{-1}(V_r(1,1)*V_f(1,1)+V_r(2,1)*V_f(2,1)) \end{aligned} \quad (3)$$

Where V_r represents eigen vectors of reference image inertia matrix and V_f represents eigen vectors of float image inertia matrix. The average of the two included angles is the initial rotation angle. Based on the initial rotation angle, float image was rotated.

Scaling Correction:

Again the Inertia matrix for the rotated float image can be calculated by repeating the above procedure. Let $V_{f'}$ be eigen vectors for rotated float image. Then the slope of the eigen vectors of newly calculated eigen vectors of rotated float image and eigen vectors of reference image can be calculated by

$$\begin{aligned} m1 &= -V(2,1)/V(1,1) \\ m2 &= -V(2,2)/V(1,2) \end{aligned} \quad (4)$$

Principal axes can be plotted for both images as it passes through center coordinate $(\bar{x}, \bar{y})$ and slope of the axes is known. Shift this principal axes, till this axes just touches the object boundary and boundaries of the object is drawn by the rectangle enclosing the images. By calculating the difference between the values of those shifts, width and height of the object can be obtained. The ratio of width of reference to rotated float image is the scaling factor in y-direction and ratio of height of reference to rotated float image is the scaling in x-direction. The rotated float image will be scaled by the obtained scaling factor and the size of the scaled image is same as the size of reference image.

Translation Correction:

Again the center coordinates $(\bar{x}_{f''}, \bar{y}_{f''})$ of scaled float image can be obtained. Furthermore, the initial translation parameters of the couple images can be calculated by

$$\begin{aligned} \Delta x &= \bar{x}_{f''} - \bar{x}_r \\ \Delta y &= \bar{y}_{f''} - \bar{y}_r \end{aligned} \quad (5)$$

Based on the initial translation value, the coarse registration of the couple medical images is accomplished.

3. Fine Registration:

Mutual information (MI) is a popular entropy-based similarity measure used in the medical imaging field. The mutual information is a measure of the mutual dependence of the two images i.e. it represents the statistics correlation of two sets of data. Registration is assumed to correspond to maximizing mutual information i.e. the images have to be aligned in such a manner that the amount of information they contain about each other is maximal. The MI of two images A and B is calculated as follows:

$$I(A, B) = H(A) + H(B) - H(AB) \quad (6)$$

Where, $H(A) = -\sum P_A(a) \log P_A(a)$

denotes the entropy of image A and the joint entropy is calculated by $H(AB) = -\sum P_{A,B}(a,b) \log P_{A,B}(a,b)$.

The more large value of the MI is reached in the registration procedure, the more accurate registration results are obtained.

So varying the input image over a range of angles, a set of translation is checked for rotated image with respect to input image and the value of translation and rotation for the maximum value of mutual information is noted. Then the resultant image of coarse registration is rotated and translated by that amount to get fine registration result.

4. Result and Discussions:

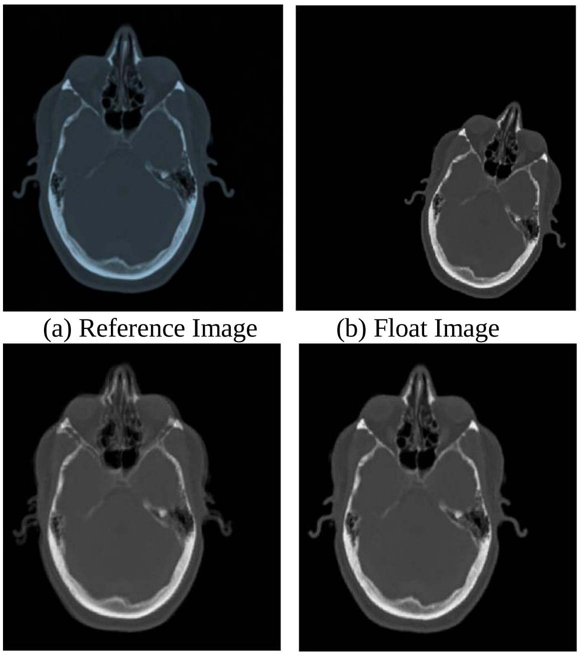
The reference and floating image consist of 256 intensity values i.e. 8 bits grey-scale medical images.The registration parameters obtained are given in Table I and Table II. Fig.1 shows the registration result between two CT images for up-scaling, Fig.2 shows the result between two CT images for downscaling.

TABLE I. COARSE REGISTRATION PARAMETERS

Fig	Rotation (in degrees)	Scaling		Translation	
		Sx	Sy	x	y
1	18.78	1.31	1.31	145	249
2	19.34	0.693	0.697	12	34

TABLE II. FINE REGISTRATION PARAMETERS

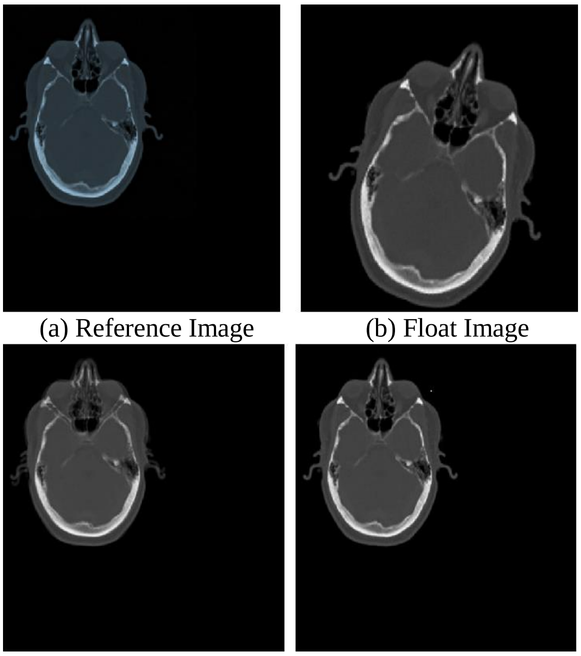
Fig	Rotation (in degrees)	Translation		Maximum MI
		x	y	
1	-4	12	11	1.7
2	-2	14	26	1.14



(a) Reference Image (b) Float Image

(c) Coarse Registration (d) Fine Registration

Fig.1 Registration between CT Images for up-scaling



(a) Reference Image (b) Float Image

(c) Coarse Registration (d) Fine Registration

Fig.2 Registration between CT Images for downscaling

As the method is a combination the feature and intensity information of images, it involves less mathematical calculations. In feature-based method, partial pixels are selected and thus, calculation is reduced and in intensity-based method, mutual information is to be calculated over a small range of angles as the course registration gives us an approximate result.

5. Conclusion: A registration method of the medical images based on contour lines of images and mutual information is proposed in the paper. The features and intensity information of images are used effectively in the proposed method. The result shows that the proposed approach involves less complexity and is an effective medical image registration method.

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