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A new technique for accurate image registration of Monomodality images

S.Arivazhagan[1], V.R.S.Mani[2] and G.Prema[1]

[1]Department of ECE, Mepco Schlenk Engineering College, Sivakasi-626005, India.

[2]Department of ECE, National College of Engineering, Kovilpatti-626005, India.

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ABSTRACT

This paper presents a new technique, used to register two images of the same modality and that are assumed to be differ from each other, by a rotation and a scale. Recently, researchers have introduced image registration techniques using log-polar transform for its scale and rotation invariant properties. However, it suffers from non-uniform sampling and it leads to inaccurate registration. Inspired by log polar transform, a new technique, fast uniform polar transform (FUPT) is used to overcome these disadvantages. The proposed method yields more accurate registration than log polar transform.

Introduction

Image registration is a crucial step in all image analysis tasks in which the final information is gained from the combination of various sources like in image fusion, change detection, and multichannel restoration. Image registration is the process of aligning two or more images of the same scene taken at different times, different sensors, and or by different sensors.

The major purpose of registration is to remove or suppress geometric distortions between the reference and sensed images, which are introduced due to different imaging conditions, and thus bring images into geometric alignment. It geometrically aligns two images—the reference image and the target image.

The main objective of image registration using fast uniform polar transform (FUPT) is to integrate the two images and to have a detailed and informative image representation. Image registration can be categorized into two major groups [1]-[5]: the feature-based approach and the area-based approach. The feature-based approach, use only the comparison of features like color gradient, edges, geometric shape and contour, image skeleton, or feature points. However, the use of feature-based approach is recommended only when the image has enough distinctive features. In some applications, like medical imaging, the images does not contain distinctive features, the feature-based approach can not be used effectively. This can be overcome by area-based approach.

The correlation approaches are found to be successful in registering images that are subjected to translation in the Cartesian, but they fail in the case when the image is subjected to scale and rotation. Combining the phase correlation technique with log-polar transform, the Fourier-Mellin [5], approach provided a breakthrough in area-based method and is invariant to scale and rotation.

Log-polar transform [6]-[10] offer a large visual field, reasonably high resolution, and significant data reduction. This is a valuable feature for real-time performance in active vision algorithms. Another well-known advantage brought by the logpolar transform is that origin-centered rotations and scaling become simple shifts in the log-polar domain. In addition to the general benefits of foveal vision, i.e., foveal sampling (sample points are densest in the centre, allows computational resources to be concentrated on regions), there is still another important advantage of using log-polar images for tracking purposes: an object occupying the central part of the visual field becomes dominant over the coarsely sampled background elements in the image periphery. These log polar transformed based image registration is robust to scale and rotation. However, despite, it suffers from nonuniform sampling, linear features and translational transformations are distorted by logpolar mapping. Hence it is applicable for images that are subjected to changes only at the fovea, because of nonuniform sampling image at the fovea is oversampled and the remaining portion of image is undersampled. Because of this, it would lead to inaccurate registration. Since, no informative information is obtained from oversampling. Hence, the computational cost is wasted. With log-polar transform, the matching process focuses only at the fovea or the area close to the center point of the transformation, while the peripheral area is given less importance.

Inspired by log polar transform, we introduce a new technique technique fast uniform polar transform (FUPT) in the spatial domain that uniformly samples the image and leads to accurate image registration. Introduction of projection transform, on the fast uniform polar transformed image the two dimensional image would be transformed into two one dimensional vectors. Hence, further processing would be easier. With FUPT, rotation and scale in the Cartesian coordinates, appears as shifting and variable-scale in the transformed domain. The proposed method is used to find two parameters: scale and rotation. FUPT is then combined with new innovative projection transform to obtain the scale and rotation parameter directly without the need to do transformation until we get optimal similarity measure. In the existing method optimization technique is used to find the parameters, and it would consumes large amount of time and sometimes misregistration. This can be overcome by the proposed methodology.

Tele:
E-mail addresses: vrsece@redoffmail.com

Fast Uniform Polar Transform

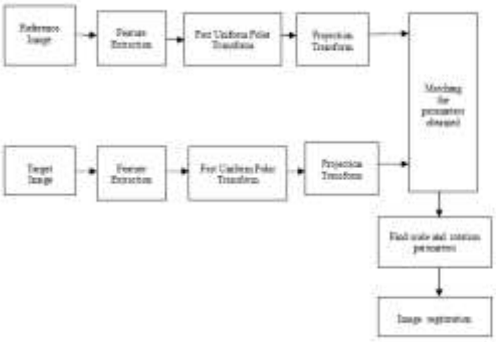


Fig. 1 Block diagram of proposed approach

Fast uniforn polar transform (FUPT) is used to accurately register two mono modality images of the same scene taken at different view points and at different times. Feature points are obtained by using Gabor transform. The reason we choose Gabor wavelet for extracting feature points is due to its invariant properties to scale, rotation, and noise. The overall block diagram of the proposed method is given in Fig.1. The disadvantage of log polar transform, is nonuniform sampling and it can be overcome by this new technique. Section II-A briefly describes about the existing method and its advantages in image registration. Section II-B describes about the proposed FUPT method. Section II-C describes about projection transform.

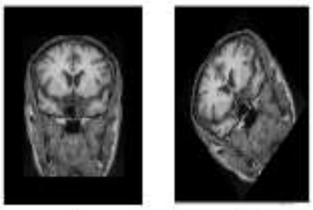
Existing Method

The log-polar transformation is a nonlinear and nonuniform sampling of the spatial domain. Consider the log-polar (log □, □) coordinate system, where *r* denotes radial distance from the center (□□ , □□) and *θ* denotes angle. Any (□, □) point can be represented in polar coordinates as follows:

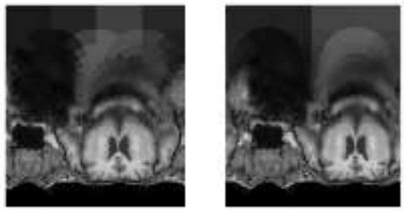
$$r = log_{base}\sqrt{(x-x_c)^2+(y-y_c)^2} \qquad (1)$$

$$\theta = \tan^{-1}\frac{y-y_c}{x-x_c} \qquad (2)$$

In this representation, image scaling and rotation about becomes shift in the log polar domain. Sampling is done by mapping image pixels in the Cartesian to the log-polar coordinates according to (1) and (2). In both the angular and radial direction the image is sampled with the same number of samples ie. for example if we take radius is equal to two and if we obtain ten samples from it means the same ten samples would be obtained for all the radius. So, image pixels close to the fovea (origin) are oversampled than at the peripheral and it would lead to loss of information at the peripherals and leads to misregistration. Rotation and scale in the Cartesian coordinates appear as shifting in the log-polar domain as shown in Fig. 2 (a) is the original image and Fig. 2 (b) is the scaled and rotated image of the original image. Fig. 2 (c) and (d) are the log polar images of Fig. 2 (a) and (b), respectively. From the figure it is observed that scale and rotation in the Cartesian coordinates are represented as shifting in the log-polar coordinates.



(a) (b)



(c) (d)

Fig. 2. (a) Original human brain image; (b) the scaled and rotated image of (a); (c) the log polar transformed image of (a); (d) the log polar transformed image of (b).

Proposed FUPT Method

Although log polar transform has been widely used in many image processing applications, it suffers from nonuniform sampling. As, the image is sampled with the same number of samples, the image content in the center is oversampled than at the periphery of the image. This would lead to loss of information content of the image which is far away from the center. In order to avoid the loss of information from the peripheral, large number of samples are needed in both the logradius and the angular direction. Another disadvantage of log polar transform in image registration is matching. However, the number of samples obtained at fovea using log-polar transform is larger than at periphery because of this, while matching reference image and target image that have large alteration at the periphery then it would lead to inaccurate registration. Let □□ denote the number of samples in the log-radius direction and the number of samples in the angular direction. Given a square image of size 2s× 2s pixels to uniformly sample the image in both the directions, let L1 as size of radius in pixel for the sample s,

L1 = 1, . . , n_r respectively.

$$S_l = l \times \frac{S}{n_r} \qquad (3)$$

To evenly sample the image in log-radius and angular direction, the parameters should be adaptive. Each circumference would cover approximately 2xl pixels, the number of samples in the angular direction for each sample l in the radius direction nl can be adjusted accordingly.

$$n_r = S,\ n_{\theta_l} = 8S_l \qquad (4)$$

The complete implementation to transform a square image with size 2S × 2S pixels in the Cartesian *I (x, y)* to fast uniform polar transform as given as: L P(r, θ)

$$l = \left(S + S_l\cos\left(\frac{2\pi m}{n_{\theta_l}}\right)\right)$$

$$m = \left(S + S_l\sin\left(\frac{2\pi m}{n_{\theta_l}}\right)\right)$$

Example for applying fast uniform polar transform (FUPT) to human brain is shown in Fig. 3. Hence, the FUPT allows the samples to be distributed adaptively according to the size of the radius and the result in this mapping is a series of sample bins arranged in the step like manner as in Fig. 3. Hence by using FUPT, the number of samples required to get the same resolution is found to be less than log polar transform. Note that in (a), the distance between consecutive sampling points in the radius direction and angular direction remains the same for all radius circumferences.

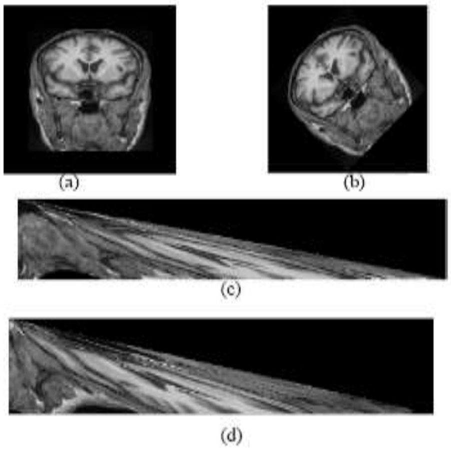


Fig.3. Examples of FUPT: (a) the original human brain image, (b) the scaled and rotated image of (a), (c) the FUPT transformed image of (a), and (d) the FUPT transformed image of (b).

Projection Transform

From Fig.3 (c) and (d) it is observed that scale and rotation in the case of Cartesian coordinates will result in simple shift in FUPT and the samples are arranges in step like manner.

However, to maintain this invariant change to scale and rotation, we use one more transform on the fast uniform polar transformed image, the *projection transform,* which is used to project two dimensional image in to two - one dimensional vectors in both radius and angular direction. Projections are well known technique allowing one to address some problems by reducing their dimensionality. From which the scale and rotation parameters of the target image with respect to the reference image can be easily found out.

Given a transformed image l p(r, θ) that consists of n sample bins in which each bin has the length of $n_{\theta l}$ for l =1,…, n_r. We denote R and θ as the projection on the radius coordinate, and the projection on the angular coordinate, respectively. The mathematical expressions of R and θ are as follow:

$$R(l) = \sum_{m=1}^{n_{\theta_l}} IP(l,m) \tag{5}$$

$$\theta(m) = \sum_{l=1}^{n_r} IP(l,m) \tag{6}$$

Scale parameter can be found out by *Fourier Method.* The scaling property of Fourier transform is given a signal x(t) whose Fourier transform can be given as,

$$x(t) \leftrightarrow X(\omega) \tag{7}$$

Then the fourier transform of the scaled signal can be given by

$$x(ut) \leftrightarrow \frac{1}{|u|} X\left(\frac{\omega}{u}\right) \tag{8}$$

From the above equation given the Fourier transform of the projection R(.) as r(.), we can obtain the scale parameter c by,

$$|c| = \frac{\Gamma^{reference\ image}(0)}{\Gamma^{target\ image}(0)} \tag{9}$$

This method performs effectively only when the scale parameter is small. This algorithm can be used in medical images.

The next step after finding the scale parameter is to find the rotation parameter. The rotation parameter can be found by using correlation function $C(\theta^{reference\ image}, \theta^{target\ image})$. Rotation parameter can also be found out by using radon transform. Where d is obtained from the maximum correlation $C(\theta^{reference\ image}, \theta^{target\ image})$.

$$\theta = \frac{2\pi d}{n_\theta} \tag{10}$$

Image Registration Using FUPT

First, extract the feature points from both reference and target image. Choose one feature point from the reference image and find the corresponding feature point from the target image. Compute the projections R and θ using the proposed FUPT method and the projection transform explained in the Section II. The projection transform will result in projection parameters in both radial and angular direction. By matching the R and θ parameters of reference image with that of the target image scale and rotation parameters can be found out.

Experimental Results

We evaluate the performance of image registration approach in general conditions, in which the images are subjected to scale, rotation. Different scale and rotation parameters are applied to the images: human brain, skull, tree using matlab.

Since, the entire area of the reference image is used in this test, the reference image is also considered as the model image. The human brain image is then scaled and rotated with the parameters of 1 and 30 degree respectively, and used as the target image. The registration results using the log polar transform based approach and the proposed FUPT approach are shown in the Table I, II, III.

The errors of the registration results compared to the the proposed method and the log polar transform as shown in the Tables, where, c represents scale and represents angle.

However, both methods yield small errors but only the proposed method can successfully register images, that are subjected to scale and rotation than that of log polar transform. This is because FUPT does not concentrate only at the fovea as the conventional FUPT, but consider importance to the entire image.

Conclusion

Although log polar transform has been widely used in many image processing applications, it suffers from nonuniform sampling. Hence, the disadvantage of log polar transform: the high computational cost in the transformation process, and mismatch of images due to over sampling at the fovea in the spatial domain, can be overcome by FUPT. Experimental results indicate that our proposed image registration approach is better than that of log polar transform.

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Table 1: Performance Comparison of Proposed and Existing method for Human Brain Image

Image (Human Brain) with image size	Proposed Method(FUPT)				Existing Method(Log polar transform)			
	scale (c)	Error in (c)	Angle in degree (θ)	Error In (θ)	Scale (c)	Error in (c)	Angle in degree (θ)	Error in (θ)
(421 x 421) c = 1.2 $\theta = 30$	1.1465	0.0535	31	1	1.0154	0.1846	31	1
(325 x 325) c = 0.9 $\theta = 35$	1.0042	0.1042	36	1	1.042	0.142	36	1
(265 x 265) c = 0.8 $\theta = 20$	0.9755	0.1755	21	1	1.0610	0.2610	21	1
(273 x 273) c =0.75 $\theta = 39$	0.8755	0.1255	40	1	1.0549	0.3049	40	1

Table 2 Performance Comparison of Proposed and Existing method for Tree Image

Image (Tree) With image size	Proposed Method(FUPT)				Existing Method (Log polar transform)			
	scale (c)	Error in (c)	Angle in degree (θ)	Error In (θ)	Scale (c)	Error in (c)	Angle in degree (θ)	Error in (θ)
(341 x 341) c =0.95 θ= 35	0.9422	0.0078	36	1	1.0203	0.0703	36	1
(325 x 325) a = 0.9 $\theta = 55$	0.9052	0.0052	56	1	1.0166	0.1166	56	1
(277 x 277) a = 0.8 $\theta = 64$	0.9336	0.1336	65	1	1.0262	0.2262	65	1
(257 x 257) c =0.75 θ = 45	0.8575	0.1087	45	0	0.8984	0.1484	45	0

Table 3: Performance Comparison of proposed and existing method for Skull Image

Image (Skull) With image size	Proposed Method(FUPT)				Existing Method (Log polar transform)			
	scale (c)	Error in (c)	Angle In degree (θ)	Error in (θ)	Scale (c)	Error in (c)	Angle in degree (θ)	Error in (θ)
(393 x 393) c = 1.1 $\theta = 35$	1.1352	0.0351	35	0	0.9547	0.1453	35	0
(409 x 409) c = 1.2 $\theta = 65$	1.1354	0.0646	64	1	0.9485	0.2515	64	1
(329 x 329) c = 0.9 $\theta = 50$	0.9878	0.0878	49	1	1.1545	0.2545	49	1
(273 x 273) c =0.75 $\theta = 45$	0.8044	0.0544	45	0	0.9774	0.2274	45	0