JOURNAL OF PATTERN RECOGNITION RESEARCH 7 (2012) 90-105

Received July 17, 2011. Revised October 24, 2011. Accepted February 24, 2012.

Image Registration Using Log Polar Transform and Phase Correlation to Recover Higher Scale

Jignesh N Sarvaiya *jns@eced.svnit.ac.in*
Electronics Engg. Department,SVNIT,
Surat-395007, Gujarat, India

Suprava Patnaik *ssp@eced.svnit.ac.in*
Electronics Engg. Department,SVNIT,
Surat-395007, Gujarat, India

Kajal Kothari *kajalkothari@yahoo.co.in*
Electronics Engg. Department,SVNIT,
Surat-395007, Gujarat, India

Abstract

Image registration is an important and fundamental task in image processing used to match two different images. Given two or more different images to be registered, image registration estimates the parameters of the geometrical transformation model that maps the sensed images back to its reference image. In all types of image registration, robustness of the algorithm is the main and required goal. Image registration is the process of spatially aligning two or more images of a scene taken at different times or with different sensors or from different viewpoints. This basic capability is needed in various image analysis applications which include remote sensing, medical image analysis, object recognition, etc. In this paper, we have proposed an algorithm that is based on Log-Polar Transform (LPT) and Phase Correlation to register images which are transformed by rotation, translation and higher value of scale. In the proposed algorithm, first we roughly estimate the scale between the images using log-gabor function and then downscale the sense image by scale factor 2. The proposed algorithm can recover scale value up to 4.10. The robustness of this algorithm is verified on different images with similarity transformation, partial data and in the presence of noise.

Keywords: Image Registration, Log-Polar Transform (LPT), Fast Fourier Transform(FFT), Log-Gabor Function

WWW.JPRR.ORG

1. Introduction

Image registration is the determination of geometric transformation between two images. It is used to detect changes in the images of same scene, integrate information from different sensors, estimate object motion [1, 2, 20]. When images are taken from different position at same viewing angle, there exist geometrical transformation such as rotation, translation and scale between two images. Various methods have been developed and surveys have been published regarding the same[1, 2, 16]. The original methods, such as NCCA (Normalized Cross Correlation Algorithm), SSDA (Sequential Similarity Detection Algorithm), and SDA (Square Difference Algorithm) are not suitable for rotated image registration [17].

Image registration is a prerequisite step prior to image fusion or image mosaic. It is classified into two categories. First is the intensity based approach, in which image intensity values of whole image is used to estimate mapping function. Second is the feature based approach, in which feature points are extracted and by using those feature points only, mapping function is calculated. The proposed algorithm is based on intensity values [1]. The algorithm should be robust that would perform automatic image registration accurately even in the presence of noise. In area-based methods, feature detection and feature matching steps are merged. The most common area based methods

© 2012 JPRR. All rights reserved. Permissions to make digital or hard copies of all or part of this work for personal or classroom use may be granted by JPRR provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or to republish, requires a fee and/or special permission from JPRR.

are correlation like methods [1, 2, 9, 13]. Image registration technique using normalized cross-correlation was described in [13], to register images, deformed by translation only. Face image registration method using normalized cross correlation algorithm is described in [15].

The approach described in [10] tried to register images, using cross-correlation-like method, which are deformed by rotation and translation. Two main drawbacks of the correlation-like methods are the flatness of the similarity measure maxima and high computational complexity [1]. The maximum can be sharpened by preprocessing or by using the edge or vector correlation. The method discussed in [9] applied image filtering as preprocessing step to improve the cross correlation performance on noisy or highly correlated images, in preprocessing step. Phase correlation is based on Fourier Shift Theorem which can be used to find rotation and translation in polar domain. An extension of the phase correlation to register images deformed by rotation and translation is introduced by [10].

The rotation invariant template matching algorithm based on ring projection transformation and Zernike moment is described in [14]. An algorithm to analyze correct translation between two input images and then, by using phase correlation, scale and rotation can be estimated [11]. The fast and accurate image registration algorithm based on pseudo-polar Fast Fourier Transform is proposed by [8]. Rotation of a two dimensional signal in Cartesian coordinate corresponds to the translations of angles in polar coordinates. Log polar mapping is a polar quantization where radial steps are taken logarithmically rather than uniformly [12]. Log polar transform is rotation and scale invariant [3, 4, 7].

Therefore combination of LPT and phase correlation is used to register images, transformed by scale, rotation and translation. An FFT-Based technique for translation, rotation, and scale-Invariant image registration, which can recover the scale value up to 1.8 is discussed in [3]. The image registration algorithm using Log polar transform and phase correlation can efficiently recover the scale factor up to 2 [7]. This algorithm applies a LPT to the magnitude spectrum of reference and sense images, the rotation and scale is recovered by using phase correlation in the log-polar space. This method exploits the fact that by operating on the magnitude spectrum of an image, the translational differences are avoided since the magnitude spectrum of an image and its translated counterpart image are identical; only their phase spectrum are different. Furthermore, the log-polar transformation causes rotation and scale to be manifest as translation, whereby phase correlation can be applied to recover the rotation angle and scale factor between the pair of input images [4].

If higher computational speed is required or if the images were acquired under varying conditions or they are corrupted by frequency-dependent noise, then Fourier methods are preferred rather than the correlation-like methods. They exploit the Fourier representation of the images in the frequency domain. The phase correlation method is based on the Fourier Shift Theorem and was originally proposed for the registration of translated images [1, 3, 6, 7]. It computes the cross-power spectrum of the sensed and reference images and looks for the location of the peak in its inverse. The computational time savings are more significant if the images, which are to be registered, are large. They have a low computational complexity and take a fixed period of time in registering any images. On the contrary, most spatial methods are with high computational costs, and the time used in registering two images with spatial methods is unpredictable, depending on the images to be registered [8].

In this proposed algorithm, LPT is used to recover the value of scale and rotation. This module supports the scale of 2. To retrieve the higher value of scale, first the sense image is down scaled by the factor of 2. The approximate value of scale between the images is estimated using Log-Gabor filter. If the scale factor between the images is greater than 2 then the sense image is downscale by

2. So that higher value of scale up to 4 can be recovered. Log polar module is used for scale and rotation estimation and phase correlation in spatial domain is used for translation estimation.

2. Log-Polar Transform (LPT)

The Log-Polar Transform is used for image registration for its rotation invariant and scale invariant properties. The log-polar image geometry is used because of the fact that scaling and rotation in Cartesian domain corresponds to pure translation in log-polar domain. The polar coordinates (ρ,θ) correspond to radial distance from the center and angle from the center respectively. Taking logarithm of radial distance ρ, we get log-polar coordinates. The log-polar transformation is a conformal mapping from the points on the Cartesian plane (x,y) to points in the log-polar plane (log(ρ),θ). Considering a polar coordinate system, where ρ is the radial distance from the center of the image say (x_c, y_c) and θ denotes the angle. Any point (x, y) can be represented in polar coordinates and is given by

$$(\rho, \theta) = \sqrt{(x - x_c)^2 - (y - y_c)^2}, \tan^{-1} \frac{(y - y_c)}{(x - x_c)} \tag{1}$$

If the polar coordinate transformation is applied to an image in the Cartesian domain, then the radial lines in the Cartesian domain maps to horizontal lines in (ρ,θ) domain.

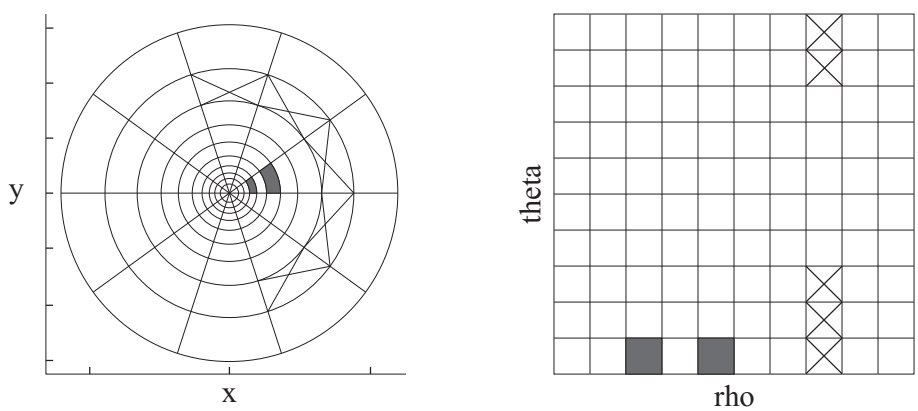


Fig. 1: Approximate mapping from Cartesian space to (ρ, θ) space [7].

Fig.1 shows the approximate mapping from Cartesian space to polar space or (ρ,θ) space. The black box shows that the pixels are at a constant angle with respect to the center. Similarly, the boxes with cross marks are at a constant radial distance from the center. It is clear from Fig.1 that if there was a rotation in the image, the black box will shift its positions on the theta axis [7]. A similar situation can be discussed for the scale variation. In log-polar coordinates, logarithm of the radial axis is taken by

$$(\rho, \theta) = (\log(\rho), \theta) \tag{2}$$

Now if the image is scaled by a factor of say α, then the coordinates (x, y) in Cartesian domain will become (αx, αy). Introduction of logarithms will simplify the procedure, the coordinates in log domain will be reflected as

$$(log((\alpha x), log((\alpha y) = ((log\alpha + logx), (log\alpha + logy)) \tag{3}$$

The reflection of scaling as translation in log polar domain is clear from (3). The effects of distortions are expressed by log-polar image translation on ρ axis and θ axis, respectively in the log-polar coordinates. However, when the original image is translated by ($\triangle$x, $\triangle$y), the corresponding log-polar coordinates is represented by

$$\rho' = log\sqrt{(e^{\rho}cos\theta - \triangle x)^2 + (e^{\rho}sin\theta - \triangle y)^2} \tag{4}$$

$$\theta' = \tan^{-1}\frac{(e^{\rho}sin\theta - \triangle y)}{(e^{\rho}cos\theta - \triangle x)} \tag{5}$$

According to Equations(4) and (5), the slight translation produces a modification of the log-polar image. Therefore, the log-polar image is not suitable for faithfully extracting translation parameters of images [5,6,17]. To overcome this limitation, the algorithm first applies Fourier transform over the images and then applies the Log-Polar Transform to the magnitude spectrum to recover scale and rotation by using phase correlation in log-polar space. This is due to the fact that the magnitude spectrums of the image and its translated counterpart are same; only their phase spectrums are different [7].

3. Fourier Transform and Phase Correlation

The Fourier transform has several properties that can be exploited for image registration. Translation, rotation, reflection and scale all have their counterpart in Fourier domain[3]. Moreover, using the frequency domain, it is possible to achieve excellent robustness against correlated and frequency dependent noise. An elegant method used to register two images which are shifted relative to one another is to use phase correlation [20]. Phase correlation relies on the translation property of the Fourier transform better known as the shift theorem [3, 7, 10, 12]. Given two images f_1 and f_2; which differ by translation (dx, dy), i.e.,

$$f_2(x, y) = f_1(x - dx, y - dy) \tag{6}$$

Their corresponding Fourier transform F_1 and F_2 will be related by

$$F_2(\omega_x, \omega_y) = e^{(\omega_x d_x + \omega_y d_y)} F_1(\omega_x, \omega_y) \tag{7}$$

Two images have the same Fourier magnitude but a phase difference directly related to their displacement. Because of the shift theorem this phase difference is equivalent to the phase of the cross power spectrum.

$$e^{\omega_x d_x + \omega_y d_y} = \frac{F_1(\omega_x, \omega_y) F_2^*(\omega_x, \omega_y)}{|F_1(\omega_x, \omega_y) F_2^*(\omega_x, \omega_y)|} \tag{8}$$

where * is the complex conjugate.

The inverse Fourier Transform of the phase difference is a delta function centered at the displacement, which in this case, is the point of registration. Fig.2 shows the block diagram of image registration algorithm using LPT and phase correlation. The Fourier Transform assumes a periodic function and the image is truncated, it is crucial to apply a window-function, like the Hanning window, to the input images.

Another implementation difficulty consists of the numerical instability for coordinates near to the origin, Here we used a filter with the following transfer function:

$$H(x,y) = (1.0 - cos(\pi x)cos(\pi y))(2.0 - cos(\pi x)cos(\pi y)), With : -0.5 \leq x, y \leq 0.5 \quad (9)$$

4. Proposed Algorithm

In this section, we have discussed the proposed image registration algorithm. After convolution with high pass filter, transform both the images in log-polar domain. By using phase correlation in log-polar domain, scale and rotation can be found and after re-scale and de-rotate, translation is found by phase correlation in spatial domain. The detail algorithm is shown in Fig.2.

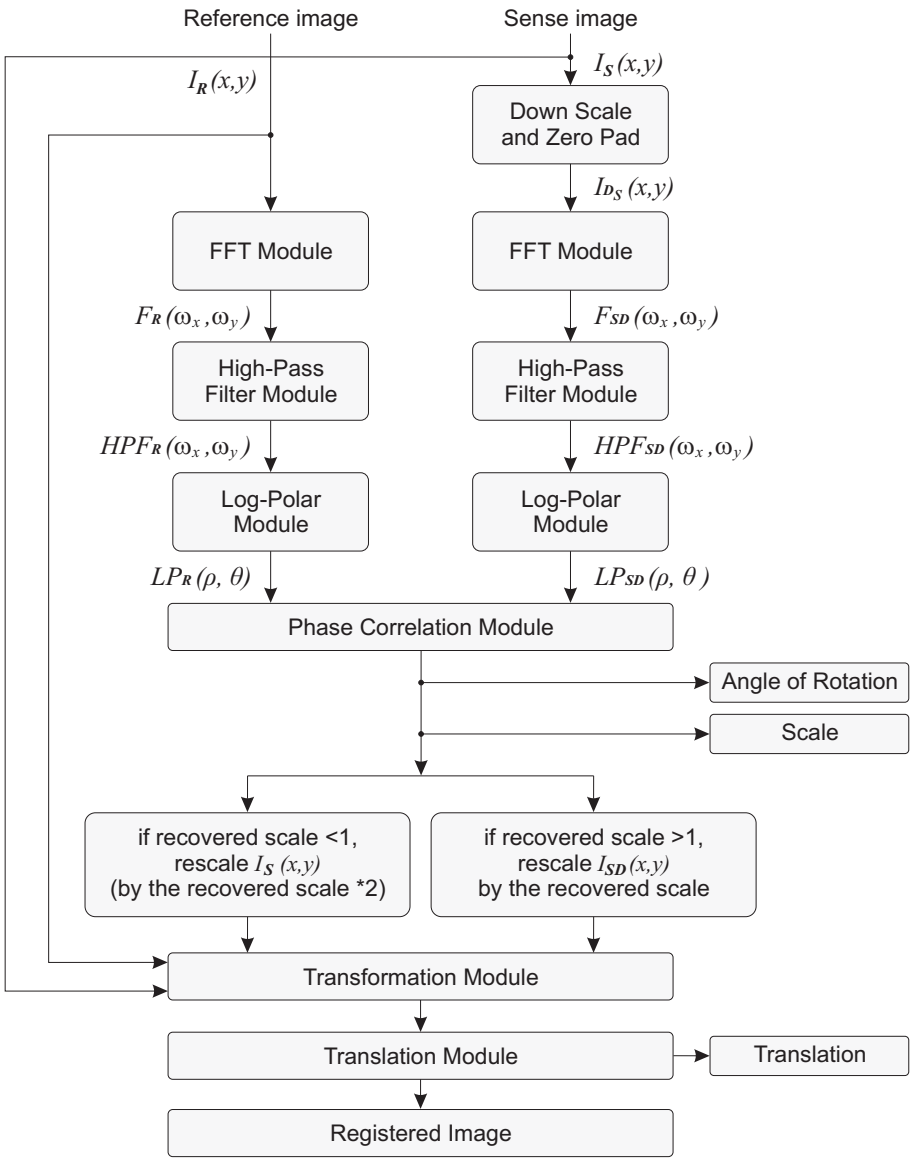


Fig. 2: Block diagram of algorithm.

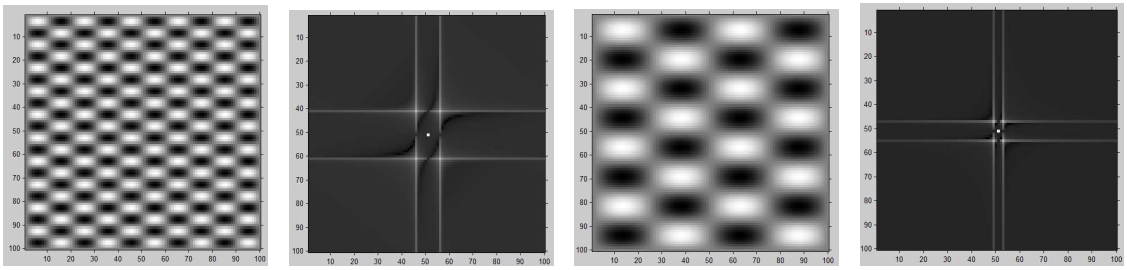
Before down scale the sense image by 2, the rough scale between the images is estimated using the log-gabor function. if there is a scale between the images then it is downscale by factor 2. The reson to use log-gabor filter is discussed below to justify for down scale the sense image by 2.

Image scaling or zooming is a process of altering the focal length of the camera. Scale up involves inclusion of minute details associated with a close up look, whereas scaling down produces an average or approximation of the scene. Zoom-in decreases the apparent angle of view of the image and is accomplished by cropping an image down to a focused area with the same aspect ratio. This increases visibility of high frequency components or the spatial details of the focused and widens the image spectrum. For example, in the image as shown in Fig.3 given below, the texture pattern highlighted in Fig.3(b) is missing in Fig.3(a).

(a) (b)

Fig. 3: Image captured for different zoom: (a) Captured from far Distance, (b) captured from close distance

However in the absence of details, scaling merely involves spatial domain expansion along with spectrum compression. For 2D sine wave pattern, zoom-in increases the size along with decrease in spectrum spread as no more detail are included to the resulting image. Rough information about the scale can then be obtained from the Fourier transform coefficients of such patterns as shown in Fig.4



(a) (b) (c) (d)

Fig. 4: (a) 2D sine wave pattern with f_{1v}=500 Hz and f_{2h}=250 Hz, (b) FFT2 magnitude plot of (a), (c) 2D sine wave pattern with f_{1v}=200 Hz and f_{2h}=100 Hz, (d) FFT2 magnitude plot of (c)

The two major problems associated with scale estimation using FFT2 are:

(i) DC component of the input image dominates in the Fourier magnitude plots and hence determining spectrum spread becomes challenging

(ii) Fourier transform may suffer from aliasing in the presence of high frequency details.

Estimation of variation in the spectrum spread due to associated scale in the presence of high frequency detail can be achieved by Gabor filtering of the image. Gabor filter being a Gaussian modulated sinusoidal results simultaneous processing for spectrum decomposition and high frequency suppression. They now play an important role in image representation because of their increasing importance in many computer vision and image analysis applications. Gabor functions are Gaussians modulated by complex sinusoids. A 2D complex Gabor function that models the responses of simple cells is denoted by [21]

$$G_{\sigma,\theta}(x,y) = \frac{1}{2\pi\sigma^2} e^{i\frac{\pi}{\sigma}(xcos\theta + ysin\theta)} \tag{10}$$

where, σ denotes the width of the Gaussian envelope in space domain, and θ is the preferred orientation.

Gabor wavelets have the optimal energy concentration in the time and frequency plane. Furthermore, they provide multi-scale and multi-orientation information of the input image. An alternative to the Gabor function is the Log-Gabor function proposed in [21]. Field suggests that natural images are better coded by filters that have Gaussian transfer functions when viewed on the logarithmic frequency scale. (Gabor functions have Gaussian transfer functions when viewed on the linear frequency scale). On the linear frequency scale the Log-Gabor function has a transfer function of the form [21]

$$G(\omega) = e^{\frac{-log(\frac{\omega}{\omega_0})^2}{2log(\frac{k}{\omega_0})^2}} \tag{11}$$

where ω_0 is the filter's centre frequency.

To obtain constant shape ratio filters the term k/ω_0 must also be held constant for varying wo. For example, a k/ω_0 value of 0.74 will result in a filter bandwidth of approximately one octave, 0.55 will result in two octaves, and 0.41 will produce three octaves. Comparing with Gabor filters, Log-Gabor filters can be constructed with arbitrary bandwidth which can be optimized to have minimal spatial low frequencies.

There are two important characteristics to note. Firstly, Log-Gabor functions, by definition, always have no DC component, and secondly, the transfer function of the Log-Gabor function has an extended tail at the high frequency end. Field's studies of the statistics of natural images indicate that natural images have amplitude spectra that fall off at approximately 1/ω. To encode images having such spectral characteristics one should use filters having spectra that are similar. Field suggests that log Gabor functions, having extended tails, should be able to encode natural images more efficiently than, say, ordinary Gabor functions, which would over-represent the low frequency components and under-represent the high frequency components in any encoding [21].

Our objective is to register the images having scale value greater than two between reference image and sense image. Before down scaling the sense image, we have to estimate the approximate value of scale between the images using Log-Gabor filter. The rough value of scale between the images is determined as follows.

(i) First the reference image is convolved with the LogGabor function as described in Equation (11). In this work, the Log-Gabor filter with the properties of the scaling between centre frequencies of successive filters and frequency selection is introduced. Due to the singularity in the log function at the origin, one cannot construct an analytic expression for the shape

of the Log-Gabor function in the spatial domain. Therefore, the filters are constructed in the frequency domain.

(ii) The sense image is also convolved with LogGabor function as described in Equation (11) with same parameters used for reference image.

(iii) After this, Inverse Fourier Transform (IFT) of above is calculated. The ratio of peak value of IFT will give the approximate scale factor between the images.

Proposed Algorithm:

(i) First two input images I_R (x, y) and I_S(x, y) (reference and sense) are loaded.

(ii) The approximate value of scale between the images is estimated, if there is a scale between the images then downscale the sense image by the factor of 2. After down scaling, apply zero padding to downscaled sense image I_{DS}(x,y) to keep the size of both (reference and sense) images same.

(iii) 2D-FFT of both the images (reference image and downscaled sense image) is calculated.This step will give two 2-D arrays of FFT co-efficient F_R and F_{SD} one for the reference image and other for the sense image.

(iv) The magnitude of FFT co-efficient (the arrays as obtained in step-iii.) with a high pass emphasis filter is convolved. Now it is required that modified arrays (as obtained after step iv) be arranged in the log polar space so as to calculate the scale and rotation changes between the images.

(v) The modified FFT arrays to log polar space (ρ,θ) is transformed.

   (a) Define a log space according to required scale of log axis.

   (b) Define a theta axis between 0^0 and 360^0 with interval based on image size. Since the axes of the log polar space are now defined, we need to find the equivalent Cartesian coordinates so that we can interpolate the modified FFT arrays, (from step(iv)) to convert the image to log polar domain.

   (c) Based on the above two (ρ, θ) parameters convert the polar coordinates to Cartesian coordinates.

   (d) Interpolate the image accordingly. After this step there will be two arrays in which the FFT coefficients of the images will be arranged in log polar domain.

(vi) FFT of log polar output, (as obtained after (v)), for both the images are taken.

(vii) Cross power spectrum according to Equation (8) is computed.

(viii) IFFT is calculated to find out the matching point (R_{peak}) having maximum magnitude.

(ix) Based on the coordinates of the R_{peak}, calculate the scale and rotation. If (x,y) is the coordinate of the peak, the angle is recovered as (degrees per pixel * (y-1)). Calculate scale using the log space defined earlier and peak co-ordinate x. c = 10 (log_{10}m ÷ m) , scale = c ((x-1) ÷ 2), where m = size of image

(x) The sense image is re-scale according to recovered scale factor and de-rotate it by amount equal to recovered rotation factor (θ), say it as Image I_1.

(xi) The sense image is re-scale according to recovered scale factor and de-rotate it by amount equal to recovered rotation factor (θ) plus 180^0(θ+180^0), say it as ImageI_2. if recovered scale factor is less than 1, then re-scale the sense image I_S(x,y) by the factor of (recovered scale*2) else re-scale the downscaled sense image I_{IDS}(x, y) by the recovered scale factor.

(xii) Now for images I_1 and I_2, compute Cross Power Spectrum with the reference image.

(xiii) Then IFFT is taken and calculate the peaks for both cases.

(xiv) The image with maximum peak is taken as the de-rotated and re-scaled sensed image and, let the corresponding peak be T_{peak}.

(xv) The coordinates of the above obtained peak (T_{peak}) will give the translation between the images.

(xvi) Remove the translation from the image if necessary and impose the image on the original to fuse out the necessary information. The Image is now registered.

In this algorithm first the sense image is downscaled by the factor of 2. Log-Polar algorithm gives best result for any value of rotation and translation but it will not work if the scale is more than 1.8 or 2, as the frequency components alters at high scale [7]. So in this algorithm first the sense image is down scaled so that this algorithm can recover the scale factor up to 4.

5. Performance Analysis and Results

The algorithm has been implemented using MATLAB software. Performance analysis has been done at each stage and the results at each stage is evaluated and explained below. We tested the algorithm on different gray scale images of various sizes. For analysis, Gray scale images are considered of 512 $\times$ 512 size, as shown in Fig.5(a) and Fig.5(b) as reference image I_R and sense image I_S, respectively.

First of all, the approximate value of scale is estimated between the images using Log-Gabor filter. If the images have scale between the images then the sense image is down scaled by the factor of 2. Then zero padding is appled to keep the size of both the images same. Now both the images are converted into frequency domain F_R and F_{SD}. To remove low frequency, both the images I_R and I_{SD} are convoled with high pass filter whose function response is shown in Fig.5(c).

After high pass filtering, both the images are transformed into Log-Polar space LP_R(ρ,θ) and LP_{SD}(ρ,θ) as shown in Fig. 5(d-e). In Log-Polar space, phase correlation is found between LP_R(ρ,θ) and LP_{SD}(ρ,θ), which gives the value of R_{peak} = 0.0301 and the coordinates (x,y) of R_{peak} gives the the value of angle of rotation and scale. Here value of y = 72 is received which returns the (degree per pixel*(y-1)) = 0.7031*71 = 49.9219. Also the value of x = 10 is found, so recovered scale = 1.1025 and actual scale = (2* recovered scale). Here recovered scale $>$1, so I_{SD} is rescaled by recovered scale factor and de-rotated by angle of rotation. Sense image after rescale is shown in Fig. 5(f) and sense image after derotation is shown in Fig.5(g). To find translation,phase correlation is applied between reference image and image after rescale and de-rotation. The value of T_{peak}=0.1594 and the coordinate of the T_{peak} gives the value of translation in x-direction and y-direction. After removing translation, image is registered. Sense image after removing translation is shown in Fig.5(h) and Fig.5(i) which shows the register image overlaid on reference image.

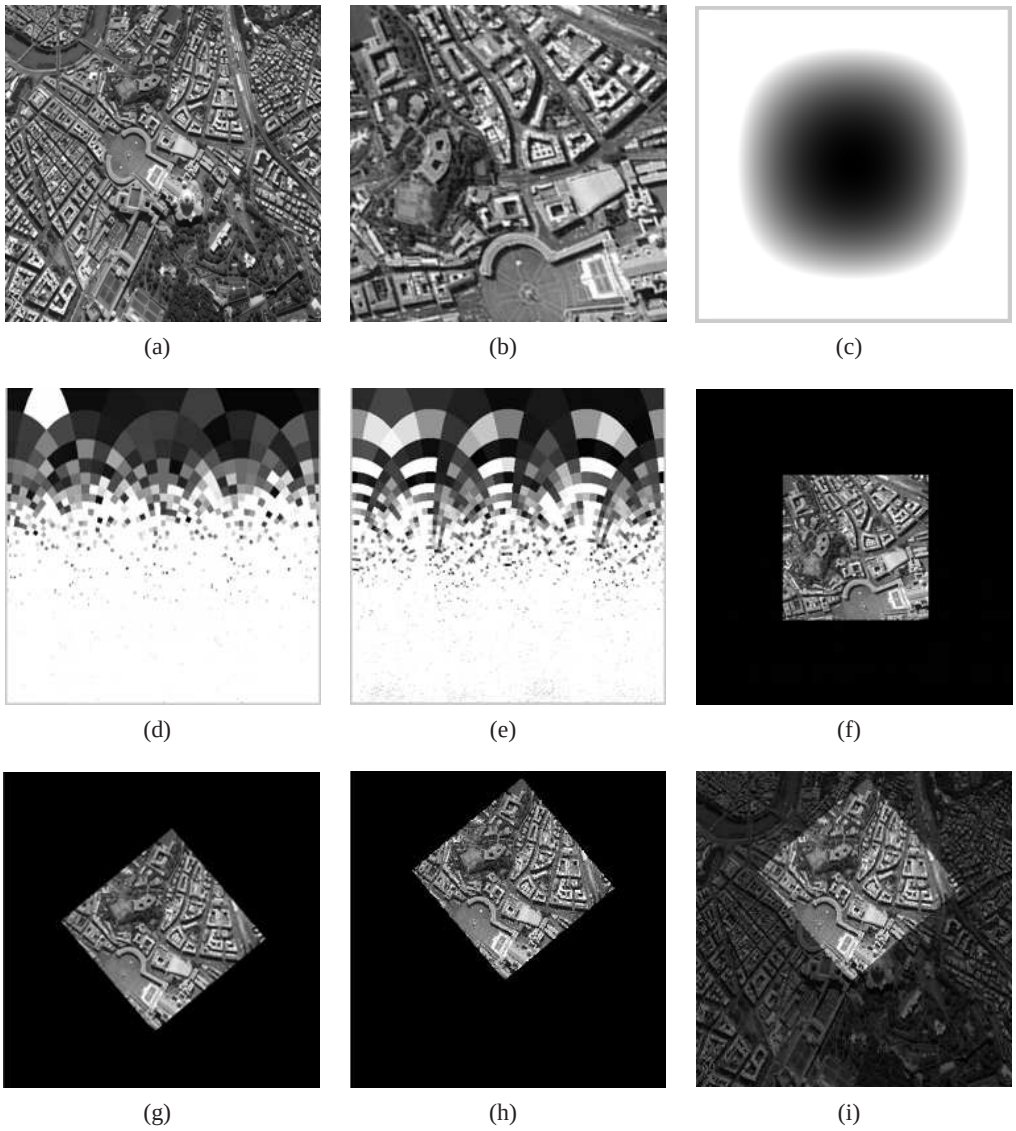


Fig. 5: (a) Reference image (b) Sense image (c) High pass filter function (d-e) Log-Polar image of reference and sense image (f) Image after re-scale (g) Image after de-rotation (h) Image after removing translation (registered image) (Obtained, Scale=2.10, Rotation=49.92°, Tanslation = (81,8)) (i) Registered image overlaid on reference image

Fig.6 to Fig.10 shows the registration results on different aerial images with different scale, rotation and translation. Table-I shows the original and recovered parameters of registration in the images with Mean Square Error (MSE) parameters. The accuracy of registered image is verified by overlying it on reference image. Moreover, the MSE parameter value between registered and reference images also indicate the accuracy of registration algorithm. The robustness of algorithm is verified on different type of images with geometrical distortions. The robustness of the algorithm is also verified by considering the partial data, Gaussian noise and bluring the sense image. By using this algorithm we can find the scale factor up to 4.18 as shown in Fig.8. Fig.11 shows the registration result of sense image with partial data. Fig.12 and Fig.13 show results of registered image for noisy sense images with Gaussian noise with σ=0.05 and bluring the sense image by applying Gaussian Blur with $\sigma = 1.4$, respectively. The registered images show the accuracy of the algorithm.

Table 1: The recovered parameter for different images

Images	Original Sense Image Parameters			Recovered Parameters			MSE
	θ	Scale	(t_x, t_y)	θ	Scale	(t_x, t_y)	
Fig.5	$50°$	2.21	(81,8)	$49.92°$	2.19	(81,8)	0.1607
Fig.6	$350°$	1.2	(1,1)	$350°$	1.19	(1,1)	0.0691
Fig.7	$16.50°$	3.8	(89,94)	$16.47°$	3.79	(89,94)	0.1938
Fig.8	$355°$	4.10	(91,95)	$354.76°$	4.09	(91,95)	0.1934
Fig.9	$10°$	2.4	(38,27)	$9.84°$	2.40	(38,27)	0.1972
Fig.10	-	-	-	$340.48°$	1.61	(11,4)	0.1983
Fig.11	$5°$	1	(33,12)	$5.6°$	1	(33,12)	0.1231
Fig.12	$10°$	2.4	(67,32)	$9.84°$	2.38	(67,32)	0.2578
Fig.13	$10°$	2.4	(67,32)	$9.84°$	2.36	(67,32)	0.2573

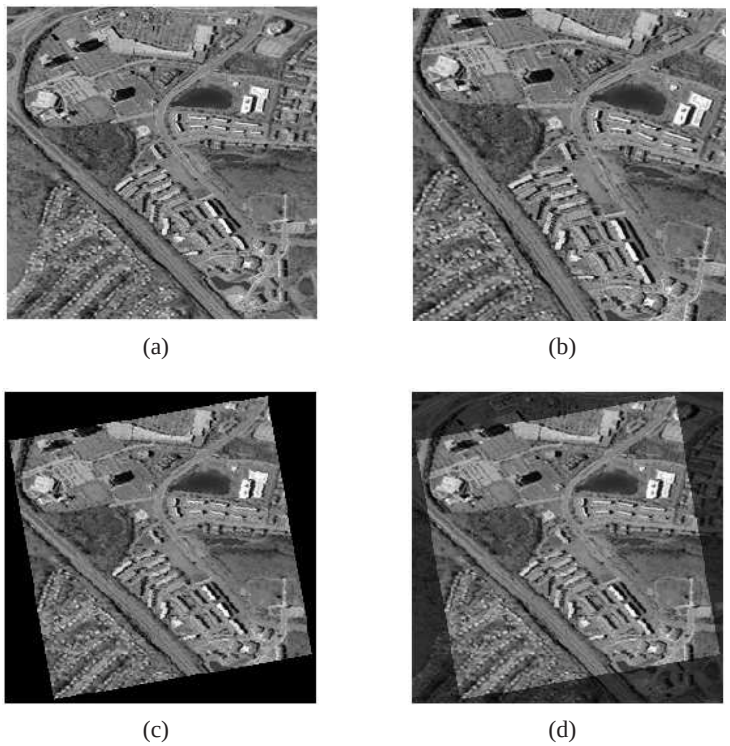
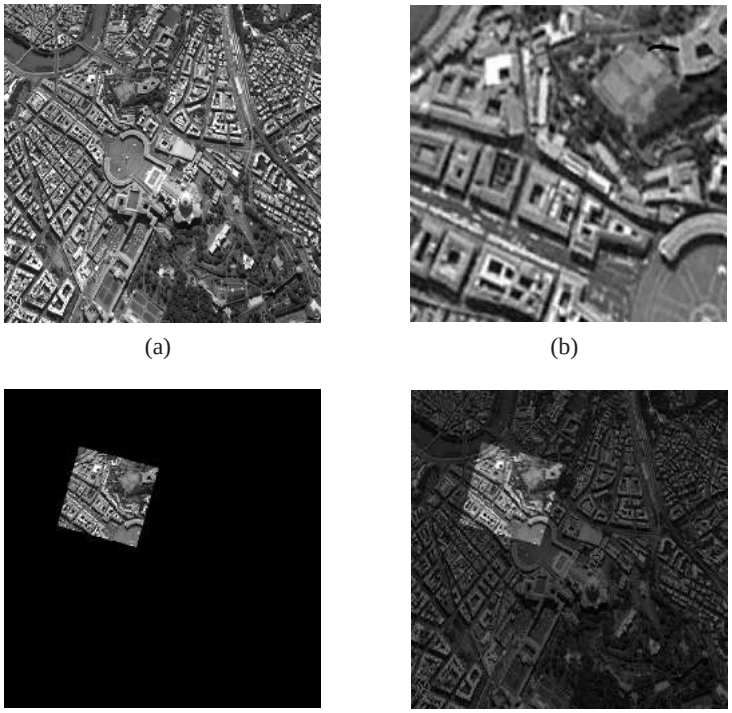


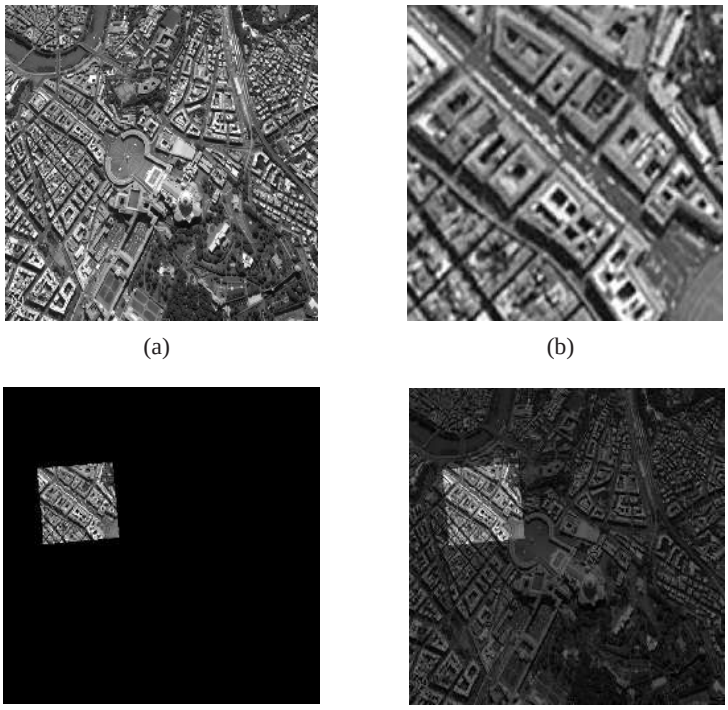
Fig. 6: (a) Reference image (b) Sense image (c) Registered image (Obtained, Scale = 1.19, Rotation = $350°$, Tanslation = (1,1)) (d) Registered image overlaid on reference image



(a) (b)

(c) (d)

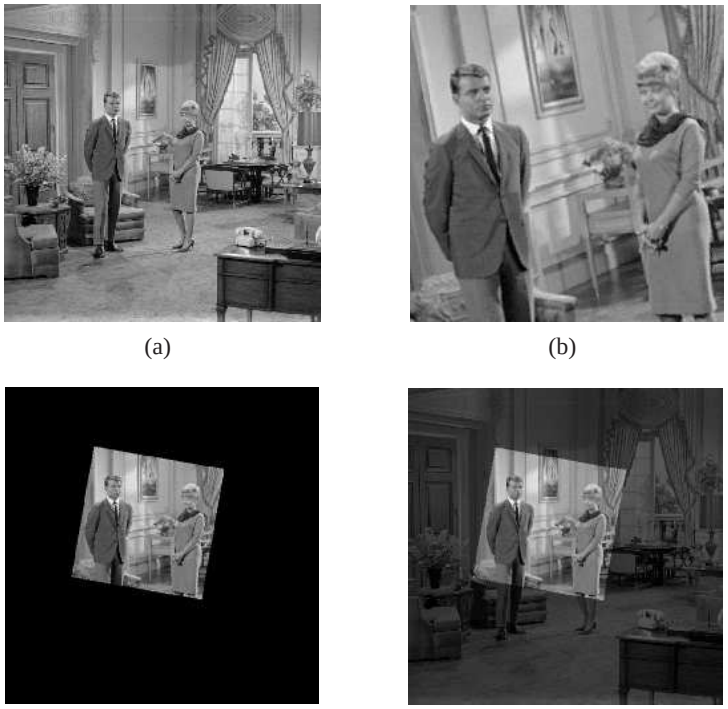
Fig. 7: (a) Reference image (b) Sense image with deformation (c) Registered image (Obtained, Scale = 3.79, Rotation = $16.47°$,Tanslation = (89,94)) (d) Registered image overlaid on reference image



(a) (b)

(c) (d)

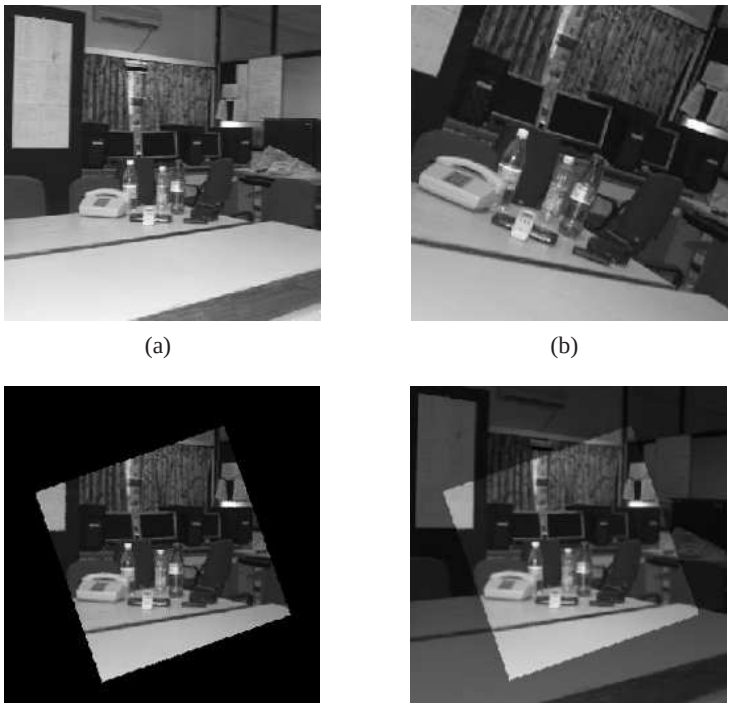
Fig. 8: (a) Reference image (b) Sense image (c) Registered image (Obtained, Scale = 4.09,Rotation = $354.76°$, Tanslation = (91,95)) (d) Registered image overlaid on reference image



(a) (b)

(c) (d)

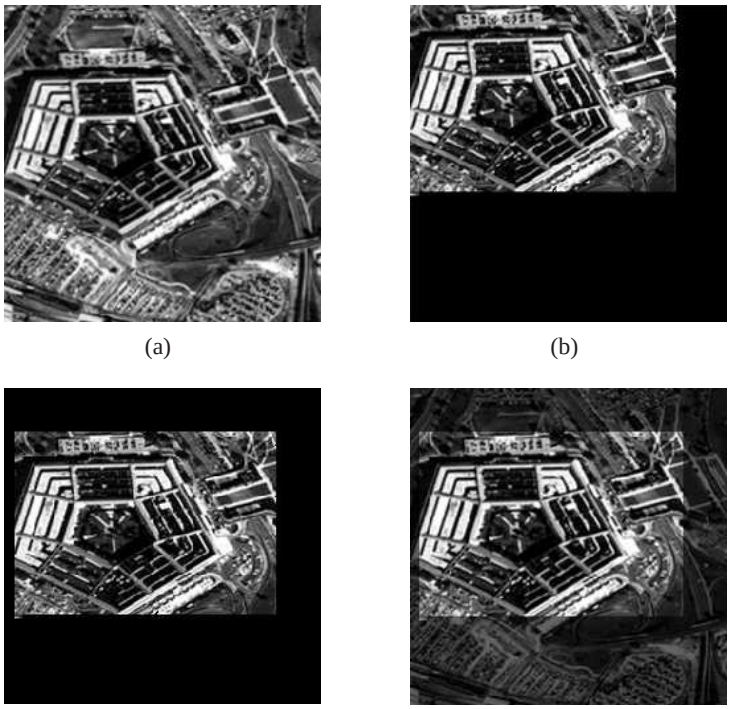
Fig. 9: (a) Reference image (b) Sense image (c) Registered image(Obtained, Scale = 2.40, Rotation = $9.84°$, Tanslation = (38,27)) (d) Registered image overlaid on reference image



(a) (b)

(c) (d)

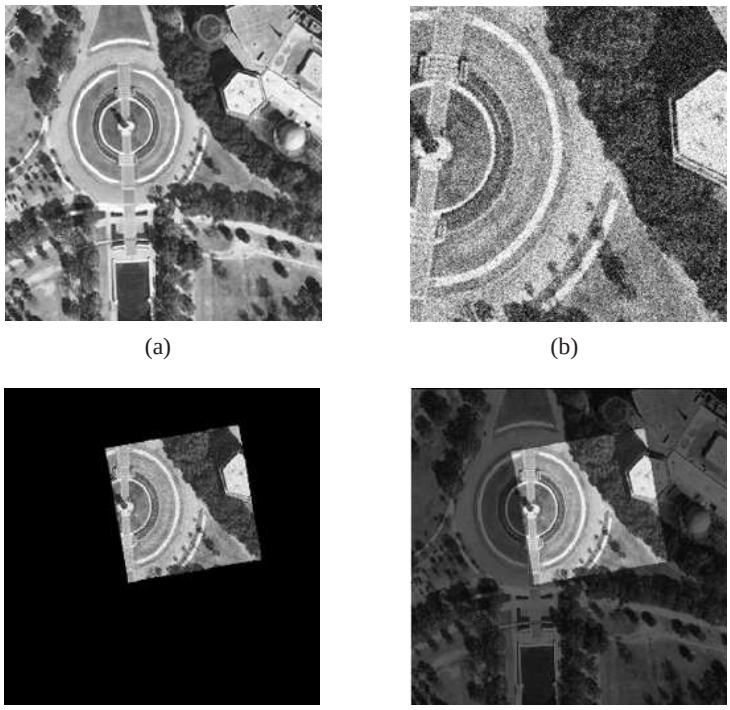
Fig. 10: (a) Reference image (b) Sense image (c) Registered image (Obtained, Scale = 1.61, Rotation=$340.48°$, Tanslation=(11,4)) (d) Registered image overlaid on reference image



(a) (b)

(c) (d)

Fig. 11: (a) Reference image (b) Sense image (Partial Data) (c) Registered image (Obtained, Scale = 1, Rotation = 5.6°, Tanslation= (33,12)) (d) Registered image overlaid on reference image



(a) (b)

(c) (d)

Fig. 12: (a) Reference image (b) Sense image (Gaussian noise with σ = 0.05) (c) Registered image (Obtained, Scale = 2.38, Rotation = 9.84°,Tanslation = (67,32)) (d) Registered image overlaid on reference image

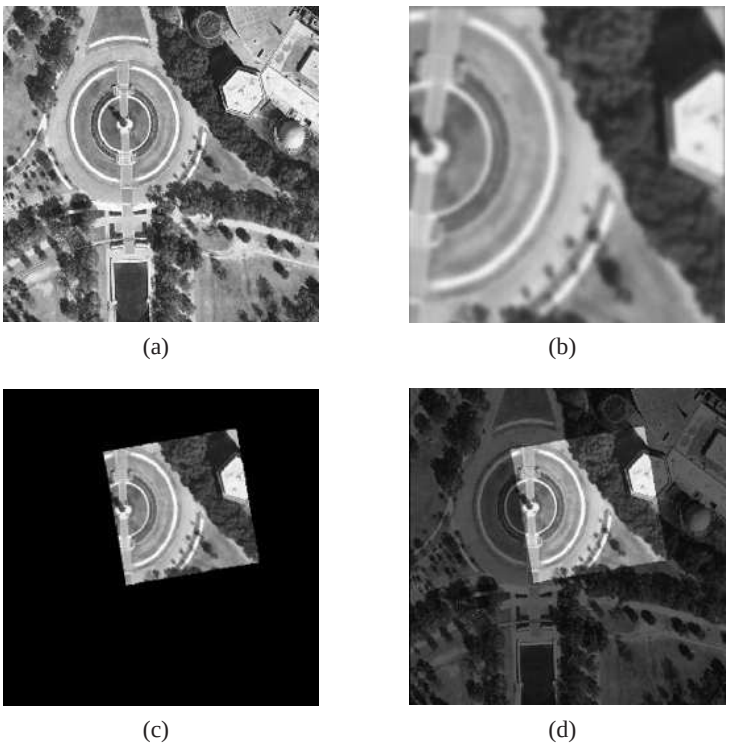


Fig. 13: (a) Reference image (b) Sense image (Gaussian Blur with σ = 1.2) (c) Registered image (Obtained, Scale = 2.36, Rotation = 9.84°,Tanslation = (67,32)) (d) Registered image overlaid on reference image

6. Conclusion

In this paper, Image registration algorithm is presentedusing Log-Gabor filter, Log-Polar Transform and Phase Correlation. The rotation and scale invariant properties of the LPT, along with FT and phase correlation allow us to develop a robust algorithm that works faithfully under geometric distortions like rotation, scale and translation. Hence this approach is highly effective in registering aerial images. Any amount of scaling and rotation in cartesian domain will be pure translation in log polar domain. Scale and rotation between images is recovered by first converting them into Log-Polar images and then applying FFT-based cross-correlation. The simulated results of image registration are verified with scaling factor up to 4.10 and with any degree of rotation. The accuracy of algorithm is verified by visual inspection of registered image by overlaiding on reference image. Moreover MSE between the registered and reference image is also calculated for all images as shown in Table-I. The ability of the algorithm to recover registration parameters in presence of noise, partial data and with blurring is also verified.

References

[1] B. Zitova, J. Flusser, "Image registration methods: a survey", *Elsevier Image and Vision Computing*, pp.977-1000, 2003.

[2] L. G. Brown, "A Survey of Image Registration Techniques", *ACM Computing Surveys (CSUR)*, Vol.24, Issue 4, pp.325-376, 1992.

[3] B. Srinivasa Reddy and B. N. Chatterji, "An FFT-Based Technique for Translation, Rotation, and Scale-Invariant Image Registration", *IEEE Trans. on Image Processing*, Vol. 5, pp.1266-1271, 1996.

[4] Wolberg G., Zokai S, "Robust image registration using log-polar transform", *In Proc. ICIP*, pp.493-496, 2000.

[5] Qin-sheng Chen, Michel Defrise, F. Deconinck, "Symmetric phase-only matched filtering of Fourier Mellin transform for image registration and recognition", *IEEE Trans. on Pattern Analysis and Machine Intelligence* 16, pp.1156-1168, 1994.

[6] Xiaoxin Guo, Zhiwen Xu, Yinan Lu, and Yunjie Pang, "An Application of Fourier-Mellin Transform in Image Registration", *Proceedings of The Fifth International Conference on Computer and Information Technology*, pp.619-623 , 2005.

[7] Jignesh N Sarvaiya, Dr. Suprava Patnaik, Salman Bombaywala, "Image registration using Log polar transform and phase correlation", *TENCON 2009 - 2009 IEEE Region 10 Conference*, pp.1-5, 2009.

[8] Haili Xu, Guoran Hua , Jian Zhuang, Sunan Wang, "A Frequency Domain Approach to Fast and Accurate Image Registration", *IEEE International Conference on Information and Automation*, pp.340-345, 2009.

[9] William K Pratt, "Correlation Techniques of Image Registration", *IEEE Trans. on Aerospace and Electronics Systems*, pp.353-358, 1974.

[10] E.D. Castro, C. Morandi, "Registration of translated and rotated images using finite Fourier transform", *IEEE Trans. on Pattern Analysis and Machine Intelligence*, 9, pp.700-703, 1987.

[11] Olan Samritjiarapon Orachat Chitsobhuk, "An FFT-Based Technique and Best-first Search for Image Registration", *Communications and Information Technologies*, ISCIT , pp.364-367, 2008.

[12] A. Ardeshir Goshtasby, "2-D and 3-D Image Regisration for Medical, Remote Sensing, and Industrial Applications", *John Wiley & Sons Publications*, 2005.

[13] Jignesh N Sarvaiya, Dr. Suprava Patnaik, Salman Bombaywala, "Image registration by template matching using normalized Cross-correlation", *IEEE International Conference on Advances in Computing, Control, and Telecommunication Technologies*, pp.819-822, 2009.

[14] Wen-Chia Lee, Chin-Hsing Chen, "A Fast Template Matching Method for Rotation Invariance Using Two Stage Process", *Intelligent Information Hiding and Multimedia Signal Processing*, pp.9-12, 2009.

[15] Kyu-Dae Ban, Jaeyeon Lee , Dae Hwan Hwang, Yun-Koo Chung, "Face Image registration methods using Normalized Cross Correlation International Conference on Control", *Automation and Systems*, pp.2408-2411, 2008.

[16] J. B. Antoine Maintz, Max A. Viergever, "A Survey of Medical Image Registration", *Medical Image Analysis*, Vol.2, No.1, pp.1-36,1998.

[17] B. Sun, D. Zhou A, "Rotated Image Matching Method Based on CISD", *ISNN 2007, Part I, LNCS 4491*, pp.1346-1352, 2007.

[18] Zhuo Liu, Shigeo Wada, Translation, "Rotation and Scale Invariant Texture Characterization Method", *IEEE proceedings of ISSPIT*, pp.103-106, 2004.

[19] R. Berthilsson, "Affine correlation Proceedings of the International Conference on Pattern Recognition", *Brisbane, Australia*, pp.1458-1461, 1998.

[20] Y.Keller, A.Averbuch, M.Israeli, "Pseudo polar-based estimation of large translations, rotations and scalings in images", *IEEE trans. on Image processing*, pp.12-22, 2005.

[21] Wei Wang , Jianwei Li, Feifei Huang, Hailiang Feng, "Design and implementation of Log-Gabor filter in fingerprint image enhancement", *Pattern Recognition Letters*, 29, pp.301-308, 2008.