# Report Assignment 3: Image Registration

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## Introduction:

The purpose of this report is to report the observations of the assignment 3 regarding implementation of image registration (using Fast Fourier Transform). Image registration is the process of transforming different images into one measuring system. This can be done in case of data in the form of images, videos, and data from sensor arrays etc. For example, we can compare two similar images for equality even though one of the image might have undergone some sort of affine transformation.

## Image Registration – The Building Blocks:

With reference to the details given in the correspondence "**An FFT-Based Technique for Translation, Rotation, and Scale-Invariant Image Registration**" by Reddy and Chatterjee, the registration method uses Fourier domain approach to match images which are translated, rotated, and are scaled with respect to one another.

## Algorithm:

Broadly, the algorithm is as follows:

1. First two input images $I_R$ (x, y) and $I_S$(x, y) (reference and sense) are loaded.
2. 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.
3. 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.
4. The magnitude of FFT co-efficient (the arrays as obtained in step-iii.) with a high pass filter is convolved. Now it is required that modified arrays (as obtained after step 4) be arranged in the log polar space so as to calculate the scale and rotation changes between the images.
5. The modified FFT arrays to log polar space (Θ, ρ) 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 4) to convert the image to log polar domain.
    c. Based on the above two (Θ, ρ) 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.
6. FFT of log polar output, (as obtained after (v)), for both the images are taken.

7. Cross power spectrum according to Equation (8) is computed.
8. IFFT is calculated to find out the matching point ($R_{peak}$) having maximum magnitude.
9. 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 (log10m ÷ m), scale = c ((x-1) ÷ 2), where m = size of image.
10. 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 $I_1$.
11. The sense image is re-scale according to recovered scale factor and de-rotate it by amount equal to recovered rotation factor (ϴ) plus 1800(ϴ+1800), say it as Image$I_2$. 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 IIDS(x, y) by the recovered scale factor.
12. Now for images $I_1$ and $I_2$, compute Cross Power Spectrum with the reference image.
13. Then IFFT is taken and calculate the peaks for both cases.
14. The image with maximum peak is taken as the de-rotated and re-scaled sensed image and, let the corresponding peak be $T_{peak}$.
15. The coordinates of the above obtained peak ($T_{peak}$) will give the translation between the images.
16. 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.

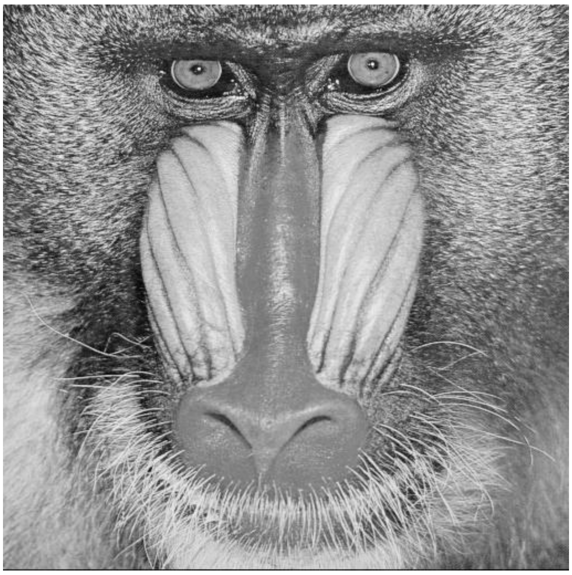
## Observations

The matlab script in my case outputs the angle of rotation of the sense image or the translation in x, y in the sense image. I have used GIMP to create sample input images. Also I have implemented the algorithm in two ways just to get a hang of the algorithm. One implementation works very successfully. Following are some sample images for which the program worked fairly well by calculating the angle of rotation and translation factors.

Figure 1

Figure 2

Figure 1 represents the original image, figure 2 represents the rotated image by 45°.



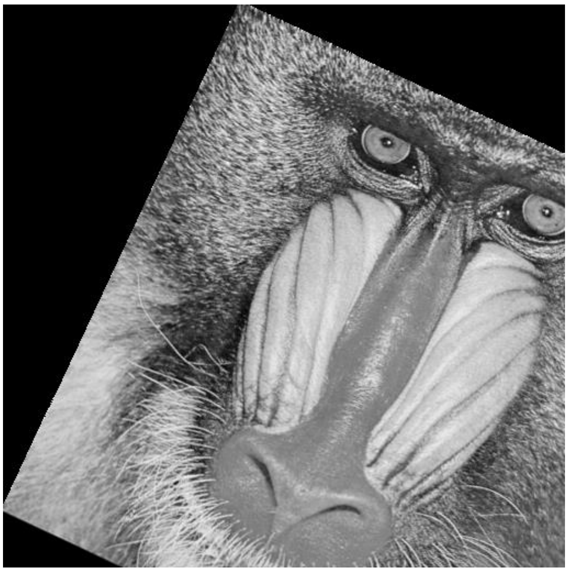


Figure 3 Figure 4

Figure 3 and Figure 4 also form a test pair for program but this time figure 4 has translation + rotation. Same goes for Figure 5 and Figure 6 respectively.

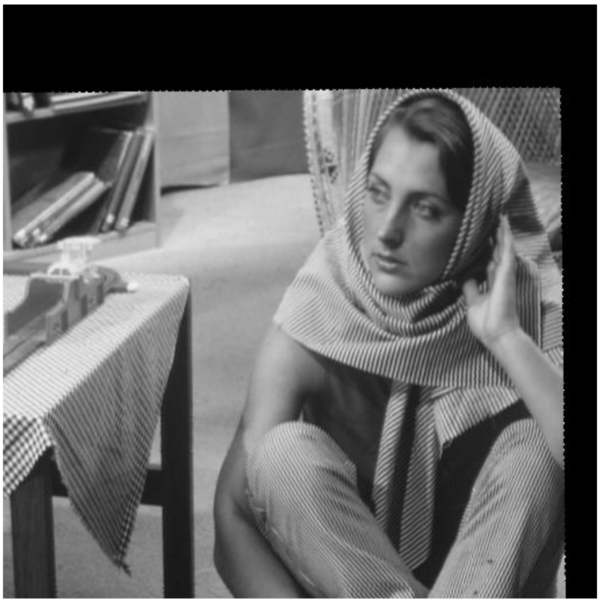


Figure 5 Figure 6

The verification for correctness of the algorithm involves the job of knowing the translation and rotation factor from GIMP in advance. These values are then compared with the values output by the MATLAB program.