# Area Based Image Registration using Wavelet Transform and Oriented Laplacian Pyramid

Trupti V. Chaudhari,
P.G. Student,
Department of Electronics and Telecommunication,
J.T.M.C.O.E, Faizpur

Dr. P. M. Mahajan,
Asso. Professor
Department of Electronics and Telecommunication,
J.T.M.C.O.E, Faizpur

***Abstract*— Many digital imaging techniques in medicine combine multiple images for analysis. Using these techniques, it is essential to align and register images prior to addition, subtraction, or any other combination of the images. An area based method for registration is proposed in this work. A technique for image registration using mutual information, cross correlation and mean squared difference has been developed. This technique consist of three main steps: extracting feature points in the reference and the sensed images, establishing the correspondence between the feature points of the images, and estimating the transformation parameters which map the target image to the reference one. Wavelet transform and oriented laplacian pyramid is used for feature extraction and features are matched using mutual information, cross correlation and mean squared difference. The obtained results of mutual information based method are compared with cross correlation and means squares techniques. The proposed algorithm is evaluated using several images brain images. Performance of these methods is evaluated using PSNR.**

***Keywords:* *Cross-correlation, Image Registration, Mutual Information, Oriented Laplacian Pyramid, Wavelet Transform, etc.***



## I. INTRODUCTION

Medical imaging is used in large number of applications that use different imaging modalities. The imaging modalities depict different kinds of information on a part of the human body involved in that application. Data obtained from the separate images is usually integrated, since information gained from two images acquired is usually of a complementary nature. This integration can be done by registration of these images. The purpose of registration is to supress or remove geometric distortions between referenced and sensed images. It is a crucial step in all image analysis tasks in which final information is gained by combining various data resources. For example the individual modalities such as x-ray Computed Tomography (CT), Ultra Sound (US), Magnetic Resonance (MR), etc., do not provide enough contrast and information to reliably segment all tissue types in images acquired of human patients when used individually. Because of these problems, much attention has been directed towards registration methods in recent years. Image registration methods can solve some of the inherent problems of monomodality images and voxel-based classification algorithms. Rigid multi-modality registration methods allow to register images of the same patient, but from different modalities. The result is that registered images contain more information in each voxel, thus making e.g. the segmentation using standard classification algorithms easier [1].

Image registration is the process of overlaying two or more images of the same scene taken at different times, from different viewpoints, and/or by different sensors. Reference and sensed images are geometrically aligned using registration. The approaches of registration are classified as area based and feature-based and according to four basic steps of image registration procedure: feature detection, feature matching, mapping function design, and image transformation and resampling[2]. It's a fundamental task in image processing used to match two or more pictures taken, for example, at different times, from different sensors, or from different viewpoints. Virtually all large systems which evaluate images require the registration of images, or a closely related operation, as an intermediate step. In this paper area based image registration using mutual information is proposed.

## II. LITERATURE REVIEW

In medical image registration it is crucial to define a metric that can measure the similarities of two image. Mutual information (MI) is an intensively researched metric because of its favorable characteristics and good results [2,3]. This information theory based metric is fully automatic, and no predefined landmarks are needed. A method using co-occurrence matrix is proposed by Rueckert et al. [4] proposed a method using co-occurrence matrix. Q. Du et al. [5] proposed the method, they combined the wavelet transform with the traditional calibration MI approach, registration criteria makes use of the maximization of the MI. A fast 2-D rigid registration scheme is proposed by A. Quddus et al. [6] for image retrieval applications. Multiscale wavelet representation in combination with MI is used for facilitating matching of important anatomical structures having multiple resolutions. S. Gahankari et al. [7] detailed a method based on steerable wavelets for medical image registration. Steerable wavelets were used to overcome limitations of conventional wavelets for multiscale and multi orientation image representation. N. Azzawi et al. [8] proposed a method which extracts salient edges and control points (CP) of medical images using nonsubsampled contourlet transform (NSCT). NSCT was used to decompose MR images, and then extracted Edge and CP from bandpass directional subband of NSCT coefficients. Then MI was adopted for the registration of feature points and translation parameters are calculated by using particle swarm optimization (PSO). A method of medical image registration based on MI of multi-scale Harris corner and feature points was proposed by J. Zhao et al. [9], it effectively improves sensitivity of noise and the situation of being trapped into a local minimum to MI registration.

J. Sarvaiya et al. [10] proposed a template-matching algorithm, for image registration based on Normalized Cross-Correlation (NCC) using Cauchy-Schwartz Inequality relying on similarity measures. Turcajova et al. [11] detailed the use of cross-correlation calculated from LFCs to register affine transformed images. An intensity-based image registration technique was proposed by J. Kim et al.[12] , a correlation coefficient was used as a similarity measure. Relative to the ordinary sample correlation coefficient, this similarity measure reduces the influence of outliers. N. Nichat [13] proposed a registration technique for area matching in high-resolution images using orthogonal Haar / Walsh transform and mean squared difference (MSD). Computational time required for WALSH transform is less than HAAR transform and the RMSE values are comparatively higher for WALSH Transform. M. [14] proposed two ways for cancer diagnostic where the displacement of normal and abnormal breast tissues under external stress are calculated using image registration technique. In the first way displacement is calculated by finding the local translation of intensity centers of gravity (ICOG).In the second way translation parameters, rotation and scaling parameters are estimated. A few control points are used to estimate displacement parameters in a minimum mean square sense. In image processing, oriented filters play a key role. Freeman [15] addressed the problem of synthesizing exactly steerable filters and has shown how the steerable filters allows use of a small set of such filters and still treat all orientations in a uniform way. Perona [16] addressed the problem of calculation of the best steerable approximation for a given impulse response. H. Greenspan et al. [17] proposed a oriented laplacian pyramid (OLP), they derived the optimal set of steering coefficients for a given overcomplete discrete representation, thus generating a steerable representation. This oriented pyramid has 8=3 redundancy, it can be transformed into a steerable one. The OLP scheme is a variation on the Burt and Aderson pyramid [18,19]. It is computational efficient and compact and lead to minimal hardware requirements Filters which are made from a bank of orientation-selective bandpass filters, like Gabor filters can be used for the initial feature extraction phase of many image-processing tasks. These tasks include edge-detection, motion-flow analysis and texture recognition.

This work is based on area based image registration, here for feature extraction two different schemes are used namely wavelets and oriented laplacian pyramid filter. We compare these two scheme with each other. We also compared feature matching scheme (i.e. MI) with cross-correlation (CC) and Means squared difference (MSD).

## III. METHODOLOGY OF IMAGE REGISTRATION

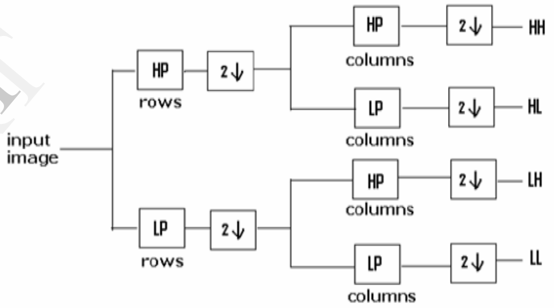
Generally, the majority of registration methods consist of the following four steps: feature extraction, feature matching, transformation of the models and resampling the image.

### *3.1 Feature Extraction*

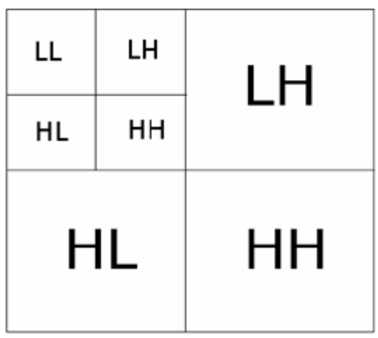
Salient and distinctive objects such as closed-boundary regions, corners, edges, line intersections, etc. are detected in this step. A set of feature points are extracted from both images. For further processing, these features can be represented by their control points. In this work we are using area based technique for registration. Wavelet transform and Oriented laplacian pyramid are used here for extraction of features.

### *3.1.1 Feature Extraction Using Wavelet Transform*

Wavelet transform is a kind of multi-scale signal analysis method. Wavelets decomposes signals into approximate and detailed coefficients which allows the signal to be described in several levels from the coarse level (lowest resolution) to the finest level (highest resolution) [20].




(a)




(b)

Figure 1. a)Two-dimensional wavelet decomposition ,b) Two layer wavelet decomposition for a 2-D signal

As the signal is two-dimensional, the decomposition is also two-dimensional. The results are approximate component LL, horizontal component LH, vertical component HL and diagonal component HH. Two dimensional wavelet decomposition is shown in Figure l.

Every time images after wavelet are decomposed into sub-block areas which are of the original size and contain the wavelet coefficients of corresponding frequency, equivalent to choose one point from every two points in horizontal and vertical direction respectively. When the new sub-block areas go into the wavelet transform again we focus on LL. The spatial distribution of wavelet coefficients corresponds well with the spatial distribution of the original image. Figure 1 (b) is two layers wavelet decomposition for a 2-D signal.First the algorithm reads reference image and input sensed image. Then images are decomposed by using Haar wavelet and the approximate coefficients are extracted to perform image registration. Block diagram for image registration using wavelet transform is shown in figure 2.

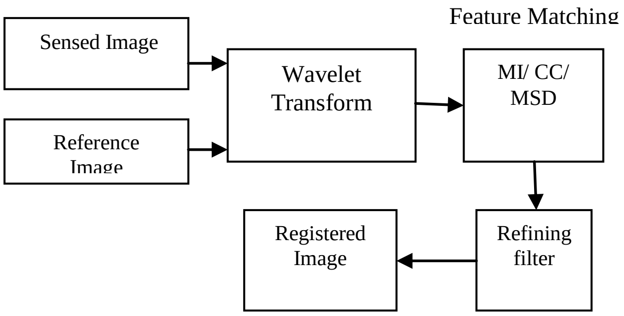



Figure 2. Block diagram of wavelet based image registration using MI,CC, MSD

*3.1.2 Feature Extraction Using Oriented Laplacian Pyramid*

In this approach sensed and reference images are decomposed into sets of lowpass and bandpass components using Gaussian and Laplacian pyramids, respectively. The Gaussian pyramid consists of lowpass filtered (LPF) versions of the input image, each stage of the pyramid is computed by lowpass filtering and subsampling of the previous stage. The Laplacian pyramid consists of bandpass filtered (BPF) versions of the input image, each stage of the pyramid is constructed by the subtraction of two corresponding adjacent levels of the Gaussian pyramid. The oriented pyramid is formed by modulating each level of the Laplacian pyramid with a set of oriented sine waves, followed by another LPF operation using a separable filter is as shown in Figure 3.

Image registration system using oriented laplacian pyramid is shown in figure 4. In this approach sensed and reference images are decomposed using oriented laplacian pyramid. Then MI or CC or MSD is applied on reconstructed images and output image is improved by using refining filter.

*3.2 Feature Matching*

Area based matching is used in this work. Area-based methods put emphasis on the feature matching step than their detection. Various area based methods are correlation methods, fourier methods, optimization methods and MI based methods and mean squared difference. In this work MI , CC and MSD these methods are used for feature matching.

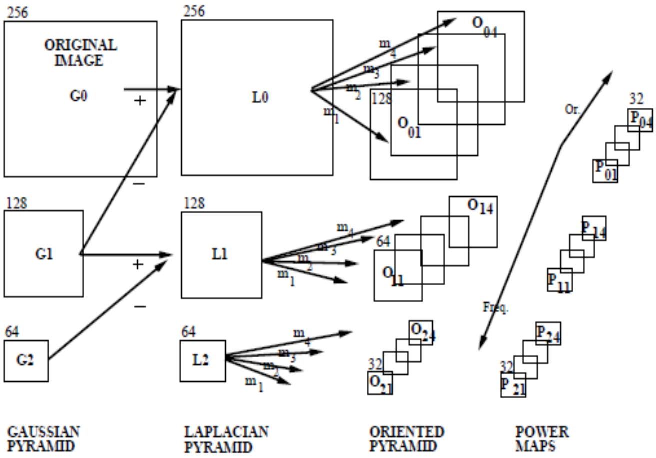



Figure 3: Block diagram of the oriented pyramid generation

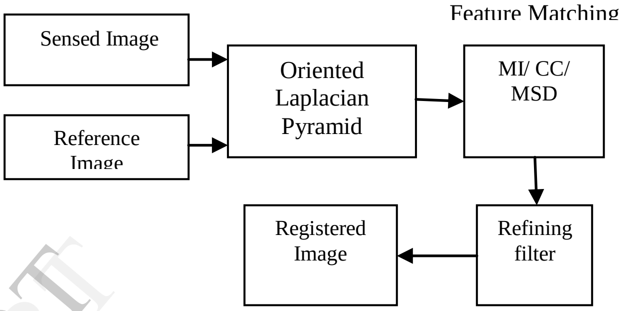



Figure 4. Block diagram of oriented Laplacian Pyramid based image registration using MI,CC, MSD

*3.2.1 Mutual Information*

The MI, is a measure of statistical dependency between two data sets. Method used here is quite similar to method used by [3][21] . MI of two images is a combination of the entropy values of the images, both separately and jointly. Entropy is low when distribution has only a few large probabilities; for a uniform distribution, entropy is maximum. The entropy of an image can be obtained by estimating the probability distribution of the image intensities. A normalized joint histogram of the gray values is calculated to estimate the joint probability distribution of two images. The marginal distributions are obtained by summing over the rows, respectively, the columns, of the joint histogram. The definition of the mutual information I of two images A and B combines the marginal and joint entropies of the images in the following manner:

$$I(A,B) = H(A) + H(B) - H(A,B) \quad (1)$$

Here, H(A) and H(B) are the separate entropy values of A and B, respectively. H(A;B) is the joint entropy, i.e., the entropy of the joint probability distribution of the image intensities. Correct registration of the images is assumed to be equivalent to maximization of the mutual information of the images. This implies a balance between minimization of the joint entropy and maximization of the marginal entropies. The joint entropy is minimal when the joint distribution is minimally dispersed, this corresponds to registration.

*3.2.2 Cross Correlation*

Normalized Cross Correlation (NCC) is often the adopted for similarity measure due to its better Robustness. The normalized CrossCorrelation of two images is given by-

$$T(u,v) = \frac{\sum[f(x,y) - \bar{f}_{uv}][t(x-u,y-v) - \bar{t}]}{\{[f(x,y) - \bar{f}_{uv}]^2 [t(x-u,y-v) - \bar{t}]^2\}^{0.5}} \quad (2)$$

It is a basic approach for image registration and the simplest but effective method for similarity measure. This similarity measure is computed for window pairs from the reference image and sensed image and its maximum is searched. The window pairs for which the maximum is achieved are set as the corresponding ones.

*3.2.3 Mean Squared Difference*

The Root Mean Square Error computes the mean squared pixel-wise difference in intensity between image *A* and *B* over a region. The formulae for calculated image matrices are:

$$MSE = \frac{1}{N \times M} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} [f(x,y) - f^*(x,y) \quad (4)$$

$$RMSE = \sqrt{MSE}$$

where, f (x, y) is the input image data and f*(x, y) is block of the reference image. *M* and *N* are the matrix dimensions in x and y, respectively. Here the root mean square error is used to compute error between transformation result of each block of reference image and input image. Matching accuracy is done based on the root mean square error (RMSE). Accurate matching must have value of RMSE which is close to 0. For images with moderate differences in content, the registration accuracy is, in general, good with an RMS error of one pixel or less.

*3.3 Transformation and Resampling*

In this step of registration, mapping functions type and parameters, which are responsible for aligning the sensed image with the reference image, are estimated. Here affine transformation is used as a mapping function. The parameters of the mapping functions are computed by means of the established feature correspondence. While transforming points from one image to another, interpolation is usually required to estimate the grey value of the resulting point. Finally, for resampling Bilinear interpolation is used. Quality of registered image is improved by using a sharpening filter to enhance the edge information of the registered image.

## 4 FLOW OF REGISTRATION SYSTEM

Image registration using wavelet based and oriented laplacian pyramid based feature extraction are described in this section:

*4.1 Wavelet based image registration using mutual information or cross correlation or mean squared difference*

Here, features are extracted using wavelet transform and for feature matching any one method out of MI or CC or MSD, can be used at a time.

Step 1: Sensed and reference images are taken as input.
Step 2: Haar wavelet is applied on sensed and reference images.
Step 3: LL subband of both images is extracted.
Step 4: LL images of reference & original images are rescaled to 256*256.
Step 5: MI / CC/ MSD is calculated.
Step 6: Maximum of MI/CC or minimum MSD is calculated.
Step 7: Control points of the reference & original images are matched.
Step 8:Bilinear interpolation is used to map the control points of the original image to the transformed.
Step 9: Registered image is refined.

*4.2 Oriented Laplacian Pyramid based image registration using mutual information or cross correlation or mean squared difference*

Here, features are extracted using wavelet transform and for feature matching any one method out of MI or CC or MSD, can be used at a time

Step 1: Original and reference images are taken as input.
Step 2: OLP is applied on sensed and reference images.
Step 3: Reconstructed images of reference & sensed images are rescaled to 256*256 if required.
Step 4: MI / CC/ MSD is calculated.
Step 5: Maximum of MI/CC or minimum MSD is calculated.
Step 6: Control points of the reference & original images are matched.
Step 7:Bilinear interpolation is used to map the control points of the original image to the transformed.
Step 8: Registered image is refined.



## IV. RESULTS AND DISCUSSION

Experiments were carried out using ten brain images. Test images were obtained from Brainix [22], simulated MRI database. The complete scheme was implemented in MATLAB. In the first method, features are extracted using 2-level haar wavelet decomposition and features are matched using three different techniques (MI, CC and MSD). Examples of wavelet based image registration are shown in Table 1. Difference between reference image and registered image is found, mean and standard deviation values are provided and time required for registration are shown in Table 2.

Similarly, in second method oriented laplacian pyramid is used for feature extraction and extracted features are matched using three different techniques (MI, CC and MS) same as that used in first method. Examples of oriented laplacian pyramid based image registration are as shown in Table 3. Its mean, standard deviation values and time required for registration are provided in Table 4. Performance of proposed work is measured in terms of PSNR for registration. Values of these parameters are enlisted in Table 5 and same is represented in Figure 5.

## V. CONCLUSION

A technique for image registration using mutual information, cross correlation and mean squared difference has been developed. This technique is based on three main steps:

Table 1. Results of Image Registration using Wavelet Transform

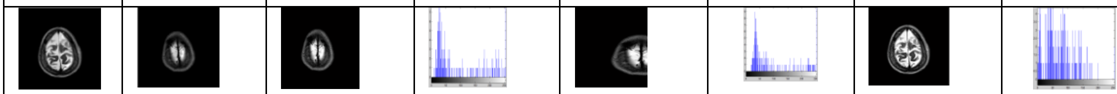
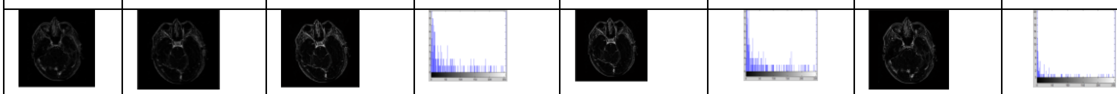
| Sensed Image | Reference Image | MI | | CC | | MS | |
|---|---|---|---|---|---|---|---|
| | | Registered Image | Histogram | Registered Image | Histogram | Registered Image | Histogram |
|  | | | | | | | |
|  | | | | | | | |
|  | | | | | | | |

Table 2. Results for image registration using wavelet transform

| Images | MI | | | CC | | | MSD | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | STD.DEV | Time | Mean | STD.DEV | Time | Mean | STD.DEV | Time |
| Ex.1 | 4.8953 | 14.7018 | 0.56595 | 4.9266 | 14.6811 | 0.41614 | 4.1186 | 9.3783 | 0.47597 |
| Ex.2 | 9.0673 | 24.631 | 0.53115 | 9.9835 | 26.3243 | 0.31184 | 6.9225 | 13.5106 | 0.34679 |
| Ex.3 | 20.4929 | 51.688 | 0.59725 | 22.7704 | 56.7011 | 0.33713 | 20.0227 | 42.6041 | 0.33036 |



Table 3. Results of Image Registration using Oriented Laplacian Pyramid

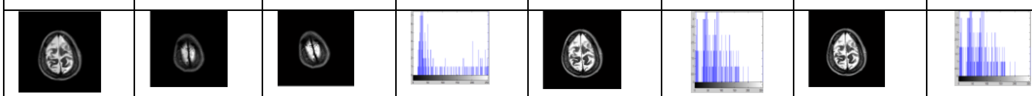
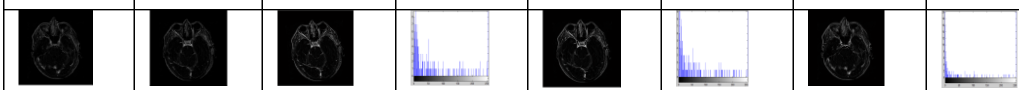
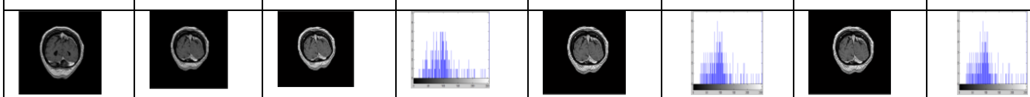
| Sensed Image | Reference Image | MI | | CC | | MS | |
|---|---|---|---|---|---|---|---|
| | | Registered Image | Histogram | Registered Image | Histogram | Registered Image | Histogram |
|  | | | | | | | |
|  | | | | | | | |
|  | | | | | | | |

Table 4. Results of Image Registration using Oriented Laplacian Pyramid

| Images | MI | | | CC | | | MSD | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | STD.DEV | Time | Mean | STD.DEV | Time | Mean | STD.DEV | Time |
| Ex.1 | 0.018127 | 0.060226 | 0.15237 | 0.025569 | 0.078534 | 0.60823 | 0.018214 | 0.037327 | 0.34842 |
| Ex.2 | 0.031672 | 0.10379 | 0.16966 | 0.044869 | 0.11948 | 0.36197 | 0.027203 | 0.053691 | 0.3327 |
| Ex.3 | 0.072967 | 0.22264 | 0.47488 | 0.11754 | 0.295 | 0.32763 | 0.078546 | 0.16762 | 0.32771 |

Table 5. PSNR for Registration UsingWavelet Transform and Oriented Laplacian Pyramid

| Images | MI | | CC | | MS | |
|---|---|---|---|---|---|---|
| | OLP | Wavelet | OLP | Wavelet | OLP | Wavelet |
| Ex.1 | 72.241 | 23.9483 | 70.3045 | 23.9136 | 72.1863 | 27.347 |
| Ex.2 | 68.275 | 20.5614 | 67.5559 | 19.9225 | 81.6849 | 26.3609 |
| Ex.3 | 62.3921 | 11.9829 | 60.2277 | 11.3584 | 70.4911 | 22.0186 |

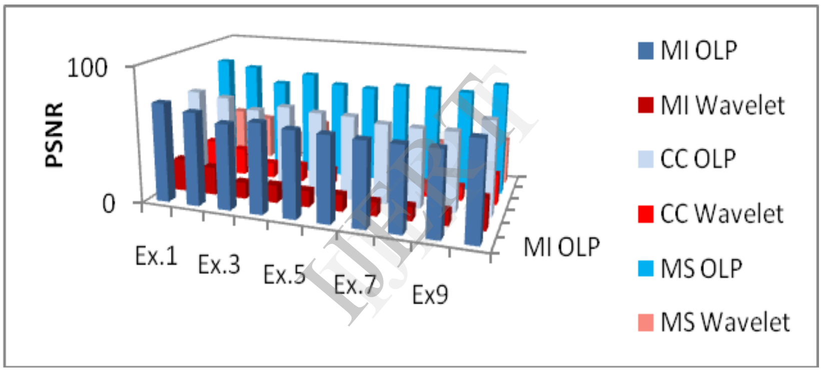



Figure 5. Representation of PSNR for registration using MI, CC, MS

extracting feature points in the reference and the sensed images, obtaining the correspondence between the feature points of the images, and estimating the transformation parameters which map the target image to the reference one. Wavelet transform and oriented laplacian pyramid is used for feature extraction and features are matched using mutual information, cross correlation and mean squared difference. The proposed algorithm was evaluated using several images. The obtained results of mutual information are compared with cross correlation and means squares techniques. The results of this work seems to be better for oriented laplacian pyramid as compared to wavelet transform based technique. Furthermore, the results are more challenging by the technique of mean squared difference using Oriented laplacian pyramid as compared to mutual information, cross correlation.

## VI. REFERENCES

1. Penhaker M., Matejka V. "Image Registration in Neurology Applications ", International Conference on Networking and Information Technology, IEEE ,2010
2. Barbara Zitova, Jan Flusser, "Image registration methods: a survey", Image and Vision Computing 21,p.p. 977–1000,2003
3. Pluim, J. P. W., J. B. A. Maintz and M. A. Viergever, "Mutual information based registration of medical images: A survey", IEEE Transactions on Medical Imaging, vol.22, no.8, pp.986-1004, 2003.
4. Rueckert, D., M. J. Clarkson, D. L. G. Hill and D. J. Hawkes, "Non-rigid registration using higherorder mutual information", Proc. of the SPIE in Medical Imaging: Image Processing, vol.3979, pp.438-447, 2000.
5. Qinsheng Du, Li Chen, "An Image Registration Method Based on Wavelet Transformation", International Conference on Computer, Mehatronics, Control and Electronic Engineering (CMCE), IEEE,2010

6. Azhar Quddus and Otman Basir, “Wavelet-Based Medical Image Registration for Retrieval Applications”,International Conference on BioMedical Engineering and Informatics, IEEE,2010
7. Sonal S. Gahankari, Bhavesh Parmar, Poornima Talwai,“Application of Steerable Wavelets in Medical Image Registration”, Second International Conference on Emerging Trends in Engineering and Technology (ICETET), IEEE,2009
8. Nemir Ahmed Al-Azzawi, Harsa Amylia Mat Sakim Wan Ahmed K. Wan Abdullah, “MR Image Monomodal Registration Based on the Nonsubsampled Contourlet Transform and Mutual Information”, International Conference on Computer Applications and Industrial Electronics(ICCAIE ), IEEE,2010
9. Jie Zhao,” Medical image registration based on feature and mutual information”, Proceedings of the Ninth International Conference on Machine Learning and Cybernetics, Qingdao, IEEE,2010
10. Jignesh N Sarvaiya,”Image registration by template matching using normalized cross-correlation”, International Conference on Advances in Computing, Control, and Telecommunication Technologies, IEEE, 2009
11. Turcajova, R. and J. Kautsky,”A hierarchical multiresolution technique for image registration”, Proc. of the SPIE Mathematical Imaging: Wavelet: Applications in Signal and Image Processing, 1996.
12. Jeongtae Kim ; Fessler, J.A.,Intensity-based image registration using robust correlation coefficients IEEE Transactions on Medical Imaging, Vol. 23, Issue: 11 pp1430-1444.
13. Nayana M. Nichat * Prof. V.K. Shandilya,” Image Registration for Area Matching by Using Transform Based Methods”, International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 4, April 2013
14. Dizaji, M.M. ; Dizaji, R.M., “Detection of internal displacement of tissues in ultrasound images using image registration technique”, Canadian Conference on Electrical and Computer Engineering, IEEE, Vol. 2,p.p 1145-1148, 2002
15. W. T. Freeman and E. H. Adelson, “The Design and Use of Steerable Filters,” IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol. 13, No. 9, 891-906, Sept. 1991.
16. P. Perona, “Deformable Kernels for Early Vision,” IEEE Conference on Computer Vision and Pattern Recognition, pages 222-227, June 1991.
17. H. Greenspan, S. Belongie R. Goodman and P. Perona S. Rakshit and C. H. Anderson, “Overcomplete Steerable Pyramid Filters and Rotation Invariance”, Computer Vision and Pattern Recognision,Procedings of CVPR,IEEE,1994
18. P. J. Burt and E. A. Adelson, “The Laplacian Pyramid as a Compact Image Code” IEEE Transactions on Communications, Vol. 31, 532-540, 1983.
19. C. H. Anderson, “A Filter-Subtract-Decimate Hierarchical Pyramid Signal Analyzing and Synthesizing Technique,” United States Patent 4,718,104, 1987.
20. Qinsheng Du , Li Chen, “An Image Registration Method Based on Wavelet Transformation”, International Conference on Computer, Mechatronics, Control and Electronic Engineering (CMCE),IEEE, 2010
21. Hua-mei Chen and Pramod K. Varshney, “Mutual Information-Based CT-MR Brain Image Registration Using Generalized Partial Volume Joint Histogram Estimation”, IEEE transactions on medical imaging, VOL. 22, NO. 9, 2003
22. www.osirix_viewer.com/datasets