WAVELET BASED SIGNAL PROCESSING TECHNIQUES FOR MEDICAL IMAGE FUSION

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To our Prophet Rasullu allah S.A.A.W.S First teacher

To my parents for always believing in me

To my brothers support and Encouragement

To my beloved Wife,

To my fruits daughters, and son

and

To My Ustaz Al-Shaheed Ismail and his Son Sinan

...

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Saif Saaduldeen

ABSTRACT

Recently signal and image processing have been central to researchers and scholars through present various applications and solve many problems in different fields in our life. This thesis presents signal processing algorithm for multi-modal medical images by fusion technique. Medical image fusion has been used to derive texture from multi-modal medical image data. The idea is to improve the image content by fusing images like computer tomography (CT) and magnetic resonance imaging (MRI) images. This derived texture can be assisted by medical examiner for various purposes such as, diagnosing diseases, detecting the tumor, surgery treatment, and clinical treatment planning system. Our object to get more as possible better image fused high quality and clearer. Previous fusion based on the spatial domain and another depends on the frequency domain, both these strategies have disadvantages like contrast reduction, weak quality, artifact, and ringing. Therefore researchers in medical fusion field attempt to solve these problems by many algorithms are presented and are competed to improve previous results. Hence, this work present an algorithm based on Discrete Wavelet Transform (DWT) to obtain the scale and detail coefficients of the various images. Different fusion methods are also used comparing ; Non-linear fusion rule (NLFR), average mean value (AMV), maximum absolute rule (MAR), and Weighted Condition Value (WCV) to correlate the coefficients each method is used separately then produce the last result by Inverse Discrete Wavelet Transform (IDWT) which based on single level transform. The novelty in this thesis are using two strategies, first one, deal with match measures are calculated as a whole to select the wavelet coefficients coming from different wavelet transform filters banking ,Second once using NLFR method, output results to compare with the chosen method so as to determine which is better. The medical fusion system implemented by MATLAB software, and analyzed the results done by Petrovic Fusion Algorithm (PFA). The method yields high scores the conventional methods. Overall this method has high potential for a better application of fusion in the medical imaging field.

ABSTRAK

Baru-baru ini isyarat dan pemprosesan imej merupakan pusat penyelidik dan ulama melalui masa ini pelbagai aplikasi dan menyelesaikan banyak masalah dalam bidang yang berbeza dalam kehidupan kita. Tesis ini membentangkan isyarat algoritma pemprosesan imej perubatan multi -modal dengan teknik fusion. Idea ini adalah untuk meningkatkan kandungan imej dengan menggabungkan imej seperti komputer tomografi (CT) dan pengimejan resonans magnetik (MRI) imej. Gabungan sebelumnya berdasarkan domain ruang dan satu lagi bergantung kepada domain frekuensi, kedua-dua strategi ini mempunyai kelemahan seperti pengurangan Sebaliknya , kualiti lemah, artifak , dan nada . Oleh itu penyelidik dalam gabungan perubatan bidang usaha untuk menyelesaikan masalah-masalah ini oleh banyak algoritma dibentangkan dan bersaing untuk meningkatkan hasil sebelumnya. Oleh itu , kerja ini membentangkan satu algoritma berdasarkan diskret ubahan wavelet (DWT) untuk mendapatkan skala dan terperinci pekali pelbagai imej. Kaedah gabungan yang berbeza juga digunakan membandingkan ; Peraturan gabungan bukan linear (NLFR), nilai purata min (AMV), pemerintahan mutlak maksimum (MAR), dan wajaran Keadaan Nilai (WCV) untuk mengaitkan pekali setiap kaedah yang digunakan secara berasingan kemudiannya mengeluarkan hasil terakhir oleh songsang diskret ubahan wavelet (IDWT) yang berdasarkan tahap tunggal mengubah . Sesuatu yang baru di dalam tesis ini menggunakan dua strategi , pertama , menangani Perlawanan langkah dikira secara keseluruhan untuk memilih pekali ombak kecil datang dari ombak kecil yang berbeza mengubah perbankan penapis, sekali menggunakan kaedah NLFR Kedua , keputusan output untuk membandingkan dengan kaedah yang dipilih jadi untuk menentukan yang lebih baik. Sistem gabungan perubatan dilaksanakan oleh perisian MATLAB, dan menganalisa keputusan dilakukan oleh Petrovic Fusion Algoritma (PFA). Kaedah ini menghasilkan markah yang tinggi kaedah konvensional. Keseluruhan kaedah ini mempunyai potensi tinggi untuk kegunaan yang lebih baik daripada gabungan dalam bidang pengimejan perubatan.

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LIST OF ABBREVIATIONS

CT	-	Computed Tomography
MRI	-	Magnetic Resonance Imaging
PET	-	Positron Emission Tomography
SPECT	-	Single photon Emission Computed Tomography
PSNR	-	Peak to noise Signal Ratio
MSE	-	Mean Square Error
NIR	-	Night Image Resolution
BT	-	Brovey Transform
IHS	-	Intensity Hue Saturation
PCA	-	Principle Component Analysis
SVR	-	Synthetic Variable Ratio
IF	-	Image Fusion
MIF	-	Medical Image Fusion
MRA	-	Multi-resolution Analysis
LPT	-	Laplacian Pyramid Transform
WT	-	Wavelet Transform
DWT	-	Discreet Wavelet Transform
CWT	-	Continues Wavelet Transform

FIR	-	Finite Impulse Response
1 D	-	One Dimension
2 D	-	Two Dimensions
LPF	-	Low Pass Filter
HPF	-	High Pass Filter
LL1	-	Low Frequency coefficient (approximation) in one Level
HL1	-	High Frequency coefficient (Horizontal) in one Level
LH1	-	High Frequency coefficient (Vertical) in one Level
HH1	-	High Frequency coefficient (Diagonal) in one Level
Db2	-	Daubechies 2
Db4	-	Daubechies 4
FB	-	Filter Banking
AMV	-	Average Mean Value
MAR	-	Maximum Absolute Rule
WCV	-	Weighted Condition Value
NLFR	-	Non Liner Fusion Rule
HVS	-	Human System System
PFA	-	Petrovic Fusion Algorithm

LIST OF APPENDICES

CHAPTER 1

PROJECT OVERVIEW

1.1 Introduction

Many modern medical scenes need fusion techniques in order to produce images capable of improving clinical diagnosis. The medical image can be classified into high resolution and low resolution, or classified according to sensor device and physical process which is used to generate the images (multi-modality image).

Take for example, the CT and MRI images of the brain; each one has high resolution but different multi-modality, the CT provides better analysis in hard tissue while the MRI is more useful in soft tissue. Positron emission tomography (PET) low resolution image contains functional information, while Single Photon Emission Computed Tomography (SPECT) image provides information about visceral metabolism and blood circulation [1]. Fusion process is applied on these images to get a new image containing all texture of the original images as will be proved and discussed in the subsequent parts to come.

Therefore this research uses image fusion technology, and applies it on the brain images, by using two samples from images; one from sample magnetic resonance imaging (MRI) and second from sample computed tomography (CT) scan, and then these images are integrated using Wavelet Transform Methods This is illustrated in Figure 1.1.

The research tries to work on getting acceptable results through applying wavelet transform methods in the remote sensing field of medical imaging.

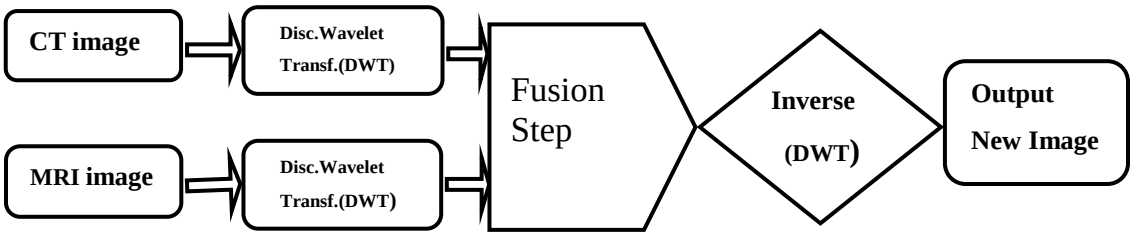

Figure 1.1 Block diagram medical image fusion process

This research will also evaluate the performance of the organization of fusion technology suitable for medical images after getting results by modern methods of evaluation, and then ultimately determined by the user in general as shown in Figure 1.2. There are many methods to check and evaluate the results after fusion process is finished such as peak signal to noise ratio (PSNR), Petrovic Algorithm which is used in this project.

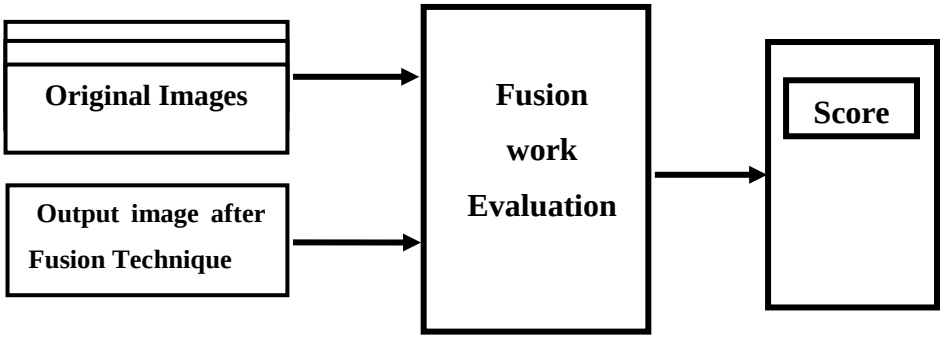

Figure 1.2 Block diagram evolution of a fusion work

1.2 Problem Statement

Fused medical image is required to get better contrast and quality is important for medical images. Previous studies that used wavelet transform technique to fuse medical image did not cover many wavelet banking filters and as such did not obtained optimum results. Earlier algorithms are based on traditional methods, hence less accurate fusion result were obtained. Most previous works fusion evaluation methods are based on PSNR, mean square error (MSE) and Entropy that caters for only one image at a time.

1.3 Motivations for the Research

There is need to provide the technique of image fusion more effectively through analytical study of medical images using wavelet transforms technique. A new tool for medical diagnosis is obtained in an effective manner, dependent on the integration of two or more images, from the same scene or the same section, and then incorporating good features of each image and injecting it into a new image to form a more accurate picture and clearer input images. This process is called image fusion. Image fusion technique within short time is able to overcome many obstacles that face the subject of image enhancement compared to traditional techniques used in various fields like remote sensing, military surveillance, and medical field [2]. Therefore, more research is needed in this field to develop medical technology and so this is what this study is going to try to do by combining most of the images features in one image using image fusion technique. This technique has an important role in providing information required by medical doctors in providing better medical diagnostics services.

1.4 Objectives of Project

The basic objectives to be carried out for this research are:

i. To use spectral domain techniques of multi-resolution transform based on various banking wavelet transform filters to obtain an optimum fused image.

ii. To develop an enhanced fusion algorithm that uses correlation coefficient based on the Non-Linear Fusion Rule compared with traditional methods.

iii. To evaluate Performance using the Petrovic Algorithm. This method caters for multiple images at a time unlike other evaluation methods.

1.5 Project Scope

This project is covers the CT and MRI medical images. These images have different medical diagnosis specification but have same dimensional and quality for the same scene from a human body which is obtained from the official medical fusion website. The medical image fusion system is implemented by MATLAB software, which related on the wavelet toolbox through using most of the wavelet filters banking in single level transform. The project will be focusing on result quality evaluated by Human Visual System and Petrovic Fusion Algorithm.

1.6 Thesis Layout

Chapter 1 Project Overview, Problem Statement, Objectives of project, Motivation for the Research, project scope and limitation. Last part of this chapter will present the report layout.

Chapter 2 Two-dimensional medical signal, Example of image fusion, Properties of the CT and MRI Medical images**,** Computed Tomography and Magnetic resonance imaging specification, Fusion Technique Role to Medical Images**,** Previous Works on Image Fusion and Medical Image Fusion

Chapter 3 Continues and Discrete Wavelet transform in one, and Two Dimension, Discrete wavelet transform and filters banking, Types of Filter Banking in 2D-DWT.

Chapter 4 focuses in project design methodology including algorithm and methods implementation steps.

Chapter 5 presents the results and discussion that can be obtained from various scenarios of experiment. These results are evaluated by Human Visual System and Special statistical algorithm.

Chapter 6 summarizes the conclusions from this research. The last part of this chapter discusses recommendation for future works and project contribution.

REFERENCES

1. Parmar, K., R. K Kher, and F.NThakkar, ”Analysis of CT and MRI Image Fusion using Wavelet Transform”, Vallabh Vidyanagar, India, 2012 International Conference on Communication Systems and Network Technologies, 2012.
2. Wang, Z,D Ziou, Costas Armenakis, Deren Li, and Qingquan Li ,”A Comparative Analysis of Image Fusion Methods, IEEE transactions on geoscience and remote sensing,vol. 43, no. 6, june 2005.
3. Erich, K.,”Imaging Systems for Medical Diagnostics”, Berlin and Munich Siemen Aktiengesellschaft. pp. 318–327. ISBN 3-8009-1564-2, 1990.
4. http://prixray.com/, Accessed on 14th April 2013.
5. http://www.merriam-webster.com/dictionary/computedtomography,Accessed on 10th April 2013.
6. G. T. Herman, “Fundamentals of computerize tomography: Image reconstruction from Projection”, 2nd edition, Springer, 2009.
7. https://www.arrt.org/Patient-Public/Patient-Page. Accessed on 14th April 2013.
8 http://www.asrt.org/main/standards-regulations/statelegislative-affairs/individual state- licensure-info, Accessed on 14th April 2013.
9. http://www.roentgenpraxis-lichterfelde.de/ct/ct-angiographie.php , Accessed on 14th oct.2013.
10. http://www.radiologyinfo.org/info.cfm?pg,bodyct.Accessed on 14th April2013.
11. Sheil,W.C., "Magnetic Resonance Imaging (MRI Scan)",MedicineNet.com. Retrieved, 27 April 2013.
12. Wells, P.N.T.,” Ultrasonic imaging of the human body”, Department of Medical Physics and Bioengineering and Centre for Physics and Engineering Research in Medicine, Bristol BS1 6SY, UK , Rep. Prog. Phys. 62 , 1999.

13. http://www.interhomeopathy.org/deja-vu-and-depression-a-case-of-ultrasound, Retrieved 2 jan 2014.
14. Wu, H. , Y. Xing "Pixel-based Image Fusion Using Wavelet Transform for SPOT and ETM + Image, Center for Forest Operations and Environment, Northeast Forestry University, Harbin, P.R. China , 2010.
15. Pajares, G., and J. Manuel de la Cruz, "A wavelet-based image fusion tutorial," Pattern Recognition, vol. 37, pp. 1 855-1872, September 2004.
16. Grimes, C. A., E. C. Dickey, and M. V. Pishko ,"Encyclopedia of Sensors ", 10-Volume Set, American Scientific Publishers, 2006.
17. Patil, U., and U. Mudengud, "Image fusion using hierarchical PCA"International Conference on Image Information Processing,2011.
18. Rahul, G., and R.Kalpana, " block-based feature multi level multi focus image fusion on Neural network ", IJERT,Vol. Issue 8, October – 2012.
19. Wang, Z.,D. Ziou,and C. Armenakis, D. Li, and Q. Li, " A comparative analysis of image fusion methods ," IEEE Trans. Geosci. Remote Sens.,vol. 43, no. 6, pp. 81–84, Jun . 2005.
20. Cvejic, N., D. Bull and N. Canagarajah, " Improving Fusion of Surveillance Images in Sensor Networks Using Independent Component Analysis " , IEEE Transactions on Consumer Electronics, Vol. 53, No. 3, 2007.
21. Chen, Y., and R.S. Blum, "Experimental Tests of Image Fusion for Night Vision", Proc. 8th International Conference on Information Fusion, 2005.
22. Omar, Z., " Signal Processing Algorithms for Enhanced Image Fusion Perfor-ance and Assessment ", Ph.D. thesis, Imperial College London, Page 28 ,2012.
23. http://www.sciencedirect.com/science/article/pii/S0720048X10005358, Accessed on 14th Oct. 2013.
24. http://www.radiologyinfo.org /info.cfm?gbodyct, Accessed on 14th April 2013.
25. http://www.radiologyinfo.org /info.cfmpgbodyct, Accessed on 14th April 2013.
26. http://www.neurologycontent/6/1285/F1.expansion.html, Retrieved 2 jan 2014.
27. Pajares, G., and J. Manuel de la Cruz, "A wavelet-based image fusion tutorial," Pattern Recognition, vol. 37, pp. 1 855-1872, September 2004.

28. Zhang, Y. “Understanding image fusion”, Photgrammetric Engineering and Remote Sensing , 2004.
29. Burt, P.J. and R.J. Kolczynski, “Enhanced image capture through fusion”,Proc, 4th,Intl ,Conference on Computer Vision, 1993.
30. Shivsubhamani, K.P.Soman “Implementation and Comparative Study of Image Fusion Algorithms”, International Journal of Computer Applications (0975 – 8887) Volume 9– No.2, November 2010.
31. Yonghong, J. “ Fusion of landsat TM and SAR image based on principal Component analysis “ Remote Sensing Technology and Application, vol. 13, no. 1, pp. 46–49, 1998.
32. Li, S., and B. Yang, “ Multifocal Image Fusion Using Region Segmentation and Spatial Frequency,” in Proc. of Image Vision Computing, vol. 26, no. 7, 2008, pp. 971–979.
33. Sadjadi, F.“ Comparative Image Fusion Analysis”, IEEE International Workshop on Object Tracking and Classification in and Beyond the Visible Spectrum, 2005.
34. Singh , N. and Pinky Tanwar, “Image Fusion Using Improved Contourlet Transform Technique” IJRTE ISSN: 2277-3878, Volume-1, Issue-2, June 2012.
35. Yang, Y.,D. Sun Park, S. Huang, Z. Fang, and , Z. Wang “Wavelet based Approach for Fusing Compute Tomography and Magnetic Resonance Images”, Control and Decision Conference (CCDC’09), Guilin, China,17-19 June, 2009.
36. Li, J. ” Spatial Quality Evaluation of Fusion of Different Resolution Images ” Laval University Canada COPL ,Physics department, International Archives of Photo grammetry and Remote Sensing, vol. xxxiii, Part B2, Amsterdam 2000.
37. Wald, L. “ Some terms of reference in data fusion ”, IEEE Transactions on Geoscience and Remote Sensing, Vol. 37, No. 3, 1999.
38. Toet, A.“A Morphological Pyramidal Image Decomposition”, Pattern Recognitio Letters 9, 1989.
39. Zeng, J., A. Sayedelahl, T. Gilmore and M. Chouikha, “Review of image fusion Algorithm for unconstrained outdoor scenes”, Proc. Intl. Conf. on Signal processing Processing, Vol. 2, 2006.

40. Burt, P.J. " A gradient pyramid basis for pattern-selective image fusion ", Society for Information Display, Digest of Technical Papers, 1992, pp. 467-470.
41. Li, H., B. S. Manjunath, and S.K. Mitra, "Multi-sensor image fusion using the wavelet transform ", in Proc. Of CVGIP: Graphical Model and Image Processing, vol. 57, no. 3,1995.
42. Cheng ,Y. , R. Zhao, B. Wang ,and X. Jiang ,"An optimal algorithm multi-Sensor image fusion based on Wavelet Transform", Signal Processing, Proceedings, ICSP '04, IEEE conference publications Third, 2010.
43. Chen ,Y. , L. Chen , H. Gu , and K. Wang " Technology For Multi-Focus Image Fusion Based on Wavelet Transform", Advanced Computational Intelligence, IEEE conference Publications Third ,2010.
44. Zhang,C., L.Bai , Y.Zhang and, B.Zhang, " Hierarchical Image Fusion Based on Wavelet Transform", Mechatronic and Automation, Proceedings of the 2006 IEEE International Conference on Digital Object Identifier, 2006.
45. Kagadis, C. "Medical Physicist, MSc Design and Implementation of algorithms for medical image registration and fusion," university of patras, patras 2002.
46. Shen, Y., J. Ma, and L. Ma, " An Adaptive Pixel-weighted Image Fusion Algorithm Based on Loc al Priority for CT and MRI Images " IMTC Instrumentation and measurement Technology Conference Sorrento, Italy 24-27 April 2006.
47. Calhoun, V., and T. Adalı, "Feature-Based Fusion of Medical Imaging Data", IEEE Transactions on Information Technology In Biomedicine, 2009.
48. Xiao,Z.S., and C. Zheng , "Medical Image Fusion Based on the Structure Similarity Match Measure", 2009 International Conference on Measuring Technology and Mechatronics Automation, China.
49. Quan, W. and X. Hao, "Multi-mode Medical Image Fusion Algorithm Based on Principal Component Analysis", North university of China, ©2009 IEEE, China.
50. Brahmbhatt, K. N., and R. M. Makwana, " Comparative Study On Image Fusion Methods In Spatial Domain', B.V.M Engineering College, VallabhVidyaNagar-388120, Gujarat, April 2013, India.

51. Patil, U., and ,U. Mudengudi,“ Image Fusion Using Hierarchical PCA ”, Dept. Electronics and Communication, BVB college of Eng. and Tech. Proceedings of the 2011 International Conference on Image Information Processing , 2011.
52. Singh , R. , R. Srivastava ,O. Prakash, and A. Khare, “Mixed scheme based multimodal Medical Image fusion using Daubechies Wavelet Transform”, Department of Electronicsand Communication ,University of, Allahabad, India, IEEE/Osa/Iapr International Conference on informatics , Electronics & Vision,2012.
53. Liu ,Y., J. Yang, and J. Sun, “ PET/CT Medical Image Fusion Algorithm Based on Multi-Wavelet Transform”, 978-1-4244-5848- IEEE 6 / 10 / 2010.
54. Parmar, K. ,and R. Kher ,“ A Comparative Analysis Multimodality Medical Image Fusion Methods ”, Modeling Symposium (AMS), Sixth Asia , 2012.
55. Ma,Y. “ Medical Image Fusion Based On Wavelet Transform “, school of computing ,Bleking institute of technology pingdao University ,sweden, 2010.
56. Narendra Babu, J., and S. A. K. Jilani, “Multi Sensor Medical Image Fusion Techniques and Performance Analysis” International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 2 Issue 2, 2013.
57. Gargour ,C., M. Gabrea, and, Ors., ”A short introduction to wavelet transform and their Applications ”, Second Quarter 2009,IEEE Circuits and Systems Magazine, 2009.
58. Resnikoff, Howard L. & Wells, Raymond O., “ Wavelet Analysis”, Springer-Verlag New York Inc., 1998.
59. Ekici, S. “ Beyond Wavelets ” Çankaya University, Graduation Project I, 2003.
60. Antoine, J. P., R.Murenzi, P.Vandergheynst, and S. T. Ali,” Two-Dimensional Wavelets and Their Relatives”, Cambridge, U.K.: Cambridge Univ. Press, 2004.
61. Wang, X., J. Gao, and W. Chen ”A New Tiling Scheme for 2-D Continuous Wavelet Transform with Different Rotation Parameters at Different Scales Resulting in a Tighter Frame” IEEE signal processing letters, vol. 19, no. 7, 2012.
62. C.-Lin, Liu, ”A Tutorial of the Wavelet Transform” February 23, 2010.

63. Lin, P. " An Introduction to Wavelet Transform " , Graduate Institute of Communication Engineering National Taiwan University, Taipei, Taiwan, ROC,2006.

64. Goswami, J. C. and A. K. Chan " Fundamentals of Wavelets Theory, Algorithms, and Applications ", page No.154, published by Johon Wiley & Sons, Inc., Hobken , New jersey.

65. Kingsbury, N., J. Magarey, "Wavelet Transforms in Image Processing", Proceeding First European Conference on Signal Analysis and Prediction,1997.

66. Huang, J. "The Discrete Wavelet Transform for Image Compression" Graduate Institute of Communication Engineering, National Taiwan University, Taipei, Taiwan, ROC,2010.

67. Goswami, J. C. and A.K. Chan "Fundamentals of Wavelets Theory, Algorithms, and Applications", page No.97, published by Johon Wiley & Sons, Inc., Hobken , New jersey.

68. Deyab, S., and, F. H. Elfouly ," Comparison between Haar and Daubechies Wavelet Transforming on FPGA Technology", Proceedings of World Academy of Science, Engineering and Technology volume 20, ISSN 1307- 6884 , 2007.

69. kaur, J., and R. kaur , "Biomedical Images denoising using Symlet Wavelet with Wiener filter ", International Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 3, Issue 3, May-Jun 2013.

70. Walker , J. S. "A Primer on Wavelets and Their Scientific Applications ", page No.6, University of Wisconsin Eau Claire, Wisconsin, U.S.A. Second Edition, © 2008 by Taylor & Francis Group, LLC.

71. http://www.pybytes.com/pywavelets/Wavelet Properties Browser. Accessed on 3jan,2014.

72. Peng, M. and N. K. Bose,"Parametrized Biorthogonal Wavelets and FIR Filter Bank Design with Grobner Bases", The Pennsylvania State University, University Park, PA, USA,2008.

73. Petrovic, V. and T. Cootes, "Information representation for image fusion evaluation", 9th International Conference on Information Fusion, 2006, pp. 1-7.

74. Qu ,G., D. Zhang, and P Yan, " Information Measure for Performance of Image Fusion", Electronic Letters, Vol.38(7), 313-315, 2002.

75. Piella, G., H Heijmans,"A New Quality Metric for Image Fusion", Proceedings International Conference on Image Processing, ICCV03, Vol. 3, 173-176, 2005.

76. Omar, Z. "signal processing algorithms for enhanced image fusion performance and a assessment " Ph.D. thesis, Imperial College London ,2012, Page 106.

77. http://www.neuroradiologycases.com/2011_11_01_archive.html, Accessed on 14th Oct. 2013.