STUDY ON IMAGE COMPRESSION AND FUSION BASED ON THE WAVELET TRANSFORM TECHNOLOGY

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Abstract- With the development of information technology, the rapid development of microelectronics technology, image information acquisition and use is also increasing, sensor technology also unceasingly to reform. A single sensor information obtained is limited, often can not meet the actual needs, in addition, different sensors have the advantage of the imaging principle and its unique, as in color, shape characteristics, band access, spatial resolution from the aspects of all have their own characteristics. Registration algorithm is proposed in this paper has better robustness to image noise, and can achieve sub-pixel accuracy; the registration time has also been greatly improved. In terms of image fusion, the images to be fused through wavelet transform of different resolution sub image, using a new image fusion method based on energy and correlation coefficient. The high frequency image decomposed using new energy pixels of the window to window energy contribution rate of fusion rules, the low frequency part by using the correlation coefficient of the fusion strategy, finally has carried on the registration of simulation experiments in the Matlab environment, through the simulation experiments of fusion method in this paper can get the image fusion speed and high quality fast fusion image.

Index terms*: wavelet transform; image match; image fusion; spatial resolution.*

I.   INTRODUCTION

With the development of science and technology, more and more sensors used in various fields, but the single sensor image obtained information, often can not meet the actual needs, image fusion is the use of different imaging mode of various sensors, provide complementary information, increase the amount of information of the image, in order to obtain more reliable, more accurate information for observation or further processing, which is widely applied in the field of military, medicine, remote sensing, machine vision, target recognition [1, 2, 3]. Image is an important media of information transmission, in order to make the limited symbols to express more information, image compression is very necessary, but also possible, therefore has produced a variety of image compression method, the existence of redundant great general in the original image (such as by adjacent pixels correlation caused); or the user due to various reasons, and the original image information are not interested; or when the channel resolution than the original image resolution, reducing the input original image resolution has little influence on output image resolution; or is a large amount of image information (such as satellite remote sensing image) short transmission processing [4, 18]. All of this requirement in the image processing process, must abandon the useless information, retain the useful part, the number of bytes exhausted may be less representation of the original image, in order to improve the efficiency of image transmission and reduce the storage capacity of the image [5].

All information is often the existence of redundant image data, such as spatial redundancy, information redundancy, gun visual redundancy and the redundant structure etc. The so-called compression, is the idea to remove all kinds of redundancy, retain truly useful information [6, 7]. The signal compression process is often referred to as the coding process to restore the original image is often referred to as the decoding with the development of multimedia technology and communication technology, has put forward higher requirements of multimedia entertainment and information expressway and constantly on the information of the data storage and transmission, but also to the existing bandwidth limited to a severe test, especially digital image communication with the huge amount of data, more difficult to transport and storage, greatly restricts the development of image communication, so the image compression technology has been paid more and more attention. The purpose of image compression is the original large image with less bytes and transmission, and required with good image recovery quality. The use of

image compression, image can reduce the burden of storage and transmission; realize the fast transmission and real-time processing in the network image making [8, 9].

Hierarchical wavelet tree proposed by Said and Pearlman (SPIHT) is a collection of segmentation algorithm using spatial tree hierarchical segmentation approach, effectively reduces the bit plane coding symbol set scale. Compared to EZW, SPIHT algorithm construct two different types of space zero tree wavelet coefficient, the amplitude attenuation better use. As with the EZW encoder and SPIHT encoder algorithm complexity is low, also had embedded bit stream, but the performance of the encoder is greatly improved compared with EZW. This paper based on introduction of SPIHT algorithm on the standard of the standard SPIHT algorithm are analyzed and discussed, to find its shortcomings. SPIHT algorithm has the advantage of high compression ratio, compression speed, the algorithm is simple; but the drawback is that the storage space demand, quantization sometimes is not optimal, not explicitly given a unit pixel the number of bits for encoding and decoding times SPIHT and the relationship between the scanning process, fine enough concise, code more complex.

II.   Related theory and method

A. The related theory of image registration

At present, image registration has been widely used in image fusion, pattern recognition, data fusion gathering, medical diagnosis, map correction [10, 11]. Following on the issue, the main purpose of the image registration and corresponding application example are summarized [12, 19]:

(1) Image from different observation points, the image registration can obtain a two-dimensional scene comprehensive or 3D scene images, such as image edge technology, or 3D graphic shape recovery etc.

(2) Image from different time or in different conditions, through the registration techniques, can find out the change of displacement of an object in the images, such as lesion detection in medical image change detection technology, or land use status.

(3) Images from different sensors, registration can complete the preprocessing of multi sensor fusion between doctors, such as multi modality medical image fusion, a more comprehensive understanding of the pathological information of patients.

(4) A model and the image registration, registration can locate in the model or are compared, such as product quality detection, map location or sample classification etc. According to the different image sources, needs, different imaging modes, and the scope of application, registration methods used are not static [13].

B. The common methods of image fusion

Image registration in the mathematical formula (1) can be shown [14].

$$I_2(x, y) = g(I_1(x, y)) \tag{1}$$

Among them, I_1 and I_2 represent the two fusing image representation of the two-dimensional matrix, $I_1(x, y)$ and d represent the two images in I_2 (x, y) where δ is one-dimensional gray value, gray level transformation, f represents a two-dimensional coordinate transformation [15, 16,17].

The original image signal for embedding hypothesis representation, x_n representation of signal SNR is expressed was shown in formula (1):

$$SNR = 10 * \log_{10} \left[\frac{\sum_{n=0}^{L-1} x^2(n)}{\sum_{n=0}^{L-1} [x_w(n) - x(n)]^2} \right] \tag{2}$$

Wherein, L represents the original frequency signal length, n represents the signal sampling points, and the range of n is 0<n<L, the unit of signal-to-noise ratio is dB.

Robustness is an important standard to measure the robustness of image system, more robust against attacks that ability is stronger. The robustness of the level is divided into the following categories: zero (no beast stick), junior, senior, intermediate, advanced, senior and senior. Objective to evaluate the beast bar standard usually use the bit error rate (Bits Error Rate, BER) said. The calculation of BER as shown in formula (3):

$$BER = \frac{\text{Transmission error bits}}{\text{Total bits}} * 100\% \tag{3}$$

C. Standard of image fusion evaluation

So far, the domestic and foreign experimental research and on the image registration method has quite a few for registration, a variety of methods, according to the selection of image of the element. Image registration methods are divided into two basic categories: one category is the

image registration method based on feature; another kind is the image registration method based on pixel.

This kind of methods mainly use the corner, images of cross point, line segment, edge, contour image obvious characteristic, according to these characteristics, estimate the transformation model between the images, this algorithm greatly reduces the image information, so that a small amount of calculation, high efficiency of registration. However, these characteristics must be affected by noise small, enough quantity, strong anti-interference ability, and has the characteristics of easy detection, in fact, these conditions are difficult to meet. The basic idea of image registration based on feature is the same, as shown in Figure 1. Map feature extraction and feature matching is a registration key.
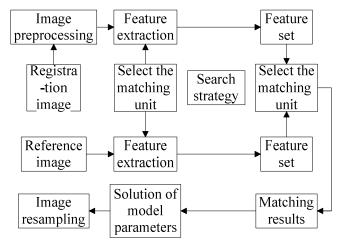

Figure 1. The basic idea of image registration based on feature

D. Wavelet transform theory

Frequency domain analysis of focus is to distinguish between burst signals and signal stability and quantitative analysis of its energy, and identification of typical applications include cell membrane, inspection of metal surface, finance fast variable detection.

In fact, the wavelet is an alternate oscillation, and the waveform is attenuated, and DC component of the oscillating wave zero. The wavelet transform is the same as Fourier transform is decomposed in the orthogonal basis, and Fourier different is that you can choose different orthogonal bases, and then through the translation and scaling decomposition. The wavelet function is defined:

Let it change for the bubble, if meet the formula full weight:

$$\int_R \frac{|\hat{\psi}(\omega)|^2}{\omega} d\omega < \infty \tag{4}$$

According to the formula (4) for dilation and translation of the basic wavelet, telescopic translation after a wavelet series $\psi_{a,b}(t)$:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}} \psi(\frac{t-b}{a}) \qquad a,b \in R, a \neq 0 \tag{5}$$

The definition of Daubechies series wavelet basis for:

$$p(y) = \sum_{k=0}^{N-1} C_k^{N-1+k} y^k \tag{6}$$

Where C is the binomial coefficient, so:

$$|m_0(w)|^2 = (\cos^2(\frac{w}{2}))^N p(\sin^2(\frac{w}{2})) \tag{7}$$

At the same time to meet:

$$m_0(w) = \frac{1}{\sqrt{2}} \sum_{n=0}^{2N-1} h_n e^{-inw} \tag{8}$$

Scaling function and wavelet function, wavelet series is determined by the coefficient of C.

III. IMAGE REGISTRATION BASED ON WAVELET TRANSFORM AND REGION MUTUAL INFORMATION

A. Multi resolution analysis

Multi-resolution analysis is to construct a set of function space, forming each space has a unified form, and the closure of all space approach in each space, all functions are composed of standard orthogonal basis of the space, and function closures all function spaces in the constitute standard orthogonal basis of L2(R), if the signal decomposition in this kind of space, can obtain the time-frequency characteristics of orthogonal. But because of the space number is infinite in number, can be conveniently analyzed some characteristics of signals we are concerned.

(1) Monotonicity

$$V_j \subset V_{j+1}, \; for \; any \; j \in Z \tag{9}$$

(2)Asymptotic completeness

$$\mathop{I}_{j \subset Z} V_j = \Phi, \ \ close \ \{\mathop{U}_{j \subset Z} V_j\} = L^2(R) \tag{10}$$

(3) The expansion of complete

$$f(t) \in V_j \Leftrightarrow f(2t) \in V_{j+1} \tag{11}$$

(4) The translation invariance:

$$\forall k \in Z, \ \phi(2^{-j/2}t) \in V_j \Rightarrow \phi_j(2^{-j/2}t - k) \in V_j \tag{12}$$

The existence of Riesz matrix: exist $\phi(t) \in V_0$, making up $\{\phi_j(2^{-j/2}t - k)|k \in Z\}$ is Riesz matrix of V_j , specific instructions regarding Riesz as follows:

If $\phi(t)$ is Riesz matrix of V_0, then there exists constants A, B, and so

$$A\|\{c_k\}\|_2^2 \leq \left\|\sum c_k \phi(t - k)\right\|_2^2 \leq B\|\{c_k\}\|_2^2 \tag{13}$$

For all double infinite square and sequence $\{c_k\}$,that is

$$\|\{c_k\}\|_2^2 = \sum_{k \subset Z} |c_k|^2 < \infty \tag{14}$$

Wavelet analysis comes from the Fourier transform, Fourier transform reveals the relationship between the function of time and frequency spectrum function, reflects the signal spectrum in the time range of compositions (Figure 2), but in the Fourier analysis, local changes of signal will affect the signal across the spectrum, difficult to locate the frequency of occurrence of the time.
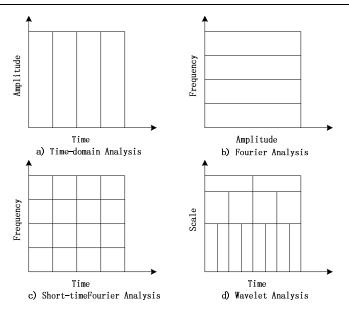
Figure 2. The signal spectrum in the time range of compositions

Although wavelet in signal processing of acoustic emission has made some achievements, but how to further by wavelet of various types of acoustic emission signal analysis, obtain the acoustic emission characteristics signal wavelet processing, further research is needed.

All the two drawbacks are owing to the inherent character of multiplicative noise. The reason of some spots after noise removing is because in the iteration the gradient in these points is with high value. In areas with high gray value, the multiplicative noise is also high, so we need to change the degree of noise removing with the gray value.

Before introducing our model, we recall the RLO model. The RLO model is depicted as (11):

$$\min_{u}\left\{E\left(u\right)=\lambda\int_{\Omega}\left|\nabla u\right|dxdy+\int_{\Omega}\left(\frac{f}{u}-1\right)^{2}dxdy\right\} \tag{15}$$

f is noise image and u is the desired original image.

Auber, Aujol [2] used the equation of:

$$\min_{u}\left\{E\left(u\right)=\lambda\int_{\Omega}\left|\nabla u\right|dxdy+\int_{\Omega}\left(\frac{f}{u}+Logu\right)dxdy\right\} \tag{16}$$

Setzer, Steidl and Tueber [11] used the equation of:

$$\min_{u}\left\{E\left(u\right)=\lambda\int_{\Omega}\left|\nabla u\right|dxdy+\int_{\Omega}\left(u-fLogu\right)dxdy\right\} \tag{17}$$

All the above model can be rewritten as :

$$\min_{u}\left\{E\left(u\right)=\lambda\int_{\Omega}\left|\nabla u\right|dxdy+\int_{\Omega}H\left(u\right)dxdy\right\} \tag{18}$$

Where $H(u)$ is the fidelity term. The Euler-Lagrange equation is:

$$\lambda \cdot div\left(\frac{\nabla u}{|\nabla u|}\right) + H'(u) = 0 \tag{19}$$

B. The classification method for image registration

The linear weighted method is respectively on the corresponding pixel location multi image fusion in in the weighted coefficient, and then adding processing, thus the final fused to form a new pixel in the image is one of the methods of image, the simplest and most basic fusion. If the image is A, B is the two images to be registered, the image size is M x N, A (I, J) denote the image of A in position (I, J) at the corresponding gray values of B (I, J) denote the image of B in position (I, J) at the corresponding gray value, new the fusion image is obtained for F (I, J), then achieve the formula can be expressed as its type (11) and (12) shown in shown.

$$F(i, j) = \omega_A(i, j)A(i, j) + \omega_B(i, j)B(i, j) \tag{20}$$

$$\omega_A(i, j) + \omega_B(i, j) = 1 \tag{21}$$

Among them, I said the image of each pixel number, i =1,2, M; J said..., in the image of each pixel column number, j =1,2,..., N.

The linear weighted method to obtain the fused image is directly related to the effect and weight selection, so how to stipulate the weights of $\omega_A(i, j),\ \omega_B(i, j)$ is the key of linear weighting, it is difficult to solve the problem.

Pyramid transform method is a fusion method based on transform domain, it is the image by a sort of filter, so as to decompose the image into different scales, a tower like structure of these image formation, each layer of the tower can choose some algorithm to get synthetic tower, finally reconstruct to form image fusion based on Pyramid transform, it uses a top to bottom by fusion method. Figure 3 shows the Pyramid transform data flow diagram.
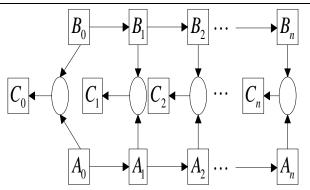
Figure 3. The Pyramid transform data flow diagram.

C. Regional mutual information

Studholme improved mutual information formula, proposed the normalized mutual information, such as the definition of type (13) is shown.

$$NMI(A,B) = \frac{H(A)+H(B)}{H(A,B)} \tag{22}$$

Comparison of registration method based on mutual information, the registration method based on normalized mutual information registration function smoothly so that to a certain extent, also made to improve the accuracy. But this method also considered only the gray information of the image, without considering the spatial information, this method in image noise or image registration in a low resolution, very easy to produce the mismatch phenomenon.

The calculation of information entropy of multiple point set distribution are considered, each pixel is represented not only the pixel value, also affect its neighborhood information, it includes the direction, comprehensive information surrounding pixels and the amplitude variation, registration function thus obtained from this method is more smooth, the robustness is stronger, the image information obtained is more accurate, but also can avoid because of local interpolation and produce local incorrect.

Calculate the average of all the elements in the P values for each element of the P and the average value obtained new vector subtraction, as shown in formula (14).

$$P = P - \frac{1}{N}\sum_{i=1}^{N} P_i \tag{23}$$

The calculation of the covariance matrix values, as shown in formula (15).

$$C = \frac{1}{N} P_0 P_0^T \tag{24}$$

The calculation of neighborhood mutual information (RMI) value was shown in formula (16).

$$RMI = H_g(C_R) + H_g(C_F) - H_g(C) \tag{25}$$

IV.   EXPERIMENTAL RESULTS

A. Software realization

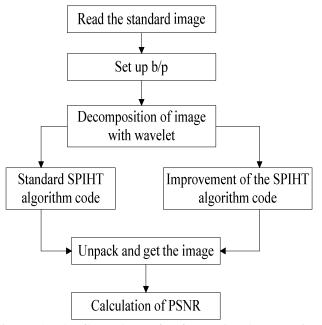The flow chart of software implementation is shown as follows (Figure 4).

Figure 4. The flow chart of software implementation.

According to the calculation of PSNR image, the original image and after decompression, and asking a Yin mouth not original image and extract the image to contrast.

Different standard SPIHT algorithm and improved SPIHT algorithm, the standard SPIHT algorithm for PSNR is slightly larger than the improved SPIHT algorithm, the output code length is less than the improved SPIHT algorithm, but the SPIHT algorithm of wavelet coefficients of the standard treatment than the SPIHT algorithm improved a lot more, and from the decompressed images can be seen, the improvement of image quality obtained with the SPIHT algorithm to than the standard SPIHT algorithm to get a little better, the standard SPIHT algorithm has more general than the improved SPIHT algorithm.

In a word, the improved SPIHT algorithm and the standard SPIHT algorithm are improved, compared with the standard SPIHT algorithm at the same time, the improved SPIHT algorithm provides a way to further research and improvement of SPIHT algorithm.

B. Image registration based on mutual information

Image registration based on mutual information is to find a space transformation, so that the space transformation of mutual information of two images reaches the maximum, is essentially a multi parameter optimization problem.

	Rotation	Translation	Zoom	Projection
Rigid	★	★		
Affine	★	★	★	
Projection	★	★	★	★
Nonlinear	★	★	★	★

The basic steps are as follows:

(1) For the two pieces of the image, with a picture as a reference image, another as the floating image, define a unified coordinate system, determine the form of image transform.

(2) According to the spatial transformation, the floating point in the image to the reference image coordinate transformation, do the pixel transform of gray level interpolation to calculate the gray value, and then calculating the mutual information of two images.

(3) Search through the optimization algorithm, changing the value of the parameter search space transformation, get mutual information space transformation parameters of maximum.

Table 1 several mathematical models of spatial transform used in image registration method. For different modified model, $\frac{\partial J(u)}{\partial u}$ has different forms. For modified RLO, $\frac{\partial J(u)}{\partial u} = \frac{2f^2}{3u^3} - \frac{f}{u^2}$.

For modified Auber, Aujol model $\frac{\partial J(u)}{\partial u} = \frac{f}{2u^2} - \frac{1}{u}$. For modified Setzer, Steidl and Tueber model,

$\frac{\partial J(u)}{\partial u} = \frac{f}{u} + Logu$. For modified Denis, Tupin, Darbon, Sigelle model, $\frac{\partial J(u)}{\partial u} = \frac{f^2}{3u^3} - \frac{1}{u}$. Submitting

$\frac{\partial J(u)}{\partial u}$ of different model to Equ.25, we will get the corresponding discrete equation.

We test the proposed method using different images. The method we compared is the original multiplicative noise removal method for the explanation of the modified term is effective.

For different kind of noise, we use different fidelity term. For judging the performance of the proposed model with the original method, we select several quantitative measurements. They are peak signal-to-noise-ratio (PSNR), signal-to-noise-ratio (SNR) and Edge-preservation index (EPI). PSNR is always used for explanation of the noise removal ability and the EPI is used for explanation of the edge preservation ability. Large PSNR and SNR correspond to the better noise removal ability. Large EPI corresponds to the better edge preservation and the EPI is small than 1 value.

Fig. 5 is the experiment on 'cameraman' image with Poisson type of multiplicative noise removing. From the experiment, we can see the noise in most sky area and on the buildings faraway is removed. The value of SNR, PSNR and EPI using our method are all bigger than using method, which proves that our method can get better result than using method.
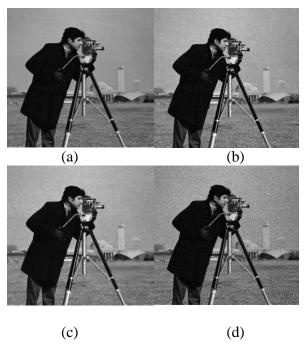

(a)   (b)

(c)   (d)

Figure 5. Experiment on 'CameraMan' image. (a) Original image. (b)Polluted by multiplicative noise with Poisson distribution(variance is 0.01). (c) Denoised image using Setzer [11] method(SNR =19.2593,PSNR =31.4944,EPI =0.9039). (d) Denoised image using our method(SNR =19.9237,PSNR = 32.0139,EPI = 0.9092).

C. Experimental results and analysis

For rotation and translation transformation of the original camera man (as shown in Figure 6), the image will be transformed (as shown in Figure 7) as the floating image, registration with the original image. When calculating the displacement difference of 1 degrees or rotation angle

above 1, that mismatch, a total of 100 times the ratio test, registration number and the total number of successful experiments for success rate. In this paper, using the general study of the other two methods based on mutual information for image contrast: method has been to match images using normalized mutual information method; method two is based on the gradient information of two images were normalized mutual information.

Figure 6. For rotation and translation transformation of the original camera man

Figure 7. The image be transformed as the floating image

Figure 8 is obtained in this paper in the transform of the curve, due to the comprehensive consideration on the image characteristics, adjacent elements and spatial information, so can effectively restrain the influence of noise brings to the objective function, obtained the convex type curve is smooth, thereby saving the computational time.

For solving w, the energy function is:

$$E(w) = \lambda \int_{\Omega} |w| dxdy + \frac{\theta}{2} \int_{\Omega} \left(w - \nabla u - b^{k+1} \right)^2 dxdy \qquad (26)$$

we can be computed by Euler-Lagrange equation:

$$w = \nabla u + b - \frac{\lambda}{\theta} \frac{w}{|w|} \qquad (27)$$

w can be computed by generalized soft threshold method.

$$w^{k+1} = Max\left(\left| \nabla u^{k+1} + b^{k+1} \right| - \frac{\lambda}{\theta}, 0 \right) \frac{\nabla u^{k+1} + b^{k+1}}{\left| \nabla u^{k+1} + b^{k+1} \right|}, 0 \frac{0}{0} = 0 \qquad (28)$$

In iterations of solving the above equations, we set $b^{k+1} = b^k + \nabla u^k - w^k$,
$b^0 = w^0 = 0$, $u^0 = f$. After some iteration, we will get the minimum of the total function energy. Then we will get the final clear image.
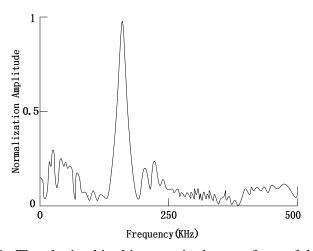

Figure 8. The obtained in this paper in the transform of the curve

V.   CONCLUSIONS

This paper based on the introduction of the principle of wavelet analysis and its application in image compression coding on the proposed an improved SPIHT algorithm. The fundamental of standard SPIHT algorithm is the quantization of the wavelet coefficients, the standard SPIHT algorithm adopted quantitative two into interval fixed, without considering the features of energy distribution of the wavelet coefficients, sometimes this is not necessarily the best method. This paper puts forward a new method based on this. The SPIHT algorithm the algorithm than the standard encoding and decoding times greatly reduced time consumption and PSNR and the standard SPIHT algorithm is quite. Finally, using MATLAB to achieve reasonable procedures show that the improved algorithm. In this paper, we propose a new adaptive multiplicative noise removal algorithm based on variation method. By analysis the shortcoming of Euler-Lagrange

equation, we find that these traditional variation models are not fitted for multiplicative noise very well. The amount of multiplicative noise is relative with the pixel value.

References

[1] Ramtin Shams, Parastoo Sadeghi, Rodney A. Kennedy, Richard I. Hartley,A Survey of Medical Image Registration on Multicore and the GPU, IEEE Signal Processing Magazine, vol. 27, no. 2, pp. 50-60, 2010.

[2] Chabi, N. ; Yazdi, M. ; Entezarmahdi, M,An efficient image fusion method based on dual tree complex wavelet transform, 2013 8th Iranian Conference on Machine Vision and Image Processing (MVIP), pp.403-407, 2013.

[3] Addesso P., et al., An interpolation-based data fusion scheme for enhancing the resolution of thermal image sequences, 2014 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), pp.4926 - 4929, 2014..

[4] M. Nguyen, S. J. Ong, and S. Vadhan, Statistical Zero-Knowledge Arguments for NP from Any One-Way Function, 47th Annual IEEE Symposium on Foundations of Computer Science. pp. 3 - 14, 2006.

[5] M. Nguyen, and S. Vadhan, Zero-Knowledge with Efcient Provers. In Proceedings of the 38th Annual ACM Symposium on Theory of Computing, pp 287-295, 2006.

[6] D. Catalano, and I., Visconti. Hybrid Commitments and Their Applications to Zero-knowledge Proof Systems. Theoretical Computer Science, vol.374, No. 1-3, pp. 229-260, 2007.

[7] Gerganov, G. ; Papucharov, A. ; Kawrakow, I. ; Mitev, K., Portal image registration using the phase correlation method, 2013 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), pp.1-3, 2013.

[8] J.M.Xin and S.A, "Linear prediction approach to direction estimation of cyclostationary signals in multipath environment", IEEE Transactions on Signal Processing, vol.49, No.4, pp.710-720, 2001.

[9] Gazzah, H.;Delmas, J.P.;Gazzah, H.;Delmas, J.P, Nonuniform. Linear Antenna Arrays for Enhanced Near Field Source Localization, 2014 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP),pp.2252-2256, 2014.

[10] T.B.Lavate, V.K.Kokate and A.M.Sapkal, "Performance analysis of MUSIC and ESPRIT DOA estimation algorithms for adaptive array smart antenna in mobile communication", International Journal of Computer Networks, vol.2, No.3, 2010, pp. 152-158.

[11] R.W. Ives, P. Eichel and N. Magotra: 'A new SAR image quality metric.' in: Proceedings of 42nd IEEE Midwest Symposium on Circuits and Systems, vol. 2, pp. 1143–1145, 1999.

[12] S. Jianhong: 'Weber's Law and Weberized TV Restoration.' CMLA Report, pp. 02-20, 2002, http:///url?q=ftp://ftp.math.ucla.edu/pub/camreport/cam02-20.pdf.

[13] L. Denis , F. Tupin , J. Darbon, and M. Sigelle: 'SAR Image Regularization with Fast Approximate Discrete Minimization.' IEEE Trans Image Process., vol.18, no.7, pp. 1588-600, 2009.

[14] Wei Liang, S.C. Mukhopadhyay, Rajali Jidin and Chia-Pang Chen, Multi-Source Information Fusion for Drowsy Driving Detection Based on Wireless Sensor Networks, Proceedings of the 2013 Seventh International Conference on Sensing Technology, ICST 2013, December 3 – 5, 2013, Wellington, New Zealand, pp. 861-868, ISBN 978-1-4673-5221-5.

[15] J. Shi and S. Osher: 'A Nonlinear Inverse Scale Space Method for a Convex Multiplicative Noise Model.' SIAM J. Imaging Sciences, vol.1, no.3, pp. 294–321, 2008.

[16] Y. Huang, L. Moisan, M.K.Ng, T. Zeng: Multiplicative Noise Removal via a Learned Dictionary, Image Processing, IEEE Transactions on, Vol.21, no.11, pp. 4534 - 4543,2012.

[17] Guodong Wang, Zhenkuan Pan,et al., Multiplicative noise removing using sparse prior regulization, 2013 6th International Congress on Image and Signal Processing (CISP), pp.304-308, 2013.

[18] N. K. Suryadevara, S.C. Mukhopadhyay, R.K. Rayudu and Y. M. Huang, Sensor Data Fusion to determine Wellness of an Elderly in Intelligent Home Monitoring Environment, Proceedings of IEEE I2MTC 2012 conference, IEEE Catalog number CFP12MT-CDR, ISBN 978-1-4577-1771-0, May 13-16, 2012, Graz, Austria, pp. 947-952.

[19] Chastine Fatichah, Diana Purwitasari, Victor Hariadi, Faried Effendy, Overlapping white blood cell segmentation and counting on microscopic blood cell images, International Journal on Smart Sensing and Intelligent Systems, vol.7, no.3, pp. 1271-1286, 2014.

[20] S. Bhardwaj, D. S. Lee, S.C. Mukhopadhyay, and W. Y. Chung, "A Fusion Data Monitoring of Multiple Wireless Sensors for Ubiquitous Healthcare System", Proceedings of the 2nd International Conference on Sensing Technology November 26-28, 2007 Palmerston North, New Zealand, pp. 217-222.

[21] Zongyang Zhanga, Zhenfu Caoa, Haojin Zhua, Constant-round adaptive zero-knowledge proofs for NP, Information Sciences: an International Journal, vol.261, pp.219-236, 2014.

[22] Yoshihisa Mori, Asami Koaze, Cognition of different length by Physarum polycephalum: Weber's law in an amoeboid organism, Mycoscience, vol. 54, no. 6, pp.426-428, 2013.