Robust Digital Image Watermarking based on Evolutionary Optimization Technique

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Abstract: This paper presents a novel optimization method for digital images in the Digital image watermarking system. Digital image watermarking has proved its efficiency in protecting illegal authentication of data. The visibility factor of the watermark is the significant parameter that helps in improving the perceptual transparency and robustness of watermarking system. The trade-off between the transparency and robustness is considered as an optimization problem and is solved by applying Gravitational Search Algorithm (GSA) based Optimization technique. Gravitational Search Algorithm (GSA) is used to identify the position for marking. The Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), and computational time are evaluated for a set of images using the MATLAB R2015b software.

Keywords: Computational Time, DWT, Gravitational Search Algorithm (GSA), MSE, PSNR, Robustness, Transparency.

I. INTRODUCTION

The need for digital image copyright protection methods has become a fundamental essence in multimedia applications due to the rapid growth of unauthorized access and reproduction of original digital objects like audio, video and images. Thus multimedia data protection is one of the major challenges and has drawn the attention of several researchers towards the development of protection approaches.

Watermarking is a concept of embedding a special pattern, watermark, into a document so that a given piece of information, such as the owner's or authorized consumer's identity, is indissolubly tied to the data.

Digital watermarking is the process of embedding information into a digital signal in a way that is difficult to remove. The process of digital watermarking involves the modification of the original multimedia data to embed a watermark containing key information such as authentication or copyright codes. Digital watermarking is one among the several protection methods which embeds a secret message or valuable information (watermark) within a host image, [3] video or an audio to prevent from unauthorized access. The watermark can either be a random signal, an organization's trademark symbol, or a copyright message for copy control and authentication [2].

Digital Watermarking provides techniques to hide watermarks into digital content to protect it from illegal copy or reproduction. It should provide the qualities like imperceptibility, robustness, security of cover image. This work is an attempt to provide a conceptual understanding of the application of genetic algorithm to optimize the Robustness of watermarked images. Genetic algorithm helps in searching appropriate locations in cover images to insert watermark. The fitness function is chosen so that optimal values are achieved for Robustness.

Embedding information in a robust and reliable way has lead to the application of frequency domain techniques like discrete cosine or the discrete wavelet transforms. The watermarks are added to the transform coefficients of the image instead of modifying the pixels, thus making it difficult to remove the embedded watermark. Nevertheless, robust watermarking in spatial domain can be achieved at the cost of explicitly modelling the local image characteristics. However, these features can be obtained with much ease in the frequency domain.

The two major properties – robustness and imperceptibility are essential in preserving the security of images from unauthorized usage. The ability to detect the watermark image after application of common signal processing distortions is known as robustness. The embedded watermarks are imperceptible both perceptually as well as statistically and do not alter the attractiveness of the multimedia content that is watermarked. While embedding the watermark into the host image, the strength is maintained without considering the local distribution of the host image. Due to this, certain unnecessary perceptible objects appear in the smooth regions. These deformations reduce as the watermark strength or the visibility factor is reduced. During this process, however, the robustness cannot be achieved. Hence the watermark has to be perceptually shaped with suitable amplification values for DWT sub-bands. The choice of amplification factors can be viewed as an optimization problem and solved using Genetic Algorithm.

M. Ketcham et al., [9] have proposed an innovative DWT watermarking scheme based on Genetic Algorithms for audio signals. The optimal localization and intensity were obtained using GA and the method was found robust against cropping, low pass filter and additive noise. Ali Al-Haj et al. [11] described an imperceptible and robust digital image watermarking scheme based on a combination of DWT and DCT. Similarly, Franco et al.[5], provided a DWT based technique for evaluation of fidelity and robustness. These algorithms were capable of extracting the watermark but suffered from the problems of unsatisfactory values of fidelity and robustness to various attacks concentrated in these papers. Zhicheng Wei et al [10] proposed an algorithm that yielded a watermark that is invisible to human eyes and robust to various image manipulations, and the results showed that only some specific positions were the best choices for embedding the watermark. The authors applied GA to train the frequency set for embedding the watermark and compared their approach with the Cox's method [8] to prove robustness. The analysis of GA was restricted to JPEG compression attack in this method. In [9], proposed a scheme that does not require the original image because the information from the shape specific points of the original image were been memorized by the neural network. This scheme applies the shape specific point's technique and features point matching method by genetic algorithm for resisting geometric attacks. In [7] proposed a new flexible and effective evaluation tool based on genetic algorithms to test the robustness of digital image watermarking techniques. Given a set of possible attacks, the method finds the best possible un-watermarked image in terms of Weighted Peak Signal to Noise Ratio (WPSNR). [11] Proposed an innovative watermarking scheme based on genetic algorithms (GA) in the transform domain considering the watermarked image quality.

In this paper genetic algorithm is used to adaptively optimize the watermark visibility factor at every chosen DWT sub-band that will improve the imperceptibility and robustness of the watermark image. The proposed technique uses the normalized correlation of the cover image and the watermarked images as the basis for evaluating the fitness function. The fitness function serves as the objective function that is to be optimized and searches the population consisting of appropriate embedding locations of the watermark within the cover image.

The remainder of the paper is organized as follows: In Section II, digital Image watermarking is described. Genetic algorithm with objective function is described in Section III. Proposed Method is implemented in section IV and Experimental results and conclusions are presented in Sections V and VI, respectively.

II. DIGITAL IMAGE WATERMARKING

There are various formats of images such as Joint Picture Experts Group (JPEG), Bitmap Images (BMP), Graphic Interchange Format (GIF), and Tagged Image File Format (TIFF). The basic component in all these formats is the pixel which builds up the image. In this work, pixels values are manipulated to embed the watermark. There are various image processing tools available viz Matlab, OpenCV etc.

There are two domains by which a watermark can be embedded into an image, one in spatial domain and the other in frequency domain. In the spatial domain, one can simply insert watermark into a host image by changing the gray levels of some pixels in the host image. No transforms are applied to the host during watermark design or embedding. Combination with the host signal is based on simple operations, such as addition or replacement, and takes place directly in the pixel domain.

The concept of digital image watermarking is to add a watermark image into the host image to be watermarked such that the watermark image is unobtrusive and secure, which is capable of recovering partially or completely using appropriate crypto graphical measures. A perceptibility criterion is applied to ensure the imperceptibility of the changes caused due to the watermark embedding, which may be implicit or explicit, fixed or adaptive to the host data. As a result of this, the samples such as the pixels or the transform coefficients responsible for the watermarking can only be customized by relatively small amplitude [9].

The novelty of the Discrete Wavelet Transform (DWT) algorithm resides in the manner the robustness and the invisibility are improved on the watermark image [5]. The major objective of the wavelet transform is to decompose the input image in a hierarchical manner into a series of successive low frequency sub bands and their associated detailed sub bands. The low frequency sub band and the detailed sub bands contain the information required to reconstruct the low frequency approximation at the next higher resolution level [9]. Such kind of a superb space and frequency energy compaction is provided by wavelet techniques and hence DWT has received an incredible interest in several signal and image processing applications.

The watermark amplification factor is modulated based on the local image characteristics, in a pixel by pixel manner. Most of the DWT based watermarking concepts concentrate on the sub-bands or block based techniques, whereas, here the watermark amplification factor is adjusted pixel wise. As a consequence, the grey-level sensibility, iso frequency masking, non iso-frequency masking, noise sensibility etc., are taken into account [5]. Due to the superb spatial-frequency localization property of DWT, it is easier to identify the image areas in which a disturb can be hidden more likely [2]. In contrast to the DFT/DCT watermarking techniques, if a DWT coefficient is modified, only the region of the image corresponding to that coefficient will be modified.

2.1 Watermark Embedding

Let the image to be watermarked be initially decomposed through DWT into two levels. Let B_l^x denote the sub-band at level = 0,1,2,3 and the orientation x∈ {0, 1, 2,3} as shown in Fig.1.

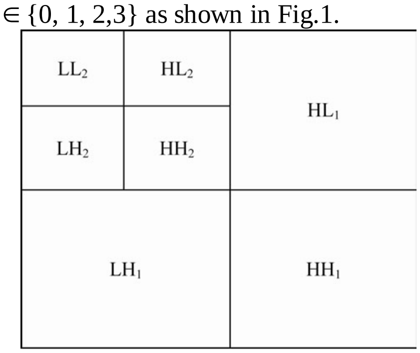

Fig.1. Decomposition of an image into two levels through DWT technique

The watermark is inserted into the three detail bands at level 0 by modifying the wavelet coefficients. The choice of inserting the watermark into this level was based on experimental tests such that the robustness and invisibility are compromised. The result of insertion is poor, resulting in a low robustness, but given the low visibitly of disturbs added, a higher watermark amplification factor is allowed thus compensating for the high fragility.

The watermark information of dimension M1 x M2 is transformed into a unidimensional antipodal sequence d(i,j) ∈ {+1,-1}, where M1 and M2 indicate the number of rows and columns. The input image is decomposed into two levels and all the obtained wavelet coefficients at the chosen sub band are divided into n segments such that n = M1M2. The average value of each segment is computed and removed from all of the wavelet coefficients to facilitate the embedding process. The sub band coefficients are then modified according to,

$$\tilde{B}_l^x(i,j) = \tilde{B}_l^x(i,j) + \alpha w^x(i,j) d^x(i,j)$$

Where, α is the global parameter accounting for the watermark amplification and w^x(i,j) is the weighting function that considers the local sensitivity of the image to noise. The weighing function is chosen such that, w^x(i,j) = q_l^x(i,j)/2 where q_l^x((i,j) is the quantization step for a DWT coefficient at location (i,j). Disturbs having a greater value than q_l^x(i,j)/2 are assumed perceivable and those below are not. This kind of an approach allows to add each DWT coefficient to the maximum unperceivable watermark level [5]. The IDWT process is then applied to the DWT transformed image including the modified sub bands to generate the watermarked host image.

All watermarks contain some important information, so watermark cannot be stored in the file header because anyone from the computer can get the digital editing and would be able to convert the basic information and can remove the watermark at the same time. Thus, the watermark should really be embedded to the multimedia signals.

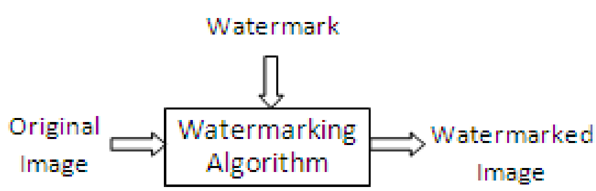

Fig 2: Watermark Embedding Process

2.2 Watermark Detection

The DWT approach applied is a blind process and hence does not require the original image for watermark detection. The DWT is applied to the watermarked image and the sub band to which the watermark was embedded is chosen. The correlation between the original watermark and the extracted watermark is then computed as

$$\rho = \frac{\sum_{i=1}^{N} I.I'}{\sqrt{\sum_{i=1}^{N} I.^2}\sqrt{\sum_{i=1}^{N} .I'^2}}$$ where *I* and *I'* represent the original

and the extracted watermarks respectively. Each of the computed correlation value is then compared with a mean correlation. If the computed value is greater than the mean then the extracted watermark bit is considered as 0, else if the computed value is lesser then it is taken as 1 [11]. Finally the watermark image is reconstructed using the extracted bits and the similarity between the original and the watermarked image is determined.

Original multimedia and watermark are the inputs to the algorithm. The watermarked data or image is the product by the algorithm which consists of the secret key and the original data. Properties of a watermark depend on the applications to be used. The most important requirement for a good digital watermarking scheme can be summarized as:

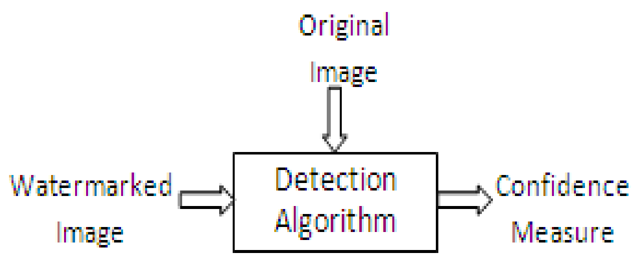

Fig 3: Watermark Extraction Process

III. GRAVITATIONAL SEARCH ALGORITHM

Gravitational Search Algorithm (GSA) is a recent algorithm that has been inspired by the Newtonian's law of gravity and motion. Since its introduction in 2009, GSA has undergone a lot of changes to the algorithm itself and has been applied in various applications. At present, there are various variants of GSA which have been developed to enhance and improve the original version. The algorithm has also been explored in many areas. Nevertheless, it is still unknown how much the algorithm has evolved and how far the research and development has been done since its introduction. Hence, this paper is intended to dig out the algorithm's current state of publications, advances, its applications and discover its future possibilities. GSA is a heuristic optimization algorithm which has been gaining interest among the scientific community recently. The steps of GSA are as follows:

Step 1: Agents initialization: The positions of the N number of agents are initialized randomly. Xi = (xi 1 ,…xi d , …, xi n), for i= 1,2,..,N. (3) xi d represents the positions of the ith agent in the dth dimension, while n is the space dimension.

Step 2: Fitness evolution and best fitness computation: For minimization or maximization problems, the fitness evolution is performed by evaluating the best and worst fitness for all agents at each iteration. Minimization problems: best(t) = min fit j(t) (4) j {1,…,N} worst(t) = max fit j(t) (5) j {1,…,N} Maximization problems: best(t) = max fit j(t) (6) j {1,…,N} worst(t) = min fit j(t) (7) j {1,…,N} fit j(t) represents the fitness value of the j th agent at iteration t, best(t) and worst(t) represents the best and worst fitness at iteration t. Norlina et al. 4

Step 3: Gravitational constant (G) computation: Gravitational constant G is computed at iteration t [4]. G(t) = G0e (-αt/T) (8) G0 and α are initialized at the beginning and will be reduced with time to control the search accuracy. T is the total number of iterations.

Step 4: Masses of the agents' calculation: Gravitational and inertia masses for each agent are calculated at iteration t. Mai = Mpi = Mii = Mi , i = l, 2, ... ,N. (9) Mai and Mpi are the active and passive gravitational masses respectively, while Mii is the inertia mass of the ith agent.

Step 5: Accelerations of agents' calculation: Acceleration of the ith agents at iteration t is computed. ai d (t) = Fi d (t) / Mii(t) (12) Fi d (t) is the total force acting on ith agent calculated as: Fi d (t) = Σ randj Fij d (t) (13) j Kbest, j i Kbest is the set of first K agents with the best fitness value and biggest mass. Kbest will decrease linearly with time and at the end there will be only one agent applying force to the others. Fij d (t) is computed as the following equation: Fij d (t) = G(t).(Mpi(t) x Maj(t) / Rij(t) + ε).(xj d (t) - xi d (t)) (14) (10) (11) 5 A Review of Gravitational Search Algorithm Fij d (t) is the force acting on agent i from agent j at d th dimension and t th iteration. Rij(t) is the Euclidian distance between two agents i and j at iteration t. G(t) is the computed gravitational constant at the same iteration while ε is a small constant.

Step 6: Velocity and positions of agents: Velocity and the position of the agents at next iteration (t+1) are computed based on the following equations: vi d (t+1) = randi x vi d (t) + ai d (t) (15) xi d (t+1) = xi d (t) + vi d (t+1) (16)
Step 7: Repeat steps 2 to 6 Steps 2 to 6 are repeated until the iterations reach their maximum limit. The best fitness value at the final iteration is computed as the global fitness while the position of the corresponding agent at specified dimensions is computed as the global solution of that particular problem.

VI. IMPLEMENTATION

In digital image watermarking, the population is initialized by choosing a set of random positions in the cover image and inserting the watermark image into the selected positions. The optimal solutions for digital watermarking using DWT are obtained based on two key factors: the DWT sub-band and the value of the watermark amplification factor [11]. The GSA algorithm searches its population for the best solution with all possible combinations of the DWT sub-bands and watermark amplification factors. The genetic algorithm procedure will attempt to find the specific sub-band that will provide simultaneous perceptual transparency and robustness. In order to improve the robustness of the algorithm against attacks, the watermark strength or the amplification factor α should be optimized, but this factor varies on each sub-band.

The objective function also known as the fitness function is a combination of the Peak Signal to Noise Ratio (PSNR) and the correlation factor ρ (α * NC) and is given as,

$$\text{Fitness function} = \text{PSNR} + 100 * \rho$$

Where, PSNR is computed as,

$$\text{PSNR}=10\log\left(\frac{MAX_i^2}{MSE}\right)$$

Where, MSE denotes the mean square error between the original and watermarked image and MAXi = the maximum pixel value of the image which is generally 255 in the experiment since pixels were represented using 8 bits per sample.

Here, the correlation factor is the product of Normal Correlation (NC) and the watermark strength factor α. The fitness function increases proportionately with the PSNR value, but NC is the key factor contributing to the robustness and ultimately, the fitness value increases with the robustness measure. The correlation factor ρ has been multiplied by 100 since its normal values fall in the range 0 ~ 1, where as PSNR values may reach the value of 100.

Procedure:

- Initialize watermark amplification factor α between 0 and 1, initialize the population size, number of iterations, crossover rate, mutation rate.
- Generate the first generation of GSA individuals based on the parameters specified by performing the watermark embedding procedure. A different watermarked image is generated for each individual.
- **While** max iterations have not reached **do**
  - Evaluate the perceptual transparency of each watermarked image by computing the corresponding PSNR value
  - Apply a common attack on the watermarked image.
  - Perform the watermark extraction procedure on each attacked watermark image.
  - Evaluate robustness by computing the correlation between the original and extracted watermarks
  - Evaluate the fitness function for the PSNR and ρ values
  - Select the individuals with the best fitness values.
  - Generate new population by performing the crossover and mutation functions on the selected individuals.
- **End While**

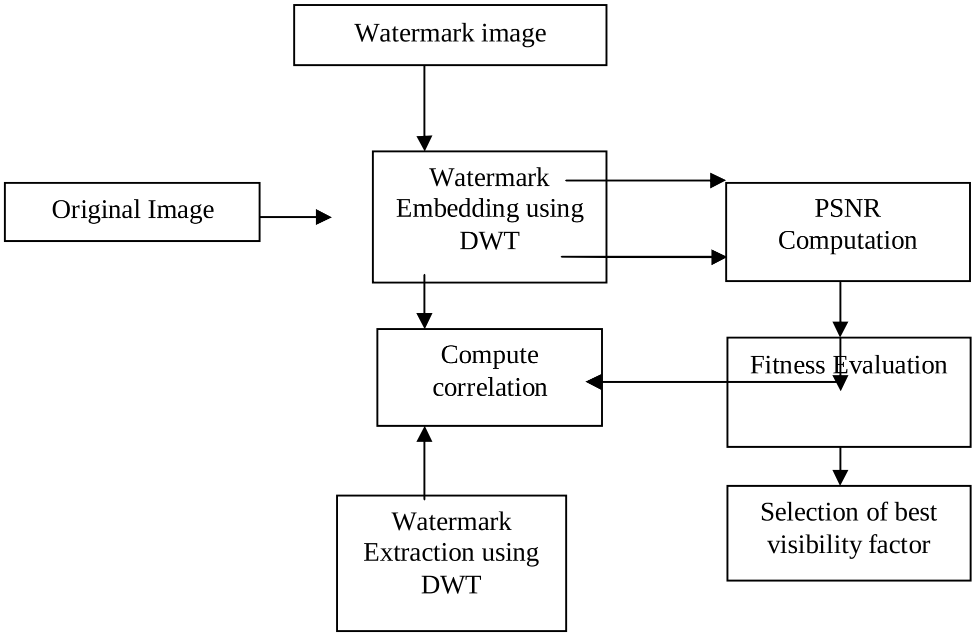

Fig.4. GSA based Optimization Procedure

V. EXPERIMENTAL RESULTS

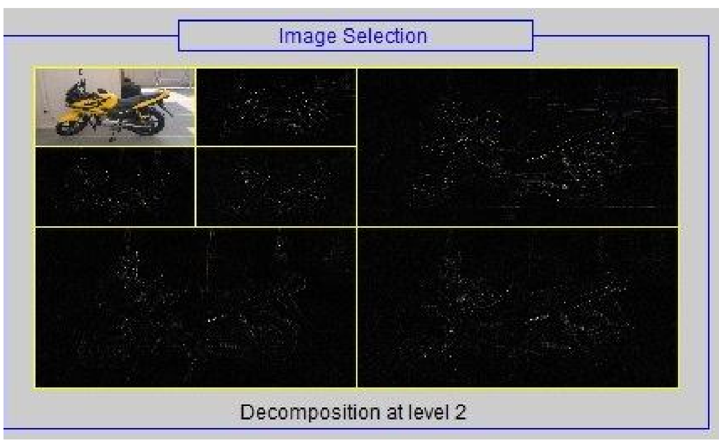

Fig.5. Decomposition of an image into two levels through DWT technique

Original image is bike.jpg as shown fig. 5.

Fig.5: Original image

Embedding watermark image cherry.jpg as shown fig.6.

Fig.6: Watermark image

Table 1: Proposed watermarking Technique (According to Iteration=100)

No. of Agents	MSE	PSNR	NCC	Fitness	Alpha
10	**0.0330**	**35.2261**	**0.9860**	**55.3469**	**0.2038**
20	0.0334	35.0966	0.9860	55.3454	0.2053
30	0.0348	34.4813	0.9860	54.8149	0.2122
40	0.0336	35.1152	0.9860	54.8147	0.2044

Table 2: Proposed watermarking Technique (No. of Agents=20)

Iteration	MSE	PSNR	NCC	Fitness	Alpha
100	**0.0330**	**34.9030**	**0.9910**	**54.8223**	**0.2046**
200	0.0330	34.8044	0.9910	53.7223	0.2046
500	0.0330	34.7031	0.9910	53.6223	0.2046
1000	0.0330	34.0034	0.9910	53.2223	0.2046

6. CONCLUSION

This Dissertation provides Digital image watermarking based on 2 Level Discrete Wavelet Transform (DWT) with Genetic algorithm, table 6.1 shows the effectiveness of proposed technique as PSNR, MSE, Fitness value at agents=10 with visibility factor=0.2038 for watermarked image & extract watermark and table 6.2 shows the effect of population size on proposed watermarking technique on PSNR at Iteration = 100 with visibility factor = **0.2046**.

REFERENCES

1. Sikander, M. Ishtiaq, M.A. Jaffar, M. Tariq, A.M. Mirza, "Adaptive Digital Watermarking of Images Using Genetic Algorithm", IEEE International Conference on Information Science and Applications, pp. 1-8, April 2010.
2. B. Jagadeesh, S.S. Kumar and K.R. Rajeswari, "A Genetic Algorithm based oblivious image watermarking scheme using Singular Value Decomposition", IEEE International Conference on Networks and Communications, pp. 224-229, 2009.
3. C. W. Tang and H. M. Hang, "A feature-based robust digital image watermarking scheme," IEEE Transactions on Signal Processing, Vol. 51, No. 4, pp. 950–959, 2003.
4. Sachin Goyal, Roopam Gupta and Ashish Bansal, "Application of Genetic Algorithm to Optimize Robustness and Fidelity of Watermarked Images", International Journal on Computer Science and Engineering, Vol. 1, No. 3, pp. 239-242, 2009.
5. M. Ketcham, and S. Vongpradhip, "Intelligent Audio Watermarking using Genetic Algorithm in DWT Domain", World Academy of Science, Engineering and Technology, pp. 336-341, 2007.
6. I. Cox, M. Miller, and J. Bloom, "Digital Watermarking: Principles and Practice", San Mateo, CA: Morgan Kaufmann, 2001.

7. Abu-Errub, Ali Al-Haj and Aymen, “Performance Optimization of Discrete Wavelets Transform Based Image Watermarking Using Genetic Algorithms”, Journal of Computer Science, pp. 834-841, 2008
8. P. Surekha and S. Sumathi,”Implementation of Genetic Algorithm For a DWT Based Image Watermarking Scheme”, ICTACT Journal On Soft Computing Special Issue On Fuzzy In Industrial And Process Automation,July 2011, Volume: 02, Issue: 01. (ISSN: 2229-6956(ONLINE)
9. Mahendra Kumar et. Al..”Fuzzy type Image Fusion using SPIHT Image compression technique”, International Journal of Engineering Research and Applications (IJERA).
10. Mahendra Kumar et. al.,” Digital Image Watermarking using Fractional Fourier Transform with Different Attacks” International Journal of Scientific Engineering and Technology, Volume No.3 Issue No.8, Aug. 2014, pp : 1008-1011. ((ISSN : 2277-1581))
11. Roma Rewani, Aditya Kumar Singh Pundir and Mahendra Kumar,” Digital Image Watermarking: A Survey” International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 4, July-Aug. 2013, pp.1750-1753.
12. Nisha Soni, Garima Mathur and Mahendra Kumar,” Face Recognition using SOM Neural Network with Different Facial Feature Extraction Techniques” International Journal of Computer Applications (IJCA), Vol. 76, No. 3, Aug. 2013, pp.7-11.
13. Nisha Soni, Garima Mathur and Mahendra Kumar,” A Matlab Based High Speed Face Recognition System Using SOM Neural Networks” International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 4,July-Aug. 2013, pp.785-790.
14. Mahendra Kumar et. Al.,” Robust Digital Image Watermarking using DCT based Pyramid Transform via image compression”, 4th IEEE International Conference on Communication and Signal Processing (ICCSP 2015) 02-04 April 2015 - Melmaruvathur, TN, IND
15. Mahendra Kumar et. Al.,”Face Recognition Using SOM Neural Network with DDCT Facial Feature Extraction Techniques”, 4th IEEE International Conference on Communication and Signal Processing (ICCSP 2015) 02-04 April 2015 - Melmaruvathur, TN, IND.
16. Mahendra Kumar et. Al.,”Fuzzy type Image Fusion using hybrid DCT-FFT based Laplacian Pyramid Transform”, 4th IEEE International Conference on Communication and Signal Processing (ICCSP 2015) 02-04 April 2015 - Melmaruvathur, TN, IND.
17. Mahendra Kumar et. Al.,” Digital Image Watermarking using Hybrid DWT - FFT Technique with Different Attacks”, 4th IEEE International Conference on Communication and Signal Processing (ICCSP 2015) 02-04 April 2015 - Melmaruvathur, TN, IND.
18. Mahendra Kumar et.al.,”Digital Image Watermarking using Fractional Fourier transform via image compression”, In IEEE International Conference on Computational Intelligence and Computing Research 2013 (2013 IEEE ICCIC), 26-28 Dec., 2013