Multi-resolution Approach for Optimizing Strength of Watermark in Image Watermarking

Vaishali Jabade
Research Student, Department of Electronics Engineering
Walchand Institute of Technology, Solapur University, Solapur, Maharashtra, India

Dr. Sachin Gengaje
Professor and Head, Department of Electronics Engineering
Walchand Institute of Technology, Solapur University, Solapur, Maharashtra, India

Abstract- Digital image watermarking is used to protect digital images against unauthorized copying. The process of image watermarking involves inserting a watermark to prove ownership. The watermark is an electronic identifier that is embedded in the host image. The host image to be watermarked is modified in a defined manner with watermark. However this modification should not be perceived by human vision. Image watermarking involves inserting imperceptible watermark in host image in the form of pseudorandom number, chaotic sequence, text or image to generate watermarked images. These watermarked images can be analyzed for possible recovery and extraction of watermark to prove ownership when the need arises. This work focuses on embedding identifiable watermark and optimizing its strength for imperceptibility and robustness using multi-resolution analysis approach.

Keywords- Multi-resolution Analysis, Digital Image Watermarking, Discrete Wavelet Transform.

I. INTRODUCTION

The unparalleled growth of digital networks and rapid emergence of multimedia applications in the past decade has yielded significant growth in transmission of digital media such as image, audio or video. There is a need to authenticate and protect interest of the creator of such multimedia data. Imperceptible image watermarking is a technique of embedding identification mark without any visible artefacts in the host image. This necessitates embedding low strength watermark in host image to achieve invisibility of watermark. However for achieving robust and resilient watermarking, embedding high strength watermark is demanded. These two requirements are contradictory to each other. Hence there is a need to optimize strength of watermark to be embedded in the host image to establish imperceptibility as well as robustness. The approach used is multi-resolution analysis which allows an image to be described in terms of coarse overall shape and details that range from broad to narrow. Multi-resolution analysis is possible using wavelet transform [1-3]. Wavelet transform is a mathematical tool for hierarchically decomposing an image to represent image at different resolutions. With multi-resolution analysis, image can be represented at more than one resolution level. The importance and motivation for multi-resolution technique in imperceptible image watermarking is explored in this work. The wavelet transform has emerged as a fast and efficient framework for multi-resolution analysis of images resulting in localized transform. The transform is based on small waves, called wavelets, of varying frequency and limited duration. Wavelets are generated by translation and dilation or scaling of these fixed function called mother wavelet. JPEG2000, new standard for still image compression is based on DWT which gives better image quality even at high image compression ratios. It facilitates progressive transmission of image introducing scalability [4].

II. MULTI-RESOLUTION ANALYSIS USING WAVELET TRANSFORM

Wavelet transform is a localized transform as against DFT and DCT which are full frame transforms. Unlike conventional Fourier transform, temporal as well as spectral information is retained in transformation process. Wavelet transform is a 2-D transform as it gives information about time as well as frequency. In case of Short Time Fourier Transform (STFT), time information is retained by defining a window function. But fixed window size in STFT leads to resolution problem. Wider windows do not provide good localization at high frequencies whereas narrower windows do not provide good localization at low frequencies [5-7]. Time frequency tiling of STFT leads to fixed resolution. Wavelet transform overcomes resolution problem by adjusting time frequency tiling which results in variable length window as shown in Fig.1.

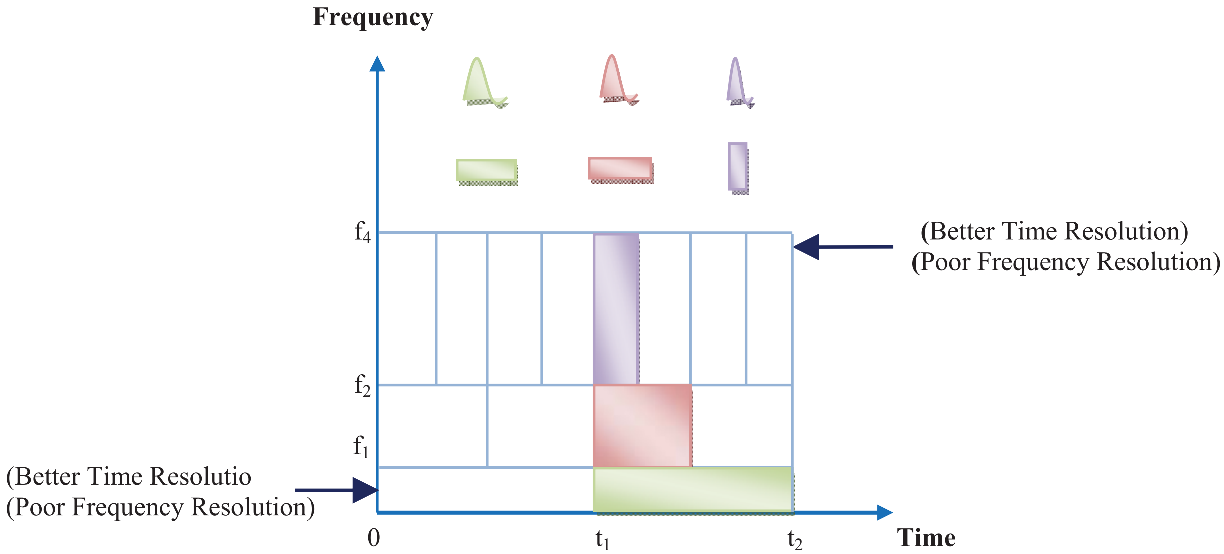

Fig.1. Time-Frequency Tiling

Psycho-visual experiments have provided motivation for investigation in multi-resolution techniques. Small size and low contrast objects in an image are examined at high resolution whereas for large size and high contrast objects, a coarse view at low resolution is required. If both small and large objects and low and high contrast objects are present simultaneously in an image, then image is analyzed at different resolutions [10-12]. This is the fundamental motivation for multi-resolution processing. This is possible using adjustable tile width in wavelet transform but keeping area of the tile constant. Scaling mother wavelet function either dilates a signal giving global information or compresses a signal giving detail information about the signal. In order to isolate signal discontinuities, one would like to have some very short basis functions. At the same time, in order to obtain detailed frequency analysis, one would like to have some very long basis functions [12].

A way to achieve this is to have short high-frequency basis functions and long low-frequency ones. Scale or resolution is noted as a very important property of human vision. Human vision hierarchically decomposes an image in different resolution levels leading to necessity of multi-resolution analysis of an image. High frequencies are analysed using narrower windows so that better time resolution is achieved. Similarly, low frequencies are analysed using wider windows. This achieves better frequency resolution. Temporal analysis is performed with a contracted, high-frequency version of prototype wavelet, while frequency analysis is performed with a dilated, low-frequency version of the same wavelet [13].

Thus wavelet transform processes data at different scales and resolutions using variable window size. The advantage is that features in an image that might go undetected at one resolution level may be easily located at another level. It is very useful for processing non stationary signals. Good time resolution and poor frequency resolution at high frequencies is achieved whereas good frequency resolution and poor time resolution is achieved at low frequencies. Mother wavelet integrates to zero and is square integrable or has finite energy. The wavelet function can be scaled and translated over the input function and correlation between the two is obtained as wavelet coefficient. In general, a J-level wavelet pyramid using multi-resolution approach is shown in Fig. 2.

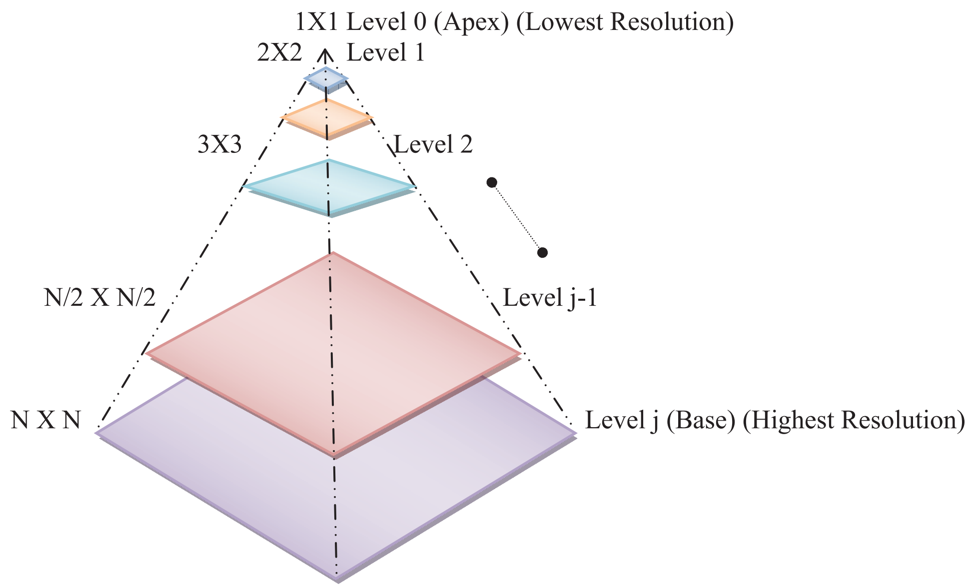

Fig.2. Wavelet Pyramid with Multi-Resolution Analysis

The multi-resolution decomposition is also described in terms of subspaces Vj and Wj which relate to intermediate signals at the output of the level j. As the number of decomposition levels is increased, subspace number j also increases. The resulting decomposition bands are not of the same size. The Wavelet space Wj corresponds to the difference between current scaling space Vj and previous scaling space $Vj\text{-}_1$. The relation at level j is given by following equation.

$$Vj\text{-}_1 \oplus Wj\text{-}_1 = Vj \quad (1)$$

The nested spaces relationship between wavelet and scaling function for 1^{st} level of decomposition is shown in Fig.3.

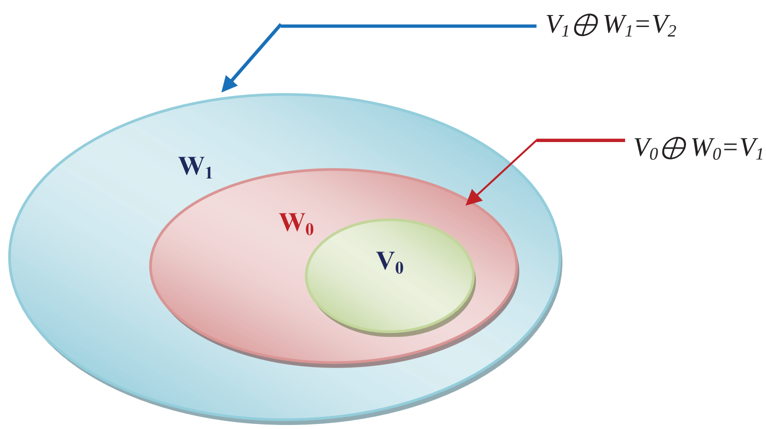

Fig.3. Multi-resolution Representation

DWT represents HVS in a better way as compared to other transforms due to multi- resolution approach. This can be utilized for frequency as well as scale sensitivity of human vision. It decomposes an image in three spatial directions as horizontal direction, vertical direction and diagonal direction exploring directional properties for human vision. The block based approach may introduce blocking artefact in watermarked image. It gives better identification of data relevant to human perception. No need to block image as in case of DCT. DWT can have higher compression ratio without any blocking artefacts in reconstructed image. DWT is more suitable for short duration of higher frequency and longer duration of lower frequency components. It can work better on discontinuous data like image [14].

III. WATERMARK EMBEDDING PROCESS

The functional block diagram of watermark embedding process is shown in Fig.4.

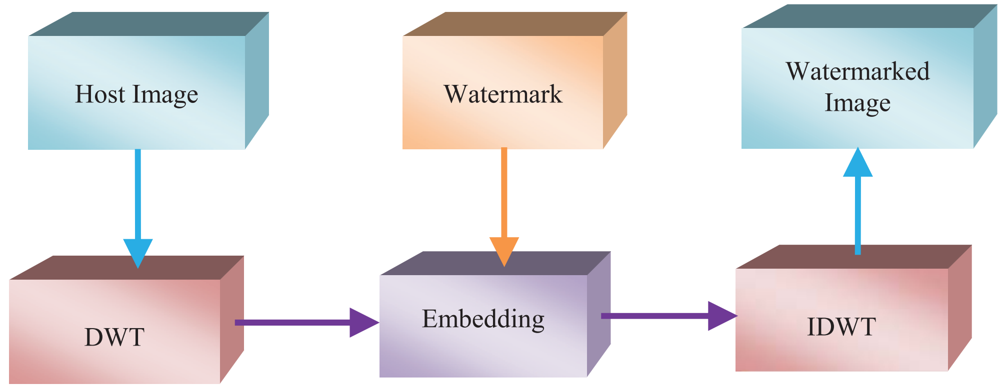

Fig.4. Block Schematic for Watermark Embedding

Host image to be watermarked is decomposed up to three levels using discrete wavelet transform. It is decomposed along rows and then along columns resulting in four wavelet sub-bands after first level of decomposition. Wavelet transform decomposes host image in three spatial directions i.e. horizontal, vertical and diagonal. These sub-bands are approximation components (LL_1), horizontal details (HL_1), vertical details (LH_1) and diagonal details (HH_1) in the host image. Approximation sub-band LL_1 of host image is the lowest frequency component in the first level of decomposition. Second level decomposition of wavelet transform is applied to decompose $LL_{1.}$ The process results in sub-bands LL_2, HL_2, LH_2, and HH_2. They represent approximation and detail bands at second level of decomposition. Similarly, third level decomposition is applied to LL_2 approximation sub-band resulting in sub-bands LL_3, LH_3, HL_3, and HH_3. Watermark is inserted in the form of logo by modifying significant wavelet coefficients at each level of decomposition structure. The watermark is embedded in different frequency DWT components of a specific sub-image. Quantization steps for DWT coefficients are then computed in order to generate watermark weighting function and watermark is then inserted in sub-bands. The insertion of watermark is performed as per following equation.

$$C'band\ (i, j) = Cband\ (i, j) + \alpha\ W\ (i, j) \qquad (2)$$

Where
Cband (i, j) : Original wavelet coefficient
C'band (i, j): Watermarked wavelet coefficient
α : Strength of watermark
W (i, j): Watermark signal

The global parameter *α* is also called as modulation index and decides the strength of watermark. Inverse discrete wavelet transform is applied to reconstruct watermarked image. As pointed out earlier, the property of perfect reconstruction and symmetry of wavelet basis function is needed for reconstructing watermarked image. Performance evaluation is carried out for imperceptibility analysis. Watermark extraction and host image restoration is performed in this process at the receiving side. To realize watermark extraction and detection process, DWT is realized on watermarked image and reverse process is followed. Wavelet transform is applied on host image as well as watermarked image.

IV. PERFORMANCE EVALUATION

Performance evaluation is carried out in terms of subjective and objective evaluation. The subjective evaluation is based on human vision whereas objective evaluation is based on computing performance metric PSNR (dB). One should not distinguish between host image and watermarked image visually. PSNR is used for quantitative evaluation of the watermarked image quality [15]. Peak signal to noise ratio is used as image quality metric and is defined in decibels as follows.

$$PSNR\ (dB) = 10 \cdot \log_{10} [(255x255) / MSE] \qquad (3)$$

MSE in above equation is Mean Square Error. It is the error between host image and watermarked image and calculated as follows.

$$MSE = (1/Nt) \sum_{i,j} (I(i, j) - Iw(i, j)) \quad (4)$$

Where
$I(i, j)$: Pixel value of host image
$Iw(i, j)$: Pixel value of watermarked image

PSNR is calculated between host image and attacked watermarked image. It is measured in units of dB. The larger the PSNR value, higher is the quality of the resulting image. This is widely used parameter for quality assessment of degraded watermarked image.

Human vision cannot perceive difference in the watermarked image and the host image if PSNR is greater than 30dB. The quality of watermarked image is satisfactory for PSNR values greater than 35dB. The global parameter, strength of watermark alpha α, also called as modulation index, is selected by evaluating PSNR values for watermarked images. Insertion of watermark in host image is nothing but the process of degradation of host image. The level of degradation becomes the function of strength of watermark inserted. This degradation is measured in terms of PSNR of watermarked image. PSNR is computed for all images by modifying α value. The experiments are carried out for inserting five different types of logo watermarks (WM1, WM2, WM3, WM4, WM4, WM5) and using 24 diversified host images. The host images widely vary in respect of their characteristics.

V. RESULTS AND DISCUSSION

Multi-resolution decomposition is applied on the host image using DWT. DWT is applied up to third level of decomposition. Each level of decomposition divides parent image into four child images. Each of these sub-images is one fourth of the size of its corresponding parent image. The sample result for Lena image is shown in Fig. 5. Host image is decomposed into distinct bands. The sub-images are placed according to position of each sub band in two dimensional partition of frequency plane as shown in Fig. 5(a). Sub images for the first level of decomposition are presented. The sub-images are placed according to the position of each sub band in the two-dimensional partition of frequency plane. Visual quality of approximation sub band is degraded gradually as the level of decomposition increases resulting in lower resolution. This is because fine details at higher resolution in the image are separated. The lower frequency bands are very noisy compared to higher frequency bands. Watermark detection at lower resolution is computationally effective because at each successive resolution, smaller frequency bands are involved. Each of such sub-image is one fourth the size of parent image. The size goes on decreasing by 2^l at each level of wavelet decomposition l. Wavelet coefficient distribution at first level of decomposition is shown for Lena image in Fig. 5(b). In DWT, the most prominent information in signal appears in higher amplitudes and less prominent information appears in lower amplitudes.

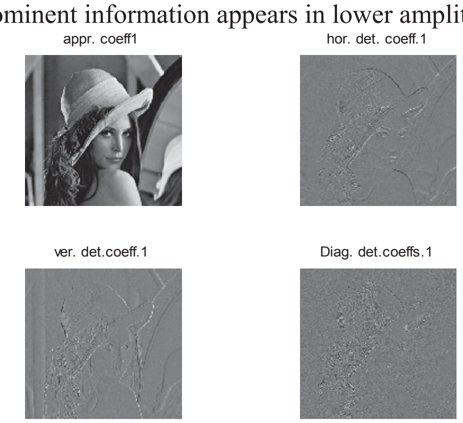

Fig. 5(a) Sub-images after 1st Level Decomposition

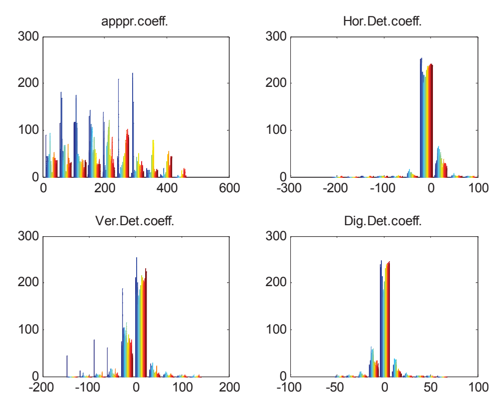

Fig. 5(b) Wavelet Coefficients Distribution

The relationship between PSNR (dB) and strength of watermark is plotted graphically for watermark WM1in Fig. 6(a). The value for strength of watermark, α is varied from 0.5 to 3.5. The upper limit of α is selected depending upon minimum PSNR value for imperceptibility criterion. Thus the range of α depends upon PSNR values of watermark image. The value of PSNR decreases as the strength of watermark α is increased. It shows that α should be kept small to gain high image fidelity. But if strength α is kept very low, robustness cannot be achieved. Higher alpha value ensures probability of watermark extraction from watermarked image. It is seen that strength of watermark α gives average PSNR value of 35.71dB. If α is increased further, quality of image is degraded leading to poor image fidelity. Thus a tradeoff between these two aspects should be established such that higher strength of watermark is embedded still retaining image quality. Hence the optimal strength of watermark, α is set at 2.5 giving reasonably high value of PSNR for almost all the host images. PSNR values for all the images used using different watermarks are shown graphically in Fig. 6(b).

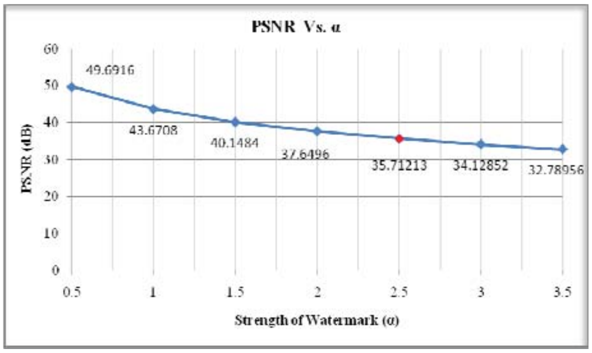

Fig. 6(a) PSNR Values for different α values

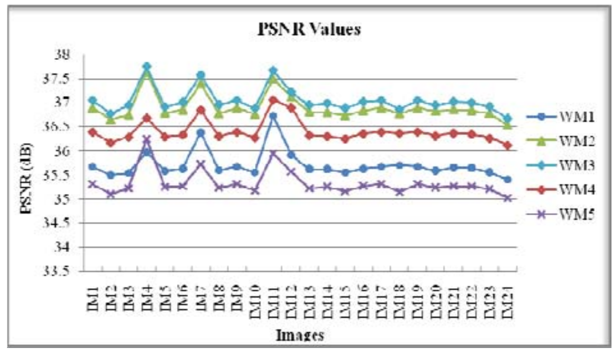

Fig. 6(b) PSNR Values for Different Images

VI.CONCLUSION

Analysis of multi-resolution approach using DWT for image watermarking is focused. Experiments are carried out to select strength of watermark α so as to satisfy imperceptibility of embedded watermark and image quality. Analysis is carried out to optimize strength of watermark α to achieve trade off between imperceptibility of watermark in the host image as well as survival that is robustness of watermark in the watermarked image. The relationship between strength of watermark α and PSNR value is established. The optimal value of α is selected to provide reasonably better quality of watermarked image for all the host images by inserting different watermarks. The results show that PSNR values for all the host images and watermarks are above 35dB for optimal value of α. This ensures imperceptible embedding of watermark in the host image with highest possible strength of watermark.

REFERENCES

[1] Vaishali S. Jabade and Sachin R. Gengaje, "Comprehensive Survey of Image *Watermarking", International Journal of Advances in Advances in Engineering and Technology (IJAET),* Volume 6, Issue 3, July 2013, pp. 1271-1282.

[2] Vaishali S. Jabade and Sachin R. Gengaje, "Literature Review of Wavelet Based Digital Image Watermarking Techniques", *International Journal of Computer Applications (IJCA)*, (0975 – 8887) Volume 31– No.1, October 2011, pp. 28-35.

[3] Anil N. Bhure and Vaishali S Jabade, "A Modified Approach of Image Steganography based on Block DCT and Huffman Encoding without Embedding Dictionary into Stego-Image", Volume 94 - Number 8, May-2014, pp. 24-27.

[4] A. Piva, M. Barni, F. Bartolini, and V. Cappellini, "DCT-Based Watermark Recovering Without Restoring to the Uncorrupted Original Image", *IEEE International conference on Image Processing*, 1997, *Vol. 1*, pp. 520-523.

[5] Liu Yuejun, "Research on Information Hiding System based on DCT Domain", *Second IEEE International Conference on Computer Modeling and Simulation,* 2010, pp.11- 14.

[6] Bo Chen, Hong Shen, "A New Robust-Fragile Double Image Watermarking Algorithm", *Third International Conference on Multimedia and Ubiquitous Engineering,*2009, pp. 153-157.

[7] Der-Chyuan Lou , Hao-Kuan Tso, Jiang-Lung Liu "A Copyright Protection Scheme For Digital Images Using Visual Cryptography Technique", *Computer Standards and Interfaces 29,* 2007, pp. 125-131.

[8] Der-Chyuanlou, Hao-kuan Tso, Jiang-lungliu, "A Copyright Protection Scheme for Digital Images Using Visual Cryptography Technique", *Computer Standards and Interfaces,* 2006, pp. 125-131.

[9] Dr. M.A. Dorairangaswamy, B. Padmavathi, "An Effective Blind Watermarking Scheme for Protecting Rightful Ownership of Digital Images", *IEEE, TENCON,* 2009, pp. 1-6.

[10] Jun Sang and Mohammad S. Alam, "Fragility and Robustness of Binary-Phase-Only-Filter-Based Fragile/Semi fragile Digital Image Watermarking," *IEEE Transactions on Instrumentation And Measurement, Vol. 57, No. 3, March 2008,* pp.595-606.

[11] M.F. Fahmy and G. Fahmy, "A Quasi Blind Watermark Extraction of watermarked Natural Preserve Transform Images", *IEEE Ineternational Conference on Image Processing*,2009, pp.3665-3668.

[12] Santa Agreste, Guido Andaloro, Daniela Prestipino, Luigia Puccio, "An Image Adaptive Wavelet Based Watermarking of Digital Images", Science Direct *Journal of Computational and Applied Mathematics*, 2006, pp. 1-9.

[13] Vaishali S. Jabade and Sachin R. Gengaje, "Bi-orthogonal Wavelet based Adaptive Image Watermarking using Human Visual System and Fuzzy Inference System", *International Journal of Computer Applications (IJCA),* (0975 – 8887) Volume 72– No.14, May 2013, pp. 39-43.

[14] Vaishali S. Jabade and Sachin R. Gengaje, "Logo based Image Copyright Protection using Discrete Wavelet Transform and Fuzzy Inference System", *International Journal of Computer Applications (IJCA)*, (0975 – 8887) Volume 58– No.10, November 2012, pp. 22-28.

[15] Vaishali S. Jabade and Sachin R. Gengaje, "Performance Evaluation of DWT and FIS Based Digital Image Watermarking", *International Journal of Computer Applications (IJCA)*, (0975 – 8887) Volume 4, Issue 1, January 2016, pp. 892-900.