Digital Image Watermarking using Fuzzy Logic and Genetic Algorithm

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***Abstract*— *The need for digital image copyright protection methods has become vital foundation in multimedia applications due to the rapid growth of unauthorized access. Thus, multimedia data protection is one of the major challenges and has drawn the attention of several researchers towards the development of protection approaches. Digital watermarking is one among the several protection methods that hides information. The main factors to be considered during watermark is imperceptibility and robustness. Imperceptibility is the quality that the host image should not be destroyed by embedding the watermark. Robustness implies the strength of watermark against various image processing attacks.*

Digital image watermarking is embedded using frequency domain. The perception of frequency domain is to embed the watermark into frequency coefficients of transformed image using the Discrete Cosine Transform (DCT), the Discrete Wavelet Transform (DWT), Singular Value Decomposition (SVD), or other techniques. In this paper, a new robust watermarking scheme is implemented based on DWT and SVD using Fuzzy Logic and Genetic Algorithm. In this system a reference image is used to extract the properties of original image. Directive contrast and threshold values are calculated to get a reference image. Fuzzy logic system is used to find the strength of watermark that has to be added to the original image while embedding. Genetic algorithm is implemented to find the positions for embedding the watermark in the host image. In order to test the quality and robustness, attacks are performed on watermarked image. Quantitative measures like PSNR, NCC are also calculated to test the watermarked image and extracted watermarks with and without attacks.

Keywords— *Water Marking, Digital Image, Fuzzy Logic, Genetic Algorithm.*

I. INTRODUCTION

The development of digital technology brings a demand for digital data protection. Among different protection techniques, digital watermarking is an effective solution. Digital watermarking is a kind of technology that hides the information in the original image. It provides copyright protection to an image to achieve a lawful ownership. In digital watermarking, different transformation domains are used. For providing security Discrete Wavelet Transform (DWT) domain is used and the watermark is embedded in the mid-frequencies areas, in order to achieve perceptual invisibility as well as robustness to attacks. The challenge here is to introduce a digital watermark that does not amend the perceived quality of the electronic content, while being tremendously robust to attack. The main goal is to insert the watermark with maximum strength before it becomes visible to the human visual system (HVS). The strength of the added watermark chosen is of highest relevance[1][2][3].

Fuzzy Logic is a technology where it reaches the human approach in the sense that the variables treated are not binary but of variable linguistic relatives of human language as high contrast, a lot more clearly, very textured, very homogeneous etc. Based on this, it built the rules to find the watermark strength. Genetic algorithm usually starts from a population of randomly generated individuals that happens in generations. In each generation, the fitness of every individual in the population is evaluated, the more fit individuals are stochastically selected from the current population, and each individual's genome is modified (recombined and possibly randomly mutated) to form a new population.

II. PROBLEM STATEMENT

Watermarking technology plays an important role in preventing copyright violation as it allow to place an imperceptible or perceptible watermark depending on the requirement in the multimedia data to recognize the legitimate owner or detect malicious tampering in the document. In this paper, DWT and SVD are applied to the original image and watermark image. To calculate the watermark strength, fuzzy logic is implemented by using the properties of original image and reference image. To get the reference image directive contrast and threshold values are computed and ensure that the values zero for those whose directive contrast values are less than the threshold. Genetic algorithm is used for embedding and Rank-based selection to find the positions for embedding.

III. METHODOLOGY

This work focuses on a new watermarking scheme based on DWT-SVD domain using optimization techniques like fuzzy logic and genetic algorithm to achieve robustness and imperceptibility. DWT is applied to original image and SVD is applied

to the selected band and hence, watermark strength is obtained. The initial population is generated randomly. Fitness of each chromosome is calculated. In each population the chromosome with the highest fitness value is assumed to be good, which is used to embed the watermark into the image. For the new selection of chromosomes rank selection is used to find locations in a cover image and embed watermark. Input to fuzzy logic is taken from the reference image obtained by extracting the properties of original image. Metrics like PSNR and NC are calculated to measure the imperceptibility and robustness of the algorithm.

IV. DESIGN AND IMPLENTATION OF ALGORITHM

To implement fuzzy logic reference original image is needed. So, first reference is obtained using properties of original image. Subsequently, fuzzy logic is implemented to find the watermark strength. Genetic algorithm is implemented based on DWT-SVD.

A. Reference Image

Original image is taken as an input and a band is selected from the original image. Fuzzy rules are built to find the strength of watermark that has to be embedded in the original image by using the properties of the reference image as shown figure 1.

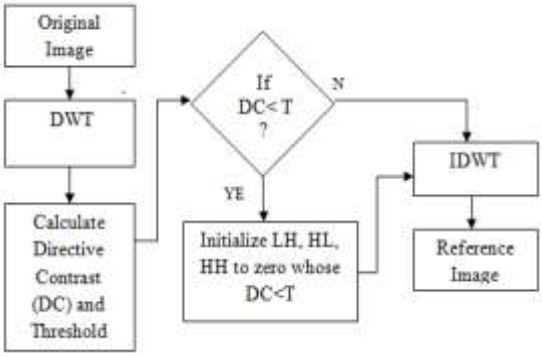


Fig. 1 Flow Chart to build Reference Image

B. Fuzzy Logic Method

In this system the fuzzy rules are built based on the intensities of pixel values. All the process and implementation of Fuzzy Inference system is shown below :

Inputs to fuzzy---> Fuzzification--> Inference Engine--> Defuzzification--> Output from fuzzy.

C. Genetic Algorithm

1. [START] Generate random population of 'n' chromosomes.
2. [FITNESS] Evaluate the fitness f(x) of each chromosome 'x' in the population.
3. [NEW POPULATION] Create a new population by repeating following steps until the new population is complete.
   [SELECTION] Select two parent chromosomes from a population according to their fitness.
   [CROSSOVER] with a crossover probability, crossover the parents to form new offspring.
   [MUTATION] with a mutation probability, mutate new offspring.
   [ACCEPTING] place new offspring in the new population.
4. [REPLACE] use new generated population for a further run of the algorithm.
5. [TEST] if the end condition is satisfied stop and return the best solution in current population.
6. LOOP [Go to step 2].
7. [END]

D. Embedding Process Of Watermarking

Proposed embedding process of watermarking is based on DWT-SVD using Fuzzy Logic and Genetic Algorithm. Fuzzy Logic is used to find the watermark strength and Genetic algorithm is used find the positions for embedding and then, do the the extraction process of watermarking based on DWT-SVD using Fuzzy Logic and Genetic Algorithm by applying attacks

Two metrics are used to measure the imperceptibility and Robustness of the algorithm. PSNR is for measuring the imperceptibility and NC is to measure the robustness[4][5].

1. Peak Signal to Noise Ratio (PSNR)
2. Normalized Correlation (NC)

V. EXPERIMENTAL RESULTS

The experiment is tested for different images from imageprocessingplace.com. The proposed method is implemented using MATLAB. In this experiment a watermark of size $m_w * n_w$ is embedded into different images. DWT and SVD are applied to the cover image and watermark image. A singular matrix of watermark is embedded in the singular matrix of cover image by using Genetic algorithm to find the appropriate positions for embedding.

Figure 2 shows the sample watermark images and Figure 3 represents sample cover images for the experiment. All the images possess dimensions of m*n with different contrasts levels. Results were obtained through PSNR and NC. PSNR is used to measure the imperceptibility and NC is used to measure the robustness by applying different types of attacks[6][7].

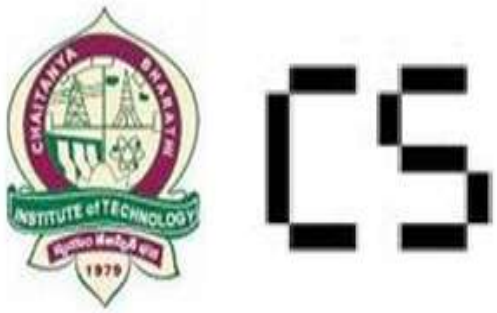


Fig. 2 Sample Watermark Images

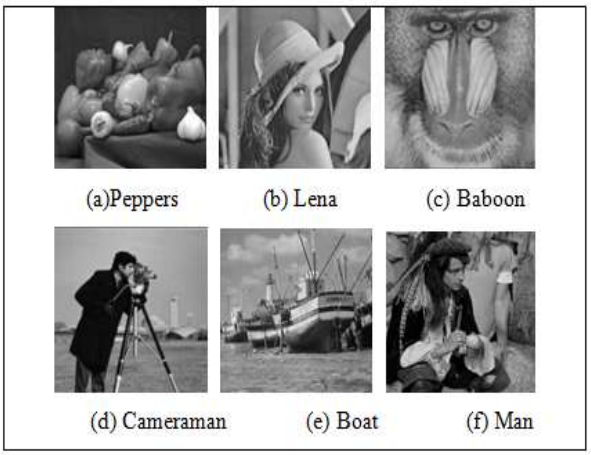


Fig. 3 Sample Cover Images ((a)-(f))

Figure 3 shows the original images of size m*n that are tested in the experiment.

Fig. 4 Watermarked Images ((a)-(f)) for DWT-SVD-Fuzzy Logic-Genetic Algorithm

Figure 4 shows the watermarked images after embedding the watermark in the cover image with Fuzzy Logic and Genetic Algorithm.

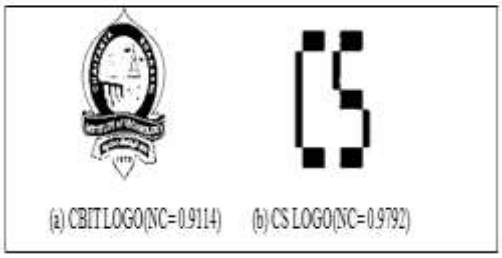


Fig. 5 Extracted watermark images for DWT-SVD-Fuzzy Logic-Genetic Algorithm

Figure 5 denotes the extracted watermark images of size $m_w * n_w$ for DWT-SVD-Fuzzy Logic- Genetic Algorithm.

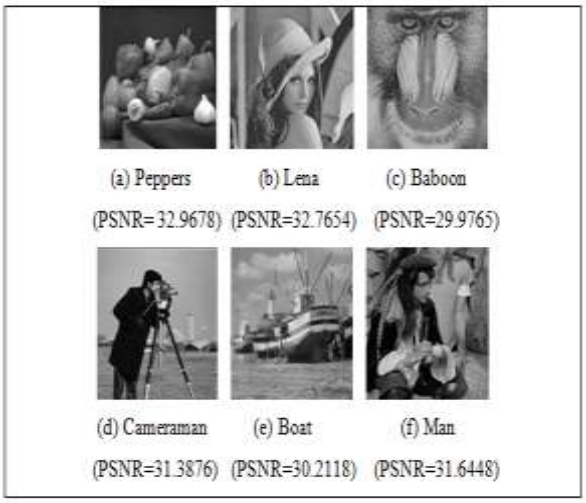


Fig. 6 Watermarked Images ((a)-(f)) for DWT-SVD-Fuzzy Logic

Figure 6 shows the embedded watermarked images for DWT-SVD-Fuzzy Logic[8].

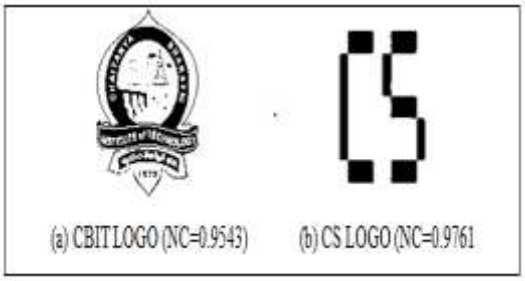


Fig. 7 Extracted watermark images ((a)-(b)) for DWT-SVD-Fuzzy Logic

Figure 7 shows the extracted watermark images of size $m_w * n_w$ by using only fuzzy logic and without applying genetic algorithm.

The cover image and the watermarked images are compared using the Peak Signal to Noise Ratio (PSNR). Higher PSNR value indicates that both the images are similar to the maximum extent. The PSNR value can be calculated using the following equation.

$$PSNR\,(dB) = 10.\log_{10}\frac{255^2}{MSE}$$

TABLE I: PSNR (dB) values for original and watermarked Images for different bands with Fuzzy Logic and Genetic Algorithm

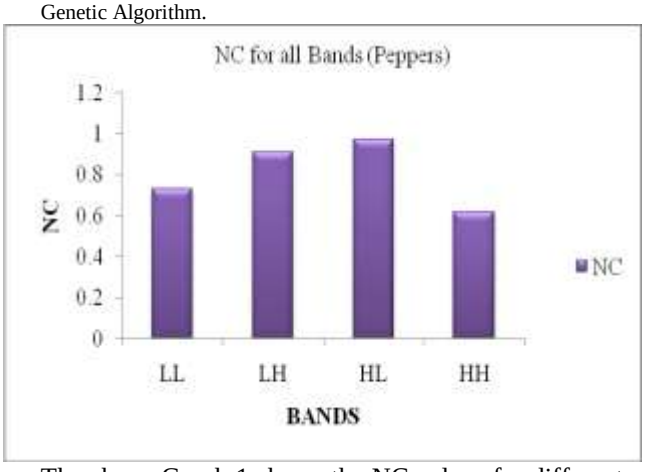
BANDS	PSNR(dB)
LL	14.6186
LH	45.0438
HL	44.8560
HH	62.4246

In Table I, PSNR (dB) values are calculated between the Cover image 'peppers' and Watermarked image for different bands by using Fuzzy Logic and Genetic Algorithm. The watermark which is embedded in the cover image is invisible. Therefore, imperceptibility is achieved as the PSNR (dB) value is 62.4246 for high frequency band (HH). And for LH and HL also PSNR is above 40dB. As observed in the table, PSNR (dB) is highest for band HH. So, compared to other bands robustness is achieved by using HH band. The NC is calculated using equation[9][10] .

$$NC = \frac{1}{m}\sum_{x,y}\frac{(I(x,y) - \bar{I})\,(I'(x,y) - \bar{I'})}{\sigma_I \sigma_{I'}}$$

where m is the number of pixels in $I(x,y)$ and $I'(x,y)$, $\bar{I}$ is the average of I, $\bar{I'}$ is the average of I', σ_I is standard deviation of I and $\sigma_{I'}$ is standard deviation of I'.

GRAPH 1: NC values for different bands with Fuzzy Logic and Genetic Algorithm.



The above Graph 1 shows the NC values for different bands between the extracted watermark image and original watermark image. Compared with other bands NC value for HL band is high. The NC value for LH band is 0.9114. The NC values for LL and HH are very less than LH and HL. Therefore, the watermark can be embedded in the middle frequency sub-bands to achieve imperceptibility[11][12].

TABLE II: NC values for watermark by applying different attacks with Fuzzy Logic and Genetic Algorithm

Type of Attack	Normalized Cross Correlation(NC)
Low-pass filtering	0.9816
Median filtering	0.9816
Jpeg Compression	0.9441
Histogram Equalization	0.9797
Rotational	0.9944
Gaussian Noise	0.9614

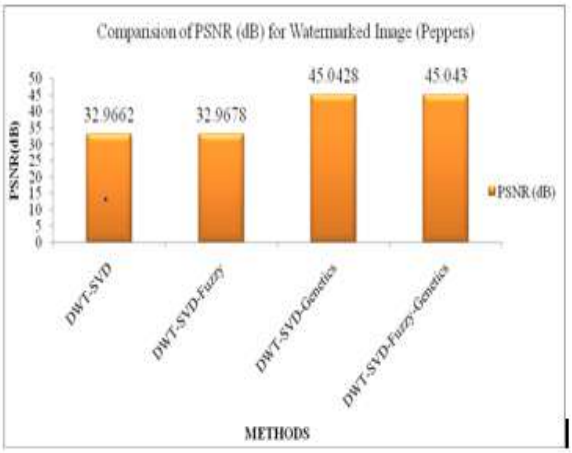
Table II shows the NC values for original watermark and extracted watermark after applying different attacks to watermarked image. As compared with other attacks NC value for rotational attack is high and it is 0.9944.

Table III: Comparison of NC values for extracted watermarks with Fuzzy Logic and Genetic Algorithm.

Images	Peppers	Lena	Baboon	Cameraman	Boat	Man
NC for CBIT Logo	0.9792	0.9642	0.7926	0.8640	0.8732	0.9442
NC for CS Logo	0.9999	0.9944	0.8944	0.9640	0.9866	0.9930

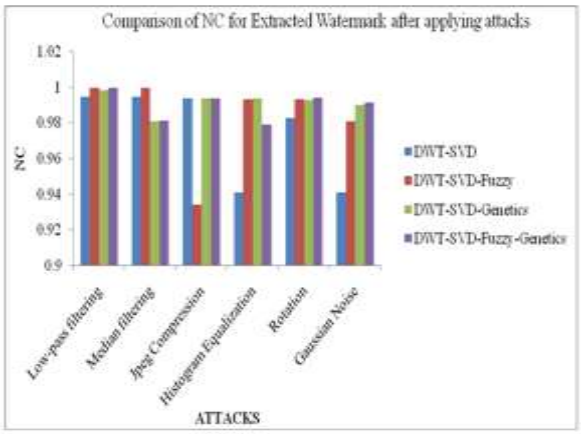
The Table III shows the NC values for original and extracted CBIT Logo and CS Logo for different images. NC for maximum images is above 0.9. Compared with CBIT, NC for CS image is high and it is 0.9999. Robustness is achieved by the proposed algorithm and it also resist against the different type of attacks.

GRAPH 2: Comparison of PSNR (dB) for DWT-SVD, DWT-SVD-Fuzzy Logic, DWT-SVD- Genetic Algorithm and DWT-SVD-Fuzzy Logic-Genetic Algorithm



The above Graph. 2 shows a chart that compares PSNR (dB) values for watermarked image by using four methods. These values are obtained using the input image "Peppers" and watermark image "CS Logo". PSNR (dB) for DWT-SVD-Fuzzy Logic and Genetic Algorithm is 45.0430 and it is high when compared with other algorithms. Therefore, imperceptibility is achieved by the proposed algorithm[13].

GRAPH. 3: Comparison of NC values for extracted watermark image for four methods.



The above Graph 3 shows the NC values for extracted watermark after applying different attacks to all the four methods. NC value for DWT-SVD-Fuzzy is 1.000 and it is high for attacks Low-pass and Median filtering. NC value for DWT-SVD-Genetic Algorithm is 0.9937 and it is high for Histogram Equalization attack. NC value for DWT-SVD-Fuzzy Logic-Genetic Algorithm is 0.9941 for Jpeg Compression, 0.9944 for Rotation and 0.9914 for Gaussian noise. Therefore robustness is achieved by the proposed algorithm as the NC values are high for attacks Jpeg compression, Rotation and Gaussian noise.

VI. CONCLUSION

In this work, a robust and imperceptible watermarking scheme is used based on reference image, DWT and SVD. Fuzzy logic and Genetic algorithm are two optimization techniques used to get an optimal solution by achieving the robustness and imperceptibility. Optimization techniques are used to maximize the values of PSNR. Finally a comparative analysis has been done on the algorithms based on DWT-SVD, DWT-SVD-Fuzzy Logic and proposed DWT-SVD-Fuzzy Logic-Genetic Algorithm. From the implementation a conclusion has emerged that embedding a watermark using proposed method has high PSNR and NC which means that the algorithm is robust and imperceptible.

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