ROBUST DATA HIDING TECHNIQUE IN WAVELET DOMAIN USING SALIENCY MAP

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ABSTRACT

Visual saliency signifies the region of perceptual significance in an image to Human Visual System (HVS).It is the inherent quality that discriminates an object from its neighbors. The Saliency map computes such regions in an image. In this paper, we present the application of Wavelet domain data hiding in such prominent regions. The proposed algorithm embeds information into visually interesting areas within the host image, determined by the visual attention model. This algorithm is very simple in structure and has enhanced robustness that aids it to survive against various geometric and filtering attacks. A thoroughly verified subjective and objective evaluation speaks out our claim of enhanced ability in maintaining image quality under such impairment.

KEYWORDS: *Saliency Map, Human Vision System, Wavelet.*

I. INTRODUCTION

The current development in digital and multimedia technology enables constant creation and distribution of digital contents throughout the globe. This also provides convenience for unauthorized manipulation and duplication of the digital contents, thus providing efficient challenges to multimedia security [1]. This concern has led to research interest towards developing a new copy deterrence and protection mechanism. One such effort in this field is focusing escalated interest in digital watermarking techniques as described in [2]. It is defined as the technique that embeds secret messages named watermark by making imperceptible changes to the original host asset. Digital watermarking has become an active and intense area of research. The development and commercialization of watermarking techniques is being deemed essential to overcome some of the challenges faced by the rapid proliferation of digital content [3].

The performance of data hiding technology can be evaluated on mainly three basic features: robustness, fidelity, and payload. There exists a trade-off among the above mentioned parameters so as to enhance the performance of an existing model. By exploiting the characteristics of Human Visual System (HVS), we can actually make our watermarks more robust. The HVS is an information processing system, receiving spatially sampled images from the cones and rods in the eye and creates the impression of the objects it observes by processing this image data. The discrete Wavelet Transform is well accepted means for obtaining the multi-scale representation of an image which has striking similarity with the way the HVS processes visual information. Methods of image decomposition that closely mimic the human visual system (HVS), can be utilized in robust data hiding application. On the other hand we have improved imperceptibility. The Saliency map was intended as input to the control mechanism for concealed discriminatory attention. In our algorithm we incorporate the benefit of Saliency map in order to impart imperceptibility. The Saliency map represents the rich-information area of an image which has shown promising results to various signal processing operations. Hence they are used in data hiding techniques to resist various intentional and non-intentional attacks. For obvious reason Saliency map can be a promising candidate for determining suitable locations for embedding secret information.

It is observed that DWT offers fair decomposition of the host image in the frequency domain, but it does not exploit complete behavioral visual attention. Thus, a combination of the human visual attention based model with the DWT is chosen as this symbiosis improves image imperceptibility while maintaining the robustness. We separate the blue component of the RGB cover image and perform three-level Selective DWT. Then we obtain the Saliency map for purpose of selecting suitable wavelet coefficients as our embedding channels. Since the Saliency map has an irregular shape we used the technique of Maximum Bounding Box as our embedding region. The given secret message is embedded into the selected wavelet coefficients by means of additive spread spectrum CDMA technique. In order to achieve synchronization between the encoder and decoder sections the co-ordinates of the Maximum bounded box enclosing Salient region are also encoded into another set of suitable wavelet coefficients at different DWT level. Finally, the co-ordinates and then the watermark are detected by the correlation values calculated in the decoder section. The algorithm proposed in this paper is highly secure and works very well with various attacks like 3x3 Low Pass Filtering, JPEG compression, resizing, and different noises like Gaussian, Poisson Speckle and Salt & Pepper noise.
This paper is organized as follows: In section II we discussed about Related Works in relevant area. In section III we described about our proposed watermarking model using Graph Based Visual Saliency Map. The algorithm of watermark embedding and extracting are discussed in section IV and V respectively. Section VI demonstrates the experimental results and analyses the performance. Section VII summarizes and concludes this paper.

II. RELATED WORKS

Several methods have been proposed by authors for finding out the Saliency Map of a given image [6-8]. X. Hou et al. analyzed the log-spectrum of an input image and extracted the spectral residual of an image in the spatial domain and then using this constructed the corresponding Saliency Map [18]. Mainly these are different approaches of finding the maximum rich-information area of an image. In recent times this maps were used with digital watermarking concepts to find suitable locations for embedding a given watermark. C. Li et al. [12] presented an integrated watermarking scheme which included two stages, extracting Salient region and then embedding the given watermark in hyper-complex frequency domain. However the experimental results showed that the proposed method is not robust enough and poor in recovery of watermark against attacks like JPEG Compression and Gaussian Noise. A. Sur et al. [13] proposed a watermarking scheme by embedding the information in the pixels with the least Saliency value. L. Tian et al. [14] proposed a semi-blind integral visual Saliency based watermarking approach by embedding the watermark into the ROIs of the images using Discrete Cosine Transform (DCT) and Quantization Index Modulation (QIM). Although the marked image has high PSNR values but the recovered watermark had very small correlation values against general attacks as compared to our method. D. W. Lin et al. [16] proposed a new technique for extracting salient regions in an image by adding the areas that correspond to different significant coefficients in the horizontal, vertical, and diagonal wavelet coefficients and their ancestors. M. Oakes et al. [17] used the Visual Attention Model (VAM) of the HVS by modeling in the DWT watermarking framework to locate inattentive regions. The proposed method achieved high robustness against various filtering attacks but was not versatile as far as geometric attacks are concerned.
In this paper we have proposed a way to enhance the efficiency of DWT based digital watermarking using Saliency Map. The proposed method is justified through various experimental results obtained from extensive experiments.

III. PROPOSED WATERMARKING MODEL

The proposed method performs a 3-Level Selective DWT on the blue component of a RGB cover image as the change in blue component is the least perceptible to human visual system. We have performed a 3-Level selective DWT as this method gives the best result among all its counterparts. Lower level DWT is not attack resistant [4]. Now we obtain the Saliency map of the LH (Low-High) layer of the image obtained by performing 3-level selective DWT on the cover image. Salient regions are obtained as any changes made in these regions are imperceptible to human eyes. However for a particular image there are many salient regions present all over the image, so we categorize the salient regions with respect to their areas, and then bound the region with maximum area using a bounding box. Using the bounding box technique and hence, focusing on a particular area of the image gives us better results when compared to the contemporary works of this field. For synchronizing both the embedding and recovering section we embed the co-ordinates of the bounding box in the HH (High-High) layer, and then the watermark is embedded in both the LH and HL layer only in the region bounded inside the bounding box. Watermarking procedure is having three phases viz. Discrete Wavelet Transform, Generation of Saliency Map and CDMA Encoding [4]. Watermark embedding and detection process is shown in Figure 1.

3.1. Discrete Wavelet Transform

An image as being a 2-dimensional signal needs 2-dimensional Wavelet Transform in rows and columns, respectively. Image I is broken down into four parts by Discrete Wavelet Transform, that are high - frequency detail in sub graph and low - pass approximation of sub graph horizontally, vertically and diagonally, each child diagram is received by interval sampling filter. Similar to classical DWT, 2D DWT is a non-redundant transform, the wavelet image representation of I , at resolution J : $[a_j, \{d_j^1, d_j^2, d_j^3\}_{0<j\leq J}]$ having the same size as the original two-dimensional signal, I .

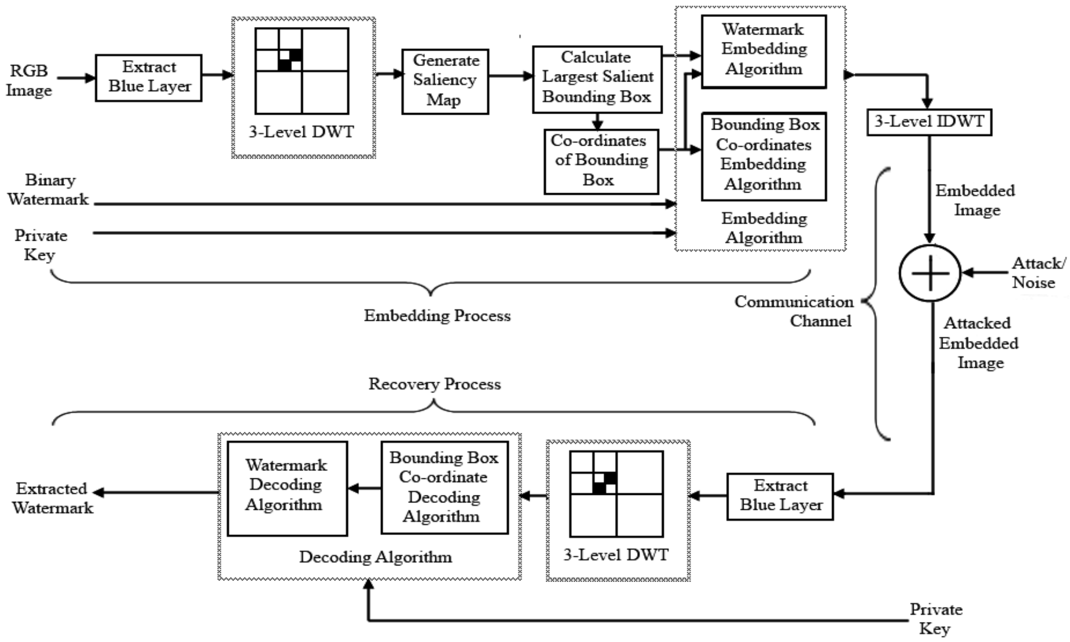

Figure. 1. Block Diagram of Watermark Embedding and Extraction

We have used 3-level Selective Haar DWT as it yields best results [4]. Initially we take the blue layer of our cover images as a change in blue layer is beyond the perceptibility on human eyes. We then divide our cover images into four DWT coefficients, and further decompose the approximation coefficient LL into four second level DWT coefficients and finally taking the diagonal or HH details; we decompose it into four third level DWT coefficients. We embed the watermark information into the LH the horizontal details and HL the vertical details of the decomposed image. Figure 2 describes the decomposition scheme used in our algorithm and Figure 3 shows the different coefficient images of our sample cover image.

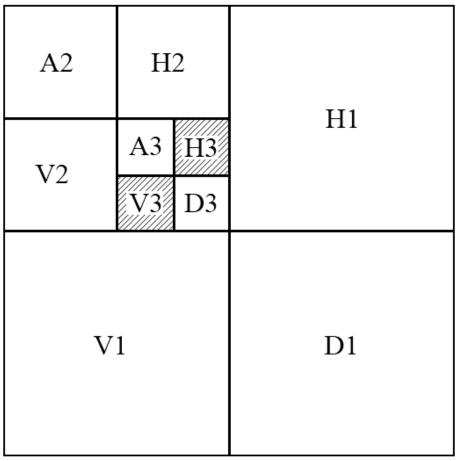

Figure 2. 3-level Selective DWT decomposition scheme: the shaded regions represent the embedding locations.

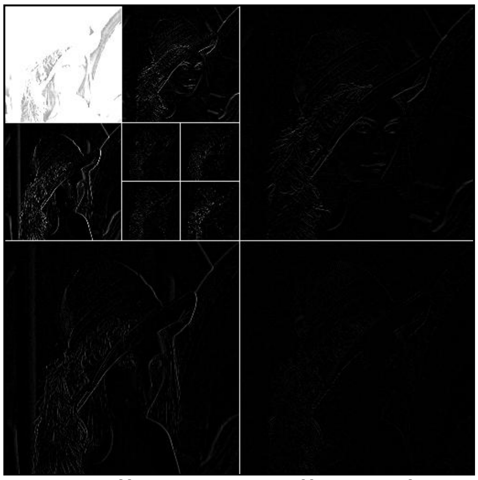

Figure 3. Different DWT coefficients of Lena.

3.2. Visually Attention Map

We have employed the Graph-Based Saliency (GBVS) to generate the Saliency map. In an image I , we wish to highlight a significant location where most of the information is located according to some criterion, e.g. human fixation. This process is conditioned on first computing feature maps e.g. by linear filtering followed by some elementary nonlinearity [6]. “Activation”, “normalization and combination” steps are described as follows [5, 6].

Suppose a feature map is given as $M:[n]^2 \to R$. Its activation map should be $A:[n]^2 \to R$, such that, intuitively, locations $(i,j) \in [n]^2$ where I , or as a proxy, $M(i,j)$ is unusual in its neighborhood will correspond to high activation value A. We denote the dissimilarity of $M(i,j)$ and $M(p,q)$ as

$$d((i,j) \| (p,q)) \triangleq \left| \log \frac{M(i,j)}{M(p,q)} \right| \quad (1)$$

The dissimilarity is the distance between one and the ratio of two quantities, measured in logarithmic scale. A fully connected directed graph G_A is obtained by connecting every node of lattice M , labeled with two indices $(i,j) \in [n]^2$ with all other nodes. A weight will be assigned in the directed edge from node (i,j) to node (p,q) as

$$w_1((i,j),(p,q)) \triangleq d((i,j) \| (p,q)) \cdot F(i-p, j-q),$$

where $$F(a,b) \triangleq \exp\left(-\frac{a^2+b^2}{2\sigma^2}\right) \quad (2)$$

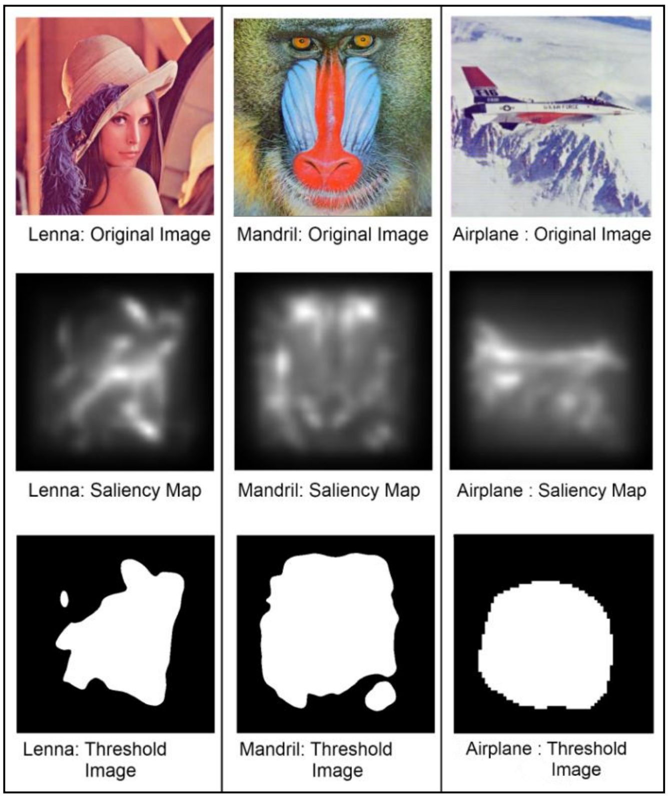

Figure 4. Original Cover Images and their respective saliency maps and threshold images

Now define a Markov chain on G_A by normalizing the weights of the outbound edges of each node to 1, and drawing equivalence between nodes and states, and edges weights & transition probabilities. The equilibrium distribution of this chain, reflecting the fraction of time a random walker would spend at each node/state if he were to walk forever, would naturally accumulate mass at nodes that have high dissimilarity with their surrounding nodes, since transitions into such sub-graphs is likely, and unlikely if nodes have similar M values. The objective of normalization and combination is to concentrate mass on activation maps. We construct a graph G_N with n^2 nodes labeled with indices from$[n]^2$. For each node (i, j) and every node (p,q)(including(i, j)) to which it is connected, we introduce an edge from (i, j) to (p,q) with weight:

$$w_2((i, j),(p,q)) \underline{\underline{\Delta}} A(p,q)\cdot F(i-p, j-q) \quad (3)$$

Again, normalizing the weights of the outbound edges of each node to unity and treating the resulting graph as a Markov chain gives the opportunity to compute the equilibrium distribution over the nodes. Mass will flow preferentially to those nodes with high activation.

After generating the Saliency map, we have further converted it into logical image map depending on certain threshold value. This threshold has been selected using Otsu's Method [9]. The original images and their corresponding Saliency maps and threshold images are depicted in Figure 4.

3.3. Spread Spectrum Encoding

The application of PN sequence is purposed on combining the signals of multi-users and still keeping them independent in CDMA encoding system. It has the obvious and natural advantage to apply its principles to digital watermarking.

Assuming, the watermark message be represented in binary form as $\hat{b} = (\hat{b}_1, \hat{b}_2,..., \hat{b}_p)$, where $\hat{b}_i \in \{0,1\}$ and p denotes the number of bits in the watermark information to be encoded. The PN sequence generated using the unique private key chosen by both embedding and decoding, and is correlated with the binary message to be embedded into the DWT coefficients of the cover images. As we earlier stated that we are using the horizontal and vertical detail coefficients of 3-level Selective DWT of the cover images having resolution of $M_c \times N_c$ pixels, we need to generate a PN sequence having size $M_c/2^3 \times N_c/2^3$.

IV. WATERMARK EMBEDDING ALGORITHM

Step 1: The blue component layer is extracted from the RGB cover image for embedding the watermark.
Step 2: The cover image is decomposed into three level Selective DWT coefficients. Out of the four sub-bands, only the high resolution bands (H_3 sub-band or HL_3 coefficient and V_3 sub-band or LH_3 coefficient) are selected for watermark embedding.
Step 3: The Saliency map of H_3 sub-band or HL_3 coefficient is generated using GBVS.
Step 4: The Saliency map is converted into logical image using Otsu's method.
Step 5: The largest connected region (blob) is then selected from the obtained logical image and the dimensions of the maximum bounding box of that region is calculated. The property of the bounding box consists of four fields viz. x and y co-ordinates of top-left vertex, $width$ and $height$.
Step 6: Now H_2 sub-band (HL_2 coefficient) is subdivided into four equal parts and each part is selected for embedding of each field of bounding box.
Step 7: Four highly uncorrelated, zero-mean, two-dimensional pseudorandom sequences (PN) are generated for each field of bounding box using a particular key for each 1 (one) bit of the field value.
Step 8: Generated PN sequences are embedded into the selected region with the first embedding strength (k_1) using (4):

$$\begin{aligned} &If \quad field\_bit(i) = 1, \\ &\quad \hat{H}_2(p) = H_2(p) + k_1 * PN\ sequence(p) \\ &If \quad field\_bit(i) = 0, \\ &\quad \hat{H}_2(p) = H_2(p) \end{aligned} \tag{4}$$

where, $1 \le i \le length(field\_bit)$ which is usually 8

and $p = \begin{cases} 1 & field = x \\ 2 & field = y \\ 3 & field = width \\ 4 & field = height \end{cases}$

Step 9: Another two highly uncorrelated, zero-mean, two-dimensional pseudorandom sequences (PN) having size of the selected bounding box are generated for H_3 and V_3 using that particular key for each 0 (zero) pixel value of the watermark image.
Step 10: The newly generated PN sequences are embedded into the selected DWT coefficients H_3 and V_3 with the second embedding strength (k_2) using (5):

$$\begin{aligned} &If \quad watermark(i) = 0, \\ &\quad \hat{H}_3 = H_3 + k_2 * PN\ sequence \\ &\quad \hat{V}_3 = V_3 + k_2 * PN\ sequence \\ &If \quad watermark(i) = 1, \\ &\quad \hat{H}_3 = H_3 \qquad \hat{V}_3 = V_3 \end{aligned} \tag{5}$$

where, $1 \le i \le length(watermark)$

Step 11: Perform 3-level IDWT on the transformed image in the reverse way to get back the desired form of blue component.
Step 12: Merge this blue component to the unchanged red and green component to generate the watermarked image.

V. WATERMARK EXTRACTION ALGORITHM

Step 1: The received watermarked image can be preceded by attack on the image like different kinds of noises and attacks.
Step 2: The blue component layer is extracted from the watermarked image.
Step 3: Three-level selective DWT is applied to the extracted blue component and the same sub-band coefficients were selected into which the bounding box fields and watermark were embedded.
Step 4: The four PN sequences were generated for bounding box fields using the same key which was used in the embedding section.
Step 5: The field values are extracted from H_2 sub-band by calculating the correlation coefficient between the selected sub-bands and the regenerated PN sequence.
Step 6: Again two PN sequences having size of extracted bounding box were generated for extracting watermark using the same key which was used in the embedding section.
Step 7: Calculate the correlation coefficient between the above selected H_3 and V_3 sub-bands and the regenerated PN sequence.
Step 8: Calculate the mean of all the correlation values obtained above and compare it with each correlation value with the mean correlation value. If the calculated correlation value is greater than the mean, the extracted watermark bit is taken as zero, otherwise one. The recovery process is then iterated through the entire PN sequence.
Step 9: The watermark is constructed using the extracted watermark bits, and then in order to check the likeliness of the original and extracted watermark we compute the Similarity Ratio or Correlation and Bit Error Rate between them.

VI. EXPERIMENTAL RESULTS

We have applied our embedding algorithm to different cover images to verify the effectiveness of our proposed method. We are showing results for four RGB images: 1) Lena, 2) Airplane, 3) Peppers and 4) Sailboat, each having size of 512×512 pixels. All the watermarked images, shown in Table 1, are visually imperceptible.

6.1. Robustness Analysis

In our experiments we have tested various kinds of attacks on our cover images, such as: (a) 4×4 Low Pass Filter, (b) Gaussian Noise of variance 0.01, (c) Salt & Pepper Noise of variance 0.1, (d) Speckle Noise of variance 0.1, (e) Poisson Noise, (f) 50% Scaling, (g) 200% Scaling, (h) 256×256 Cropping, (i) Negative Image, (j) Intensity Adjustment, (k) 30% JPEG Compression, (l) Histogram Equalization of 32 step-sizes. By increasing the level of attacks introduced to an embedded image, we have noticed that the respective Bit Error Rate (BER) obtained is relatively low. It can sustain strong attacks and still be able to recover the watermark accurately. The attacked watermarked image and the extracted watermark as observed for the cover image 'Airplane' is shown in Figure 5. It is clear from Figure 5 that the subjective watermark is recovered almost accurately for all the attacks.

Table 1. Original Cover Images along with the watermarked Images and extracted Watermarks

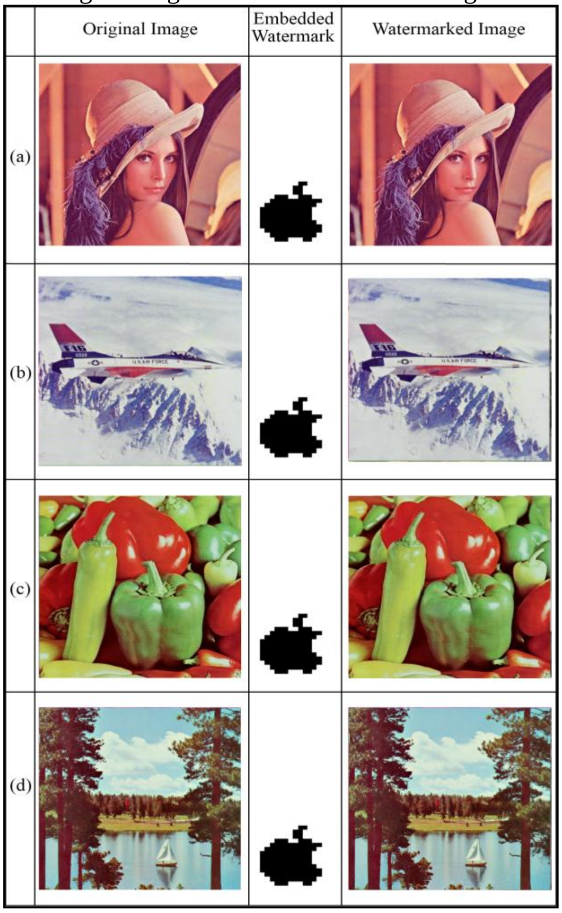

Table 2. Comparison between Tian's, Mohanty's Method and Our Method

Attack	Correlation		
	Our Method	Tian's method [14]	Mohanty's method [20]
No Attack	0.9980	0.9984	0.9947
Gaussian Blur	0.9890	0.8354	0.9856
JPEG Compression	0.9961	0.8124	0.7930
Median Filter	0.9841	0.9287	0.8373
White Noise	0.9922	0.9342	0.9286

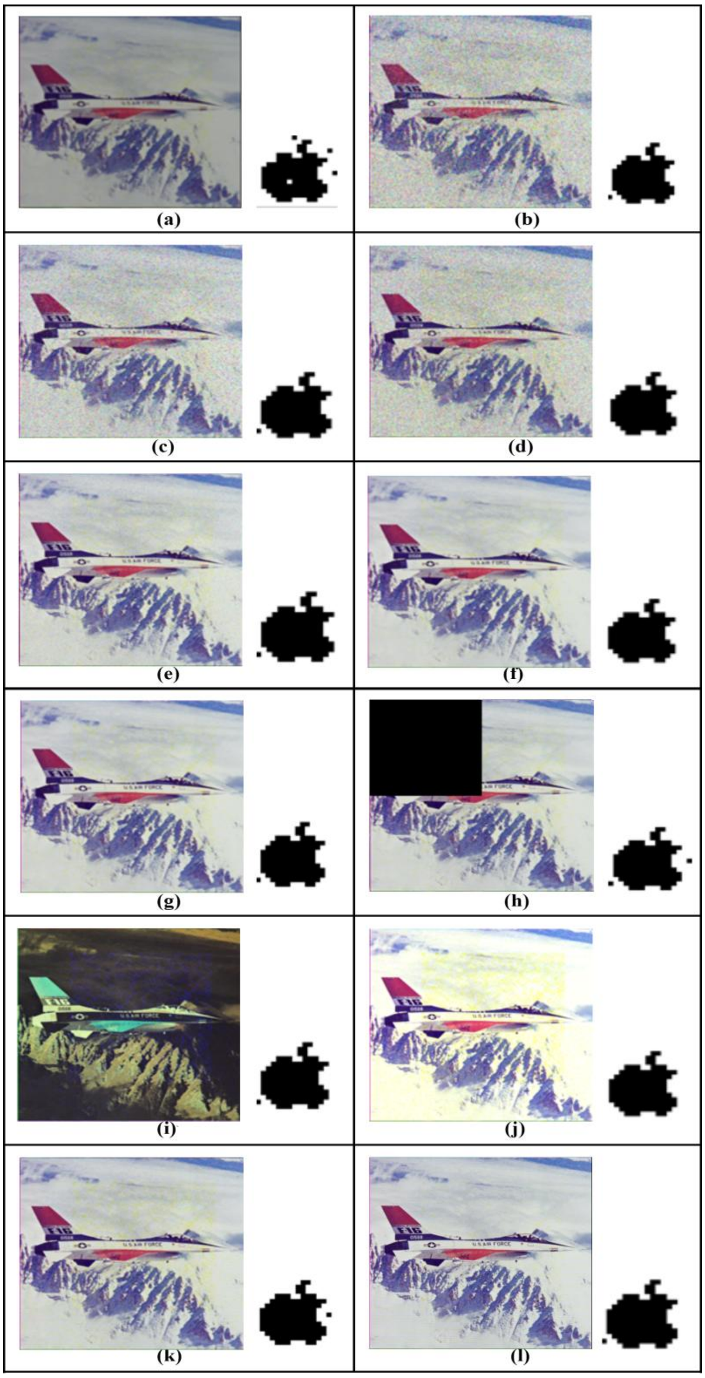

Figure 5. Various types of attacks and extracted watermark from attacked image: (a) 4×4 Low Pass Filter, (b) Gaussian Noise of variance 0.01, (c) Salt & Pepper Noise of variance 0.1, (d) Speckle Noise of variance 0.1, (e) Poisson Noise, (f) 50% Scaling, (g) 200% Scaling, (h) 256×256 Cropping, (i) Negative Image, (j) Intensity Adjustment, (k) 30% JPEG Compression and (l) Histogram Equalization of 32 step-sizes.

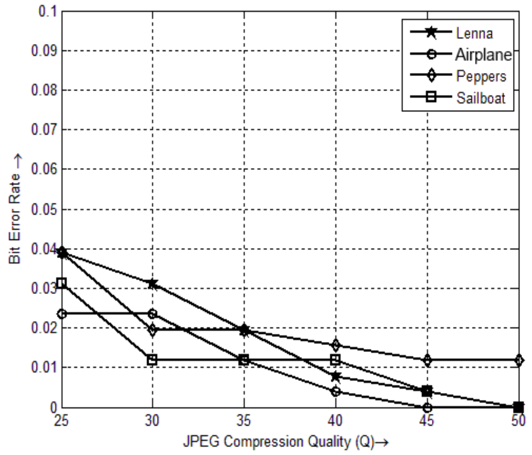

Figure 6. Curve of Bit Error Rate (BER) against Varying Quality Factor of JPEG Compression (Q) for Different Cover Images.

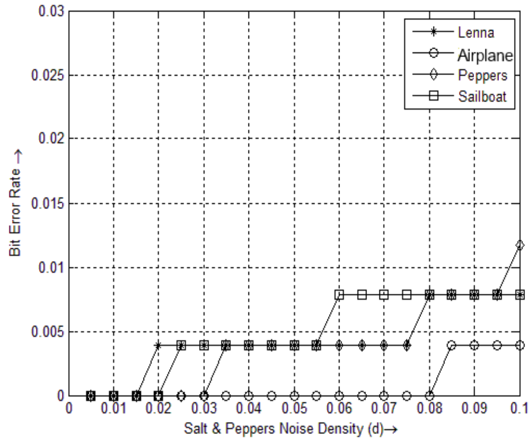

Figure7. Curve of Bit Error Rate (BER) against Varying Density of Salt & Pepper Noise (d) for Different Cover Images.

6.2. Quality Analysis

We notice that with the increase in payload (size of watermark), we obtain satisfactory results. We have taken other watermark images of varying pixels size and payloads (in bytes). We observe that if we take a 32×32 watermark (original watermark was a 16×16 image) we still are able to recover the watermark with a BER of as low as around 0.08, i.e. we are able to recover 99.92% of the hidden watermark. Figure 8 shows the nature of BER with increasing value of k_2 for different payloads.

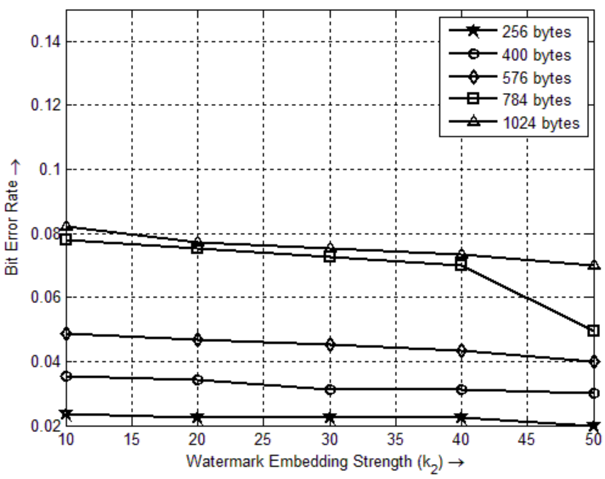

Figure 8. Curve of Bit Error Rate (BER) against Embedding Strength (k_2) for Different Watermark Images Having Different Size and Payloads.

6.3. Other Test Metrics

Different performance metrics are calculated to estimate the quality and authenticity of a watermarked image with respect to the cover image. Test metrics including,

1. Mean Square Error (MSE),
2. Normalized Cross Correlation (NC),
3. Correlation Quality (CQ),
4. Image Fidelity (IF),
5. Pearson Correlation Coefficient (PCC),

6. Correlation Factor (CF),
7. Watermark To Document Ratio (WDR),
8. Vector Correlation (CR),
9. Maximum Difference (MD),
10. Average Absolute Difference (AD),
11. Normalized Average Absolute Difference (NAD),
12. Normalized Mean Square Error $(NMSE)$,
13. Laplacian Mean Square Error $(LMSE)$,
14. Structural Content (SC)

are calculated for each of the cover image for different values of Embedding Strength (k_2), and are given in Table 3.

VII. CONCLUSION

In this paper, we enhanced the efficiency of the Saliency Map based watermarking model by combining the existing model with DWT based watermarking using CDMA technique. Our proposed method showed significant improvement in robustness and imperceptibility of the embedded image. In particular, various obtained results shows that the watermark is robust various attacks like, Low Pass Filtering, JPEG Compression, Gaussian Noise, Salt & Pepper Noise, Speckle Noise, Intensity Adjustment, Cropping, Negative and Scaling. It was believed that DWT implemented algorithms are not robust against Cropping, but we see that on combing DWT with Saliency Map of an image we are able to develop an algorithm that is robust against Cropping too. On comparing our result with [14] and [20] we see that the proposed model gives better results and is more robust. Our method is using more than one key for synchronization purpose which makes the system fragile if one of the key is not recovered properly. This is to be investigated in the future work.

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