HUMAN EYE DECEIVING MODEL FOR SECRET COMMUNICATION

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Abstract: *Visual system of human beings does not process the complete area of image rather focus upon limited area of visual image. But in which area does the visual attention focused is a topic of hot research nowadays. Research on psychological phenomenon indicates that attention is attracted to features that differ from its surroundings or the one that are unusual or unfamiliar to the human visual system. Detection of visually salient image regions is useful for applications like object segmentation, adaptive compression, and object recognition. Object or region based image processing can be performed more efficiently with information pertaining locations that are visually salient to human perception with the aid of a saliency map. Recently many authors have used wavelet domain for detection of salient regions. This domain has shown promising results but almost all the authors have ignored the detail* *components of wavelet domain which may have some useful information. So in this paper we have tried to use the wavelet domain method to detect salient regions using approximation and all detail components. Further this saliency map will be used for steganography.*

Keywords: *saliency map, wavelet transform, approximation coefficients, detail coefficients, salient region*.

1 Introduction

1.1 Saliency Maps

Humans do not process the entire area of an input visual image uniformly, but focus their attention on a limited area (attended area) in the field of view and then shift their attention from one place to another, depending on the situation and task. Research on human visual characteristics shows that people only perceive clearly a small region of 2-5^{o} of visual angle [1]. According to the way of obtaining attention regions, they can be coarsely classified into four categories, as follows:
(1) In a first approach, considering that human attention prediction is still an open problem, human machine Interaction methods are adopted to obtain the attention regions. (2) A second class of approaches uses machine vision algorithms to automatically detect interesting regions. For instance, due to the importance of human faces while people perceive the world. (3) A third class of approaches uses knowledge about human psychophysics to guide the encoding process. (4) The fourth class of approaches exploits recent computational neuroscience models to predict which regions in image are more likely to attract human attention and to be gazed at. With the development of brain and human vision science,

progress has been made in understanding visual selective attention in a plausible biological way, and several computational attention models have been proposed [2]-[4]. In these models, low-level features such as orientation, intensity, motion, etc. are first extracted, and then through non-linear biologically inspired combination of these features, an attention map (usually called saliency map) can be generated. In this map, the interesting locations are highlighted and the intensity value of the map represents the attention importance. Under the guidance of the attention map, resource can be allocated non-uniformly to improve the subjective quality [5]-[8]. Although such research shows promising results, it is still not a completely resolved problem. The use of the saliency map can be seen in object segmentation [9, 10, 12]; visual search in complex scenes [13]; traffic signs detection [14]; image retrieval [15]; image watermarking [16]; image compression [17]; image fusion [18]; and many other image/visual applications. Steganography or data hiding in images may emerge as one of the major applications of saliency map. We are working upon this application of saliency map so as to make steganography more secure.

1.2 Steganography

The term steganography is derived from the Greek word steganos, meaning "covered," and graphein, "to write" [19]. In steganography, a message is hidden within another seemingly ordinary (cover) message in such a way that only the sender and intended recipient will even know the hidden message exists. This idea is different from that of cryptography, which only tries to make the message unreadable. Modern steganography's goal is to keep its mere presence undetectable, but steganography systems because of their invasive nature—leave behind detectable traces in the cover medium. Due to this problem it is mandatory to understand the statistics of Images and to make the data hidden in such a manner so that no detectable traces are left behind.

2 Literature Review

2.1 Saliency Map

Saliency has also been referred to as visual attention [20], unpredictability, rarity, or surprise [22, 23]. Saliency estimation methods can broadly be classified as biologically based, purely computational, or a combination. In the biological category one of the reputable works is by Itti and Koch [21] whose method was based upon biologically plausible architecture proposed by Koch and Ullman [25]. They determine center-surround contrast using a Difference of Gaussians (DoG) approach. Frintrop et al. [24] present a method inspired by Itti's method, but they compute center surround differences with square filters and use integral images to speed up the calculations.

In computational Visual Saliency models, low-level features and the contrast approach are still used but the model is not constructed based on any biological mechanism. The contrast is mainly obtained through the use of Euclidian distance in different sized window filters [20, 26, 27]. The contrast images obtained in the works of [20, 26, 27] are summed to form the final saliency map.

The third category of methods is those that incorporate ideas that are partly based on biological models and partly on computational ones. For instance, Harel et al. [28] create feature maps using Itti's method but perform their normalization using a graph based approach.

Recently, there is a trend to model VS computationally in the frequency domain [11, 29]. In the works of Hou and Zhang [11], a spectral residual approach was used to generate the saliency map. The saliency map is the inverse of the spectral residual. The saliency map of this method is rather accurate in providing the locations of important regions in a given visual scene but is terribly low in resolution. In [29], Achanta et al. debated that the saliency map should have well-defined borders, uniformly highlighting the object if it is salient, and most of all; the saliency map should be in high resolution. In the authors' opinion, without conforming to the points mentioned [29], the saliency would have limited usefulness in certain applications. Therefore, Achanta et al. proposed a method which generates the saliency map solely by contrast representation. Although the approach used by Achanta et al. gives high resolution maps which has its usefulness in some applications but in many other applications such as content based image retrieval (CBIR) all that matters is the detection of salient objection with acceptable resolution. In fact, the approach used in [29] will eliminate many small detailed objects and textures which could be of importance when the smoothing is applied to the spatial domain. Furthermore, as long as the saliency map provides the correct location of important objects and is of reasonable resolution (object can be visually identified), the map can be considered acceptable. In another approach Discrete wavelet transform was used by Christopher et al. [30] to compute the saliency map. This approach is successful in detecting salient regions in an image with acceptable resolution but it considers only the contrast of LL band, it totally ignores the other three detail bands. This act will eliminate the smaller and finer details. But sometimes some important information may be present in these detail components. To solve this problem we have drawn an idea about saliency model based on wavelet transform domain by processing approximation (LL) as well as all the three detail coefficients (LH, HL, HH) in our previous research work. Here we will compare our saliency map with other techniques on the parameters of Precision, Recall and F-measure and will use the same saliency map for steganography application. It will also be shown that saliency map makes data hiding mire secure with the help of parameters like PSNR, MSE and Quality.

2.2 Steganography

Various methods of steganography have been proposed in the literature. All these methods are broadly classified into 3 categories. Firstly methods which are hiding data in spatial domain. One of the commonly used techniques in this category is the LSB where the least significant bit of each pixel is replaced by bits of the secret till secret message finishes [2, 4, 5, 6]. The risk of information being uncovered with this method as is very much prone to 'sequential scanning' based techniques [1], which are threatening its security. The random pixel manipulation technique attempts at overcoming this problem, where pixels, which will be used to hide data are chosen in a random fashion based on a stego key. However, this key should be shared between the entities of communication as a secret key. Moreover, some synchronization between the entities is required when changing the key [1]. This will put key management overhead on the system. In second category data is hidden in frequency domain. . It comprises algorithms based upon discrete cosine transforms (DCT), Fourier transforms (FT), and discrete wavelet transforms (DWT). In this domain various algorithms are Li and Wang steganography [31], McKeon 2DdiscreteFourier transform (DFT) based steganography [38], Jsteg for jpeg images [32, 33], OutGuess [34], "F5''algorithm [35]. Besides some DWT based techniques like W.Y.Chen, Color image steganography scheme using set partitioning in hierarchical trees coding [36], Abdulaziz and Pang technique based upon vector quantization called Linde-Buzo-Gray (LBG)coupled with block codes known as BCH code and 1-stage discrete Haar wavelet transforms [37] are certain wavelet based steganography techniques. The DWT-based embedding technique is still in its infancy.

The third category of steganography is Model-based steganography which introduces a different methodology, where the message is embedded in the cover according to a model representing cover message statistics. The model-based technique, proposed by Sallee, tries to model statistical properties of an image and preserves them during embedding process [39]. Hioki [38], presented an adaptive method termed ''A Block Complexity based Data Embedding'' (ABCDE). ABCDE works in a very similar method as BPCS, but employs a more sophisticated complexity metric. This model based steganography inspires for a model based upon human visual system which may be further be used for secure steganography.

3 Saliency Model Computation

The various calculations related to computation of saliency model are as follows:

The input colored image is first converted to Lab color space so as to make it device independent. Also the L component distinguishes the intensity or lightness component from the color information. Then taking the all the L, a, b components individually we performed the single level DWT decomposition. After this we got the four individual components named LL1, HL1, LH1, HH1 for all the three L, a, b images. Then for each component individually we calculate the contrast image using the Euclidean distance with the help of following formula:

$$C(x,y) = \sqrt{(l_\mu(x,y) - l_\mu)^2} \quad \ldots\ldots\{\text{Equation 1}\}$$

Where l_μ is the mean of LL component of L image (from L, a, b component images) and l_μ(x, y) is the intensity of individual pixel of LL component of L sub-image. Similarly 12 contrast images will be calculated for four sub-bands of each component image of Lab color space. The Euclidean distance is the best representative of the difference in image or pixel that is why Euclidean distance has been used in this work. Then inverse DWT operation will be performed taking four processed sub-bands of each sub-image to get processed L, a, b sub-image L_p, a_p, b_p. then these processed components will be normalized to the range [0,255].These processed sub-images will be combined to get the saliency map using the following formula:

$$Sm = L_p(x,y) + a_p\ (x,y) + b_p(x,y) \ldots\ldots \{\text{Equation 2}\}$$

where Sm is the saliency map and L_p a_p, b_p are processed sub-images of Lab Color space.

Again the saliency map will be renormalized to the range [0,255] to get the final saliency map. Finally we can equalize the histogram of saliency map to get sharper saliency maps.

This saliency map computation has been applied to various images of different dimensions. It has been observed that our method generates the saliency map which is sufficient enough to distinguish and recognize the salient objects in an image. The boundaries of the sa+ient objects are also clearly visible.

4 Saliency Map in Steganography

Now this saliency map has been used as model for hiding secret bits of data in the image. Based on the saliency map higher number of bits may be assigned to the points having lesser values in saliency map and lesser number of bits to the points having higher values in saliency map.

The strategy for this division may vary from one work to another depending upon the requirements of application. For implementation purpose we have divided the values [0-255] in eight equivalence classes assuming maximum 3 bits will be inserted in a channel and maximum of two channels will be used in a pixel. So we will insert 0-6 bits (7 classes) in a pixel depending upon the value of saliency map. We are not inserting more than three bits in a channel because it has been noticed that inserting four or more bits may cause some visible changes in statistics of image. Also higher values are more sensitive to change in color so we are inserting zero bits of secret data in pixels having values in the range [192-255] (2 classes corresponding to 0 bits). The concept could be better understood with the help of table 1 below.

Table 1. Structure of Equivalence Table Representing Range of Equivalence Classes & Corresponding Number of Secret Bits to be Inserted

Sr. no	Range of Equivalence Class	No of secret bits to be inserted
1.	0 to < 32	6
2.	32 to < 64	5
3.	64 to < 96	4
4.	96 to < 128	3
5.	128 to < 160	2
6.	160 to < 192	1
7.	192 to < 255	0

5 Results, Comparison and Discussion

We have implemented the above methodology in Matlab 7.0. We have used more than 20 sets of images of various sizes and resolution for experiment purposes.

5.1 Results for Saliency Map Computation

Some of the results for computing saliency map with proposed approach are shown in Figure 1. below:

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(a) (b) (c) (d)

Figure. 1 Column (a) and (c) are original images and column (b) and (d) are their corresponding saliency maps

5.2 Comparison of Proposed Saliency Map with Other Methods

We have also compared the visual results of our image with various state of art techniques like spectral residual approach [11], frequency tuned approach [29] and DWT based technique by Christopher et. al. [30]. The results are shown below in figure 2:

It may be noticed from figure 2 below that saliency map of proposed technique are not as much visually appealing or salient as much frequency tuned approach's results seems. But it should be understood that proposed technique is not using any filter for smoothing so no small objects would be left out which is not the case with frequency tuned approach [29]. Also our approach is using detail coefficients of DWT

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domain in addition to approximation coefficients which is not the case with Christopher et. al. approach [30]. This will definitely consider even small details which may be of importance with respect to human visual system. The extra cost of processing the detail coefficients in addition to approximation coefficients can be justified in terms of goodness of accuracy of saliency map. Precision, Recall and F-measure are various parameters which may be used for the purpose. We have annotated a rectangle from 20 different subjects about the salient region of an image. The axis points of rectangle in image are more or less same so a standard rectangle is taken and used as ground truth based upon the feedback of 20 subjects.

$$\text{Precision} = \frac{\sum_x \sum_y (t(x,y) \times s(x,y))}{\sum_x \sum_y s(x,y)} \quad \text{\{Equation 3\}}$$

$$\text{Recall} = \frac{\sum_x \sum_y (t(x,y) \times s(x,y))}{\sum_x \sum_y t(x,y)} \quad \text{\{Equation 4\}}$$

$$\text{F- measure} = \frac{(1+\sigma) \text{ X } P \text{ X } R}{(\sigma \text{ X } P) + R} \quad \text{\{Equation 5\}}$$

where s(x, y) is the saliency map image and t(x, y) is a ground truth image within user annotated rectangle

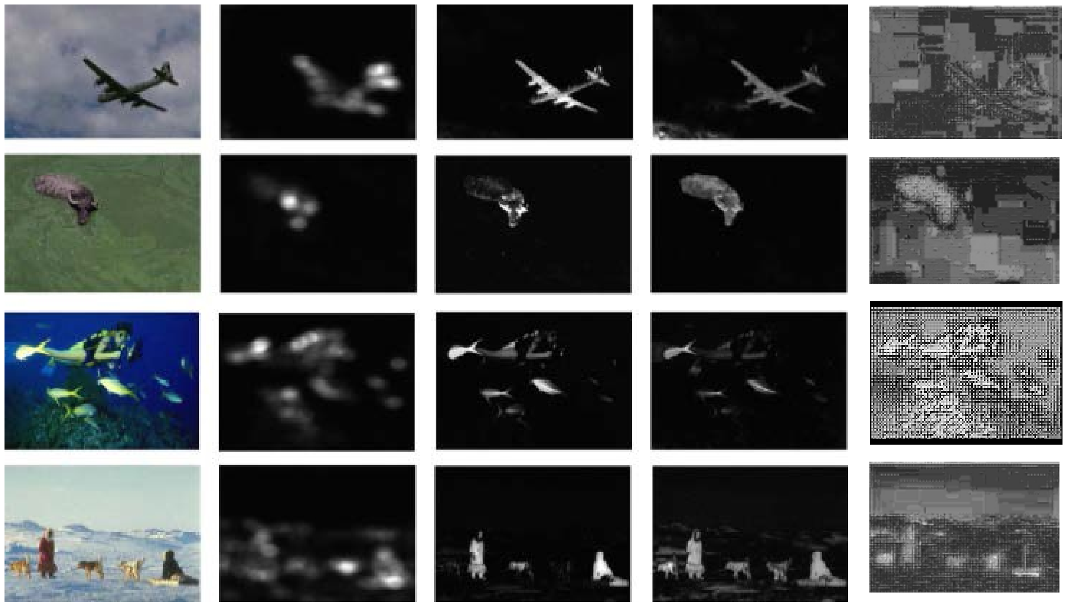

Figure 2. Implementation results: (a) original images; (b) saliency maps from spectral residual approach [11]; (c) saliency maps from frequency-tuned approach [29]; (d) saliency maps from the explored approach - using the DWT transformed domain [30].; (e) proposed method

Here precision is calculated as ratio of total saliency, i.e sum of intensities in the saliency map captured inside the user annotated rectangle to the total saliency computed for the image. Recall is calculated as the ratio of the total saliency captured inside the user annotated rectangle to the area of rectangle. F-measure is the overall performance measurement as the weighted harmonic mean between the precision and recall values. σ is real and positive constant which decides the importance of precision over recall. In our work σ is taken as 0.3 because precision is more important than recall. Precision has been taken with importance of 70% and recall with importance of 30%.

Table 2: Comparison of Proposed Saliency map with Frequency tuned [29] and wavelet domain based technique [30] for Precision, recall and F-measure

Sr. No	Image	Size	Technique	Precision	Recall	F- measure
1	Star	120 X 80	Proposed	0.9726	0.5627	0.8326
			Waveiee	0.9579	0.446	0.7573
			Frequency_tuned	0.9566	0.1904	0.4960
2	Bridge	80 X 120	Proposed	0.7503	0.5869	0.7050
			Waveiee	0.7359	0.4117	0.6227
			Frequency_tuned	0.6201	0.1176	0.3122
3	Fireman	120 X 80	Proposed	0.8728	0.5606	0.7734
			Waveiee	0.8529	0.3748	0.6589
			Frequency_tuned	0.8057	0.2083	0.4848
4	Roses	80 X 120	Proposed	0.7613	0.6087	0.7197
			Waveiee	0.7387	0.4571	0.6468
			Frequency_tuned	0.7184	0.0951	0.2859
5	Scene	120 X 80	Proposed	0.5612	0.6853	0.5857
			Waveiee	0.5462	0.5051	0.5361
			Frequency_tuned	0.5265	0.2911	0.4437
6	Elephants	120 X 80	Proposed	0.8048	0.6947	0.7764
			Waveiee	0.7996	0.4029	0.6516
			Frequency_tuned	0.7708	0.1494	0.3933
7	Horses	120 X 80	Proposed	0.7593	0.5971	0.7145
			Waveiee	0.746	0.5079	0.6732
			Frequency_tuned	0.7298	0.1075	0.3124
8	Red_Flowers	120 X 80	Proposed	0.8043	0.5961	0.7443
			Waveiee	0.7797	0.4804	0.6817
			Frequency_tuned	0.7379	0.0777	0.2492

It can be seen from the table 2. above that our technique is better in terms of precision, Recall and F-measure for almost all the images. We

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have performed the experiment for 20 images approximately but due to lack of space we have shown data only for 8 images. The details of all the images can be seen through the comparison graphs given below for all three parameters.

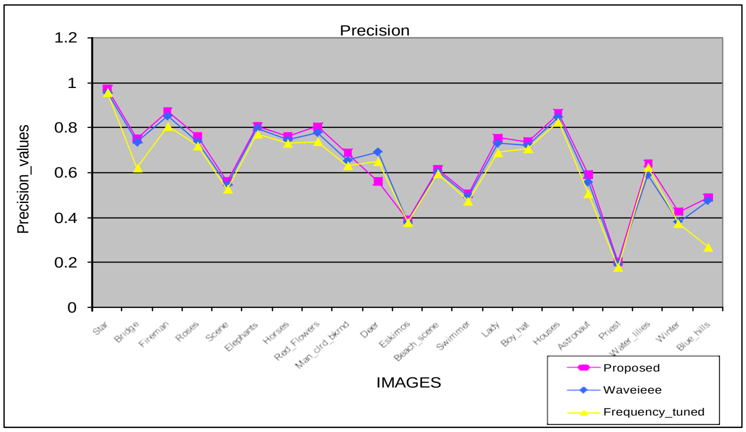

Figure 3: Comparison of Precision values of Images for Proposed saliency map Frequency tuned [29] and wavelet domain based technique [30]

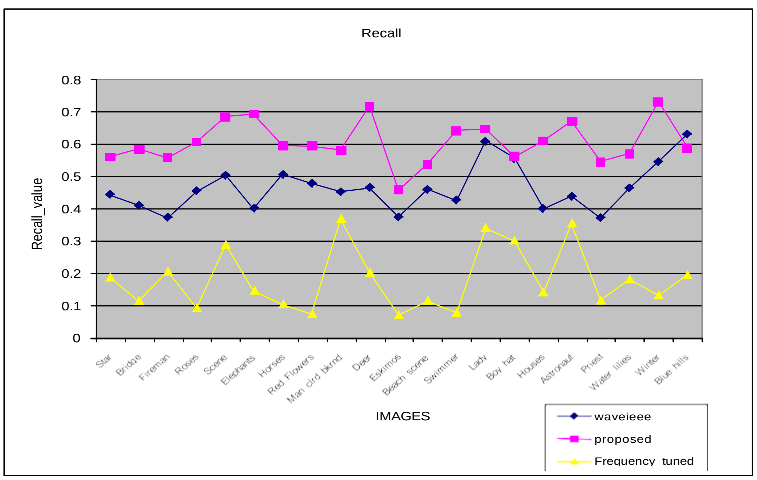

Figure 4: Comparison of Recall values of Images for Proposed saliency map Frequency tuned [29] and wavelet domain based technique [30]

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Figure 3 above shows that precision value of our proposed technique is stands above the precision value of frequency tuned [29] and wavelet domain based technique [30] represented by waveieee in the graph for almost all the images.

Figure 4 above shows that Recall value of our proposed technique has clearly outshined the frequency tuned [29] and wavelet domain based technique [30] represented by waveieee in the graph.

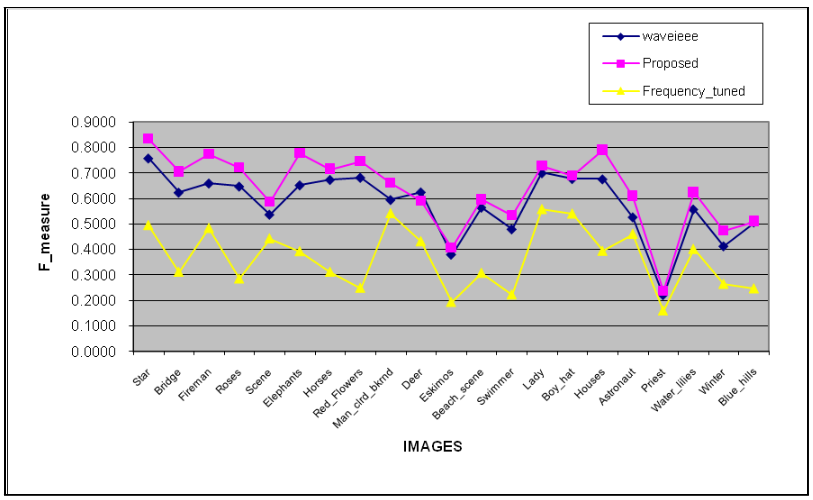

Figure 5: Comparison of F-measure values of Images for Proposed saliency map Frequency tuned [29] and wavelet domain based technique [30]

Figure 5 above shows that F-measure value of our proposed technique has clearly outshined the frequency tuned [29] and wavelet domain based technique [30] represented by waveieee in the graph.

5.2 Results for Steganography Using Proposed Saliency Map

The visual results after hiding secret information for some of the images are shown below in figure 6**:**

Cover Image **Stego Image** **Cover Image** **Stego Image**

Cover Image **Stego Image** **Cover Image** **Stego Image**

(a) (b) (c) (d)

Figure: 6 Column (a) and (c) are original cover images and column (b) and (d) are their corresponding stego images

It may be analyzed that there is no much visual difference in original and stego image using the proposed method. We have calculated the MSE and PSNR values for the experiment images with the help of following formulas:

$$\text{MSE} = \frac{\sum_{M,N}[I1(m,n) - I2(m,n)]^2}{M * N} \qquad \text{\{Equation 6\}}$$

In the previous equation, *M* and *N* are the number of rows and columns in the input images, respectively. Then the block computes the PSNR using the following equation:

$$\text{PSNR} = 10Log_{10}\left(\frac{R^2}{MSE}\right) \qquad \text{\{Equation 7\}}$$

In the previous equation, *R* is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then *R* is 1. If it has an 8-bit unsigned integer data type, *R* is 255, etc. We have calculated MSE, PSNR for the whole image as well as for each plane in RGB image. The results are shown below in table 3:

Table 3: MSE and PSNR values for Images with their corresponding MSE and SNR values for each plane of Image

Sr. No	Image	MSE	PSNR	MSE-Rplane	PSNR-Rplane	MSE-Gplane	PSNR-Gplane	MSE-Bplane	PSNR-Bplane
1	Roses	1.266	47.108	0.204	55.030	0.249	54.161	0.819	49.036
2	Tiger	1.621	46.034	0.084	58.885	0.240	54.336	1.297	47.001
3	Horses	1.572	46.165	0.065	59.983	0.177	55.640	1.330	46.893
4	Red_Flowers	1.123	47.629	0.121	57.307	0.165	55.966	0.837	48.903
5	Policeman	1.507	46.350	0.055	60.722	0.065	59.984	1.386	46.712
6	Man_clrd_bkrnd	1.074	47.822	0.049	61.228	0.125	57.162	0.900	48.590
7	Eskimos	1.295	47.008	0.079	59.167	0.193	55.266	1.023	48.033
8	Swimmer	1.390	46.701	0.036	62.552	0.183	55.508	1.171	47.446
9	Water_lilies	1.472	46.451	0.111	57.668	0.346	52.736	1.015	48.067
10	Winter	1.765	45.663	0.200	55.126	0.492	51.215	1.074	47.821
11	Blue_hills	3.865	42.259	0.106	57.894	0.305	53.283	3.454	42.747

It is clearly visible from table 3. above that MSE and PSNR value of stego images are really good for images as a whole as well as for

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individual planes. It may be noticed that MSE and PSNR values for blue plane are little bit disappointing as compared to red and green plane values. This may be tolerated as human eyes are less sensitive to blue color as compared to red and green colors.

After inserting the secret message in each channel we have also improved the stego image by applying the 2^k correction to data carrier channel of the pixel (where k is no of bits replaced by secret data) as suggested by Jae-Gil-Yu [40]. But here it was only limited to gray scale images. We have extended to the 2k correction for RGB images and retrieved the unmatched results towards positive side in terms of PSNR value. The graphs for proposed method with and without 2k correction are given below in figure 7 and 8 which itself reflects about the strength of 2k correction.

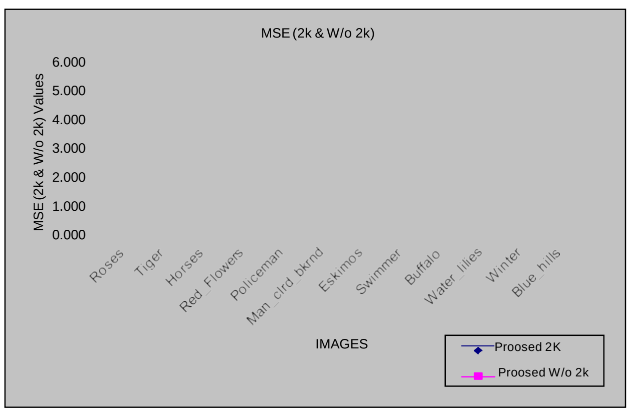

Figure 7: Comparison of MSE values of Images with and without 2k correction

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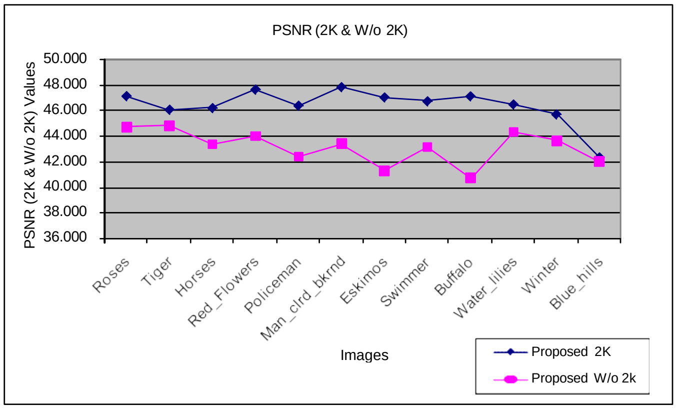

Figure 8: Comparison of PSNR values of Images with and without 2k correction

It can be noticed that 2k correction has really improved the values of MSE and PSNR almost for every image and that too with good amount of difference. So, implementing 2k correction in RGB images seems to be successful. Further, secret data may be retrieved without using saliency map at the receiving end. It is so because an indication has been embedded in the reflector channel which will guide the user towards secret data bits in the pixels of the image. As the proposed scheme is using pseudo random number generator using same seed (shared private key) at embedding as well as retrieving ends, so random number generator will decide the same reflector channel in each pixel at both the ends. In this way retrieving of secret data bits will be very much accurate at receiving end. In our experiments the accuracy in retrieving secret bits at receiving end is almost 100%.

6 CONCLUSION

In this work we have designed an implemented an algorithm for computing the saliency for RGB images. It has been shown that this saliency map is really better as compared to state of art methods based upon parameters of precision, Recall etc. Further proposed algorithm is used for steganography in which saliency map is taken as representative for Human visual system and based upon this model (saliency map) data is hidden in image proportionately in salient and non salient regions. Finally algorithm is checked for MSE and PSNR values which really show promising results. Also 2k correction is applied to stego images to improve the visual results. These MSE and P SNR values are also checked for individual planes of RGB image. The results are good for red and green planes but some what discouraging for Blue plane which can be justified with well known fact that only 2 % cones of Human eye are sensitive to Blue color so this much tolerance can be accommodated.

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