A Novel Technique for Data Embedding Using Visual Saliency Map

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Abstract --- *Steganography is a technique in which secret message is hidden in some media like image file, audio file or video file. The objective of the steganography is to prevent the unauthorized user to estimate that certain secret communication is going on by concealing the very existence of secret message. As it is clear this thing involves deceiving the human visual system (HVS) to get an impression that some secret message is hidden in image or some other media file. Saliency model is one of the methods that generate a map corresponding to the attention region of Human Visual System. So Human Visual System (HVS) is a point of interconnection between two concepts –*

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Steganography and Saliency Map. In this work we represent a method for data hiding in images based on saliency map.

Keywords: - Saliency Map, Wavelet Domain, Model Based Steganography, imperceptibility

1. Introduction

1.1 Steganography

The word steganography means "covered or hidden writing" [1]. The object of steganography is to send a message through some innocuous carrier to a receiver while preventing anyone else from knowing that a message is being sent at all. Computer based stenography allows changes to be made to digital carriers such as images or sounds. The changes represent the hidden message, but result if successful makes no discernible change to the carrier. The information may be nothing to do with the carrier sound or image or it might be information about the carrier such as the author or a digital watermark or fingerprint [1, 2, 3].

Cryptography and steganography are different. Cryptographic techniques can be used to scramble a message so that if it is discovered it cannot be read. If a cryptographic message is discovered it is generally known to be a piece of hidden information (anyone intercepting it will be suspicious) but it is scrambled so that it is difficult or impossible to understand and de-code. Steganography hides the very existence of a message so that if successful it generally attracts no suspicion at al [4]. Using steganography, information can be hidden in carriers such as images, audio files, text files, videos and data transmissions [1, 2, 3]. When the message is hidden in the carrier a stego-carrier is formed for example a stego image. Hopefully it will be perceived to be as close as possible to the original carrier or cover image by the human senses. Images are the most widespread carrier medium [5].

1.2 Saliency Map

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. The human retina possesses a non-uniform spatial resolution of photoreceptors, with highest density on that part of the retina aligned with the visual axis (the fovea), and the resolution around the fovea decreases logarithmically with eccentricity [6]. What's more, research results show that observers' scan paths are similar, and predictable to some extent [6]. These research results provide a new pathway to encode images based on human visual characteristics which will allow us to only encode a small number of well selected interesting regions (attention regions) with high priority to keep a high subjective quality, while treating less interesting regions with low priority to save bits. Recently, many subjective-quality-based image coding methods have been developed. 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 [7], [8], it is reasonable to consider that human faces may likely constitute interesting regions. (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.

2. Literature Review

2.1 Steganography

One of the commonly used techniques 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. Another technique is the Stego Color Cycle (SCC). This SCC technique uses the RGB images to hide the data in different channels. That is, it keeps cycling the hidden data between the Red, Green and Blue channels, utilizing one channel at a cycle time. The main problem of this technique is that, hiding the data in the channels is done in a systematic way. So, being able to discover the data in the first few pixels will make the discovery of the technique easy. StegoPRNG is also a different technique that uses the RGB images. However in this technique, a pseudo random number generator (PRNG) is used to select some pixels of the cover image. Then, the secret will be hided in the Blue channel of the selected pixels. Again this technique has the problem of managing the key, and problem of capacity since it uses only the Blue channel out of the three channels of their available channels [6].

2.2 Saliency Map

The term saliency was used by Tsotsos et al. [14] and Olshausen et al. [13] in their work on visual attention, and by Itti et al. [9] in their work on rapid scene analysis. Saliency has also been referred to as visual attention [37, 10], unpredictability, rarity, or surprise [11, 12]. Saliency estimation methods can broadly be classified as biologically based, purely computational, or a combination. In general, all methods employ a low-level approach by determining contrast of image regions relative to their surroundings, using one or more features of intensity, color, and orientation. In general, bottom-up VS models extract feature information by means of contrast representation be it for color, intensity, orientation, or any other low-level feature. This contrast representation is performed by obtaining the difference of a region in the image relative to their surroundings. Theoretically, this method of obtaining the contrast is akin to the center surround process in the human eye. In the biological category one of the reputable works is by Itti and Koch [9] whose method was based upon biologically plausible architecture proposed by Koch and Ullman [16]. They determine center-surround contrast using a Difference of Gaussians (DoG) approach. Frintrop et al. [15] 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 VS 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 [10, 17, 18]. The contrast images obtained in the works of [10, 17, 18] 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. [19] create feature maps using Itti's method but perform their normalization using a graph based approach.

Other methods use a computational approach like maximization of information [20] that represents a biologically plausible model of saliency detection Some algorithms detect saliency over multiple scales [9, 21], while others operate on a single scale [10, 22]. Also, individual feature maps are created separately and then combined to obtain the final saliency map [23, 10, 22, 15], or a feature combined saliency map is directly obtained [20, 21].

Recently, there is a trend to model VS computationally in the frequency domain [24, 25]. In the works of Hou and Zhang [24], 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 [25], 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 [25], 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. In their method, the original image is first smoothed using a 3-by-3 Gaussian filter to eliminate the high frequency content in the image. Then, the mean of the smoothed image is computed. Finally, the saliency map is obtained by the subtracting each pixel value of the original image from the computed mean.

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 [25] 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. [26] 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 & finer details. But sometimes some important information may be present in these detail components. To solve this problem we have proposed a 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.

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 lab so as to make it device independent. Also the L component distinguishes the intensity or luminance 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:

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

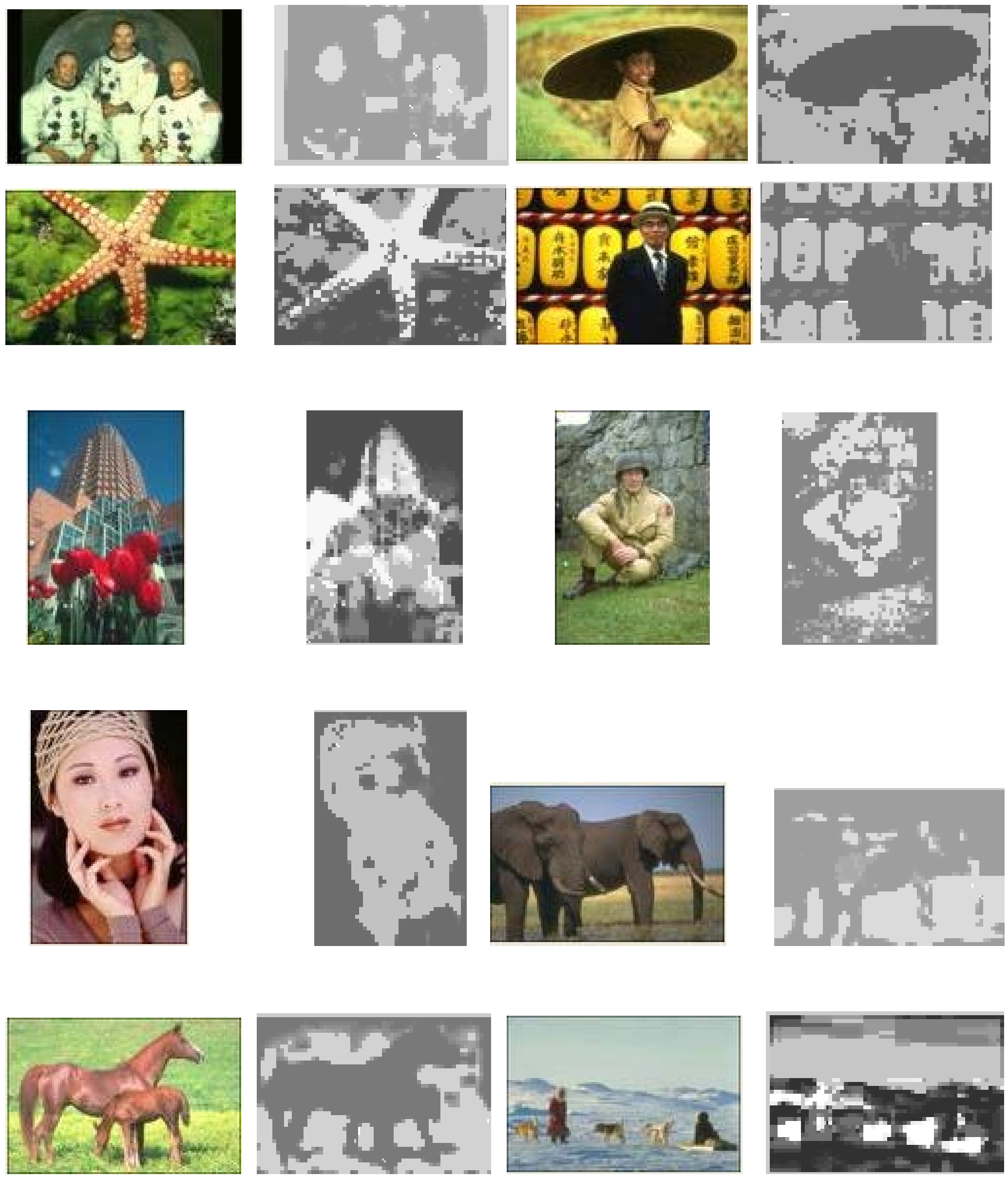
Where l_{μ} is the mean of LL component of L image of L, a, b component images & l_{μ}(x, y) is the mean intensity of all pixels of LL component of L sub-image similarly 12 contrast images will be calculated for four sub-bands of each component image of Lab color space. Then inverse DWT operation will 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:

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

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

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

The Results of saliency map for various images are shown below in Fig. 1:



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

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

4. Mapping Between Proposed Saliency Map Model and Steganography

One of the major forms of steganography is model based steganography or statistical aware steganography which is based upon some mathematical model. Basically it is an extension of spatial or frequency domain steganography. Actually after calculating some mathematical model related to cover image which represents the various statistics of image we hide the secret data based upon this mathematical model. Besides one of the main objectives of steganography is imperceptibility that is human eye should not be able to detect that certain kind of hidden communication is going on. In other words we have to deceive the human visual system (HVS). This concept indicates that we need certain mathematical model that somehow represents the human visual system (HVS). Saliency map is one of the solutions for this model. So we are using saliency map as model for model based steganography.

As it is clear from the calculation of saliency map that the points in the original image having more deviating values from their mean (or the points that are having more deviating values as compared to their neighbors) will be assigned higher values in the saliency map. On the other hand points in the original image having values near to the mean will be assigned lesser values in the saliency map. It is so because human visual system is more sensitive to variations (like edges) & less sensitive to the constant areas. The saliency map will assign high intensity values to sensitive areas & less intensity values to non sensitive areas in context with human visual system.

4.1 Secret Data Insertion Methodology

Now this saliency map will be used as model for hiding secret bits of data in the image. Based on the saliency map we will assign higher number of bits to the points having lesser values in saliency map & lesser number of bits to the points having higher values in saliency map. For this we have divided the whole range of saliency map values [0-255] in various equivalence classes. For each class we have decided the number of secret bits to be inserted in the pixels lies in that class. A general equivalence class table representing the equivalence class & the corresponding number of secret bits that may be inserted has been drawn as shown in table 1 below. After this cover image has been scanned from left to right & top to bottom. For each pixel the value of the corresponding pixel value in saliency map has been checked. & the equivalence class corresponding to saliency map value of pixel has been located in the equivalence class table. The corresponding number of secret bits in the table has been read & these many secret bits from secret data have been divided among the 3 channels of RGB. 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 & 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).

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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 $< x_1$	m_1
2.	x_1 to $< x_2$	m_2
3.	x_2 to $< x_3$	m_3
…………	…………	…………
…………	…………..	…………
n	x_{n-1} to 255	m_n

where x_1, x_2……….x_n are some numbers in between 0 & 255

m_1, m_2…..m_n are number of secret bits but $m_1 > m_2 >$…….. $> m_{ns}$

5. Results and discussion

We have implemented the above methodology in Matlab 7.0. We have used more than 15 sets of images of various sizes & resolution for experiment purposes. The visual results of some of the images are shown below in Fig. 2**:**

Cover Image

Stego Image

Cover Image

Stego Image

Cover Image

Stego Image

Cover Image

Stego Image

Cover Image **Stego Image**

Cover Image **Stego Image**

(a) **(b)**

Fig. 2 Column (a) are original cover images & column (b) are their corresponding stego images

Table 2. MSE & PSNR Values after Insertion

Sr.No	Image	Resolution	MSE	PSNR
1.	Star	120 X 80	3.702	42.447
2.	Man with colored background	120 X 80	2.992	43.371
3.	Eskimos	120 X 80	4.877	41.250
4.	Swimmer	120 X 80	2.653	43.093
5.	Deer	120 X 80	3.478	42.718
6.	Beach Scene	120 X 80	2.629	43.933
7.	Winter	800 X 600	2.842	43.595
8.	Water lilies	800 X 600	2.413	44.305
9.	Boy with hat	120 X 80	2.796	43.666
10.	Elephants	120 X 80	2.744	43.747

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We have analyzed the images for MSE & PSNR parameters which are the direct representatives of imperceptibility factor of steganography. The values for these parameters are given below:

As we can see from the table 2 above that we are getting an average MSE 2.8 & PSNR of 42 for all the images which clearly indicate that our method is really good on the parameter of imperceptibility.

Table 3. Bits per Pixel & Capacity of Various Images

Sr. No	**Image**	**Bits per pixel (BPP)**	**Percentage capacity**
1.	Star	1.574	6.557
2.	Man with colored background	1.449	6.036
3.	Eskimos	1.530	6.377
4.	Swimmer	2.241	9.339
5.	Deer	1.451	6.046
6.	Beach Scene	2.550	10.626
7.	Winter	3.668	15.286
8.	Water lilies	2.828	11.783
9.	Boy with hat	2.052	8.550
10.	Elephants	1.813	7.553

It can be analyzed from table 3 that our method can accommodate 2.25 bits per pixel on average varying from 1.45 to 3.66 bits per pixel. This leads to average percentage capacity of proposed technique to 8 .5% which is really good. If we will compare the proposed technique with 1 LSB or 2 LSB then our capacity seems to be good but our MSE & PSNR is excellent in comparison to any of the state of the art methods.

Table 4. TPR & FPR results for various Images

Sr. No	Image	Size	TPR	FPR
1	Star	120 X 80	0.5627	0.4109
2	Bridge	80 X 120	0.5869	0.4556
3	Fireman	120 X 80	0.5606	0.4944
4	Roses	80 X 120	0.6087	0.4109
5	Scene	120 X 80	0.6853	0.53
6	Elephants	120 X 80	0.6947	0.6828
7	Horses	120 X 80	0.5971	0.6634
8	Red_Flowers	120 X 80	0.5961	0.4377
9	Man_clrd_bkrnd	120 X 80	0.5833	0.6314
10	Deer	120 X 80	0.7176	0.6402
11	Eskimos	120 X 80	0.46	0.5712
12	Beach_scene	120 X 80	0.5401	0.5599
13	Swimmer	120 X 80	0.6429	0.5499
14	Lady	80 X 120	0.648	0.473
15	Boy_hat	120 X 80	0.5638	0.6141
16	Houses	120 X 80	0.6129	0.5007
17	Astronaut	120 X 80	0.6718	0.7305
18	Priest	120 X 80	0.5472	0.6084
19	Water_lilies	800 X 600	0.5717	0.4207
20	Winter	800 X 600	0.733	0.4079
21	Blue_hills	800 X 600	0.5895	0.6019

	AVERAGE		**0.6249654**	**0.566608**

Evaluating the performance of steganography method only is not sufficient to judge the proposed technique. Rather one should also evaluate the saliency map calculated on some parameter. So an important parameter receiver operating characteristics (ROC) curve has been chosen and proposed technique has been evaluated. This curve is representative of the effectiveness or accuracy of the method taking TPR (True Positive Rate) and FPR (False Positive Rate) as base for measurement. TPR represents the part which is rightly detected as salient part whereas FPR represents the part which is wrongly detected as salient part. Values for TPR & FPR calculated on some of the images have been summarized in Table 4 above. In the graphs below TPR values are taken at y-axis and FPR values are taken at x-axis. Then the points where TPR value coincides with FPR value of respective images are marked in space. It is considered that if most of the values are above the diagonal line (x=y, 45o) then the method is effective in marking the true salient region. On the other hand if most of the values are below diagonal line then method is considered not to be effective in marking the right salient region. For effective analysis, in addition to proposed technique ROC curve has been designed for waveieee method and frequency tuned method. ROC for proposed method & two other state-of-art techniques is shown below:

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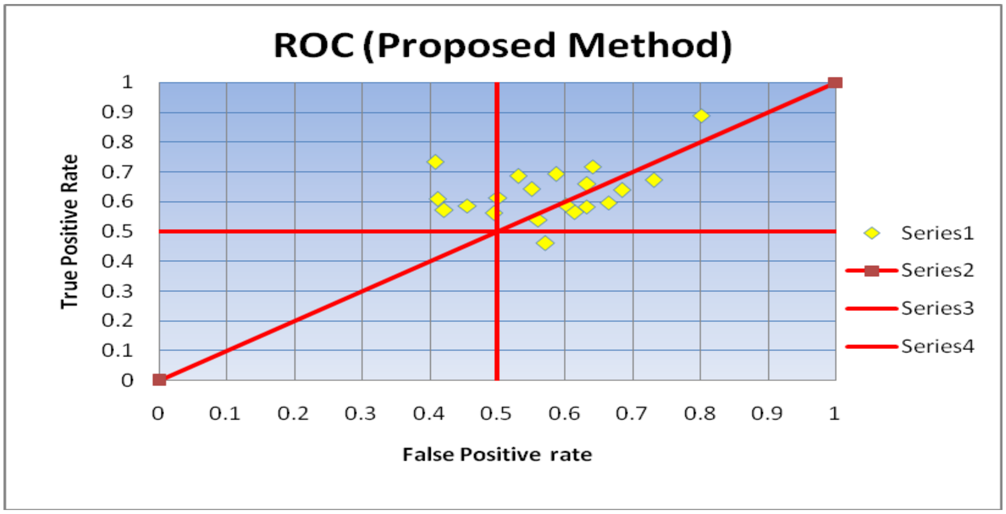

Fig 3: ROC for proposed method

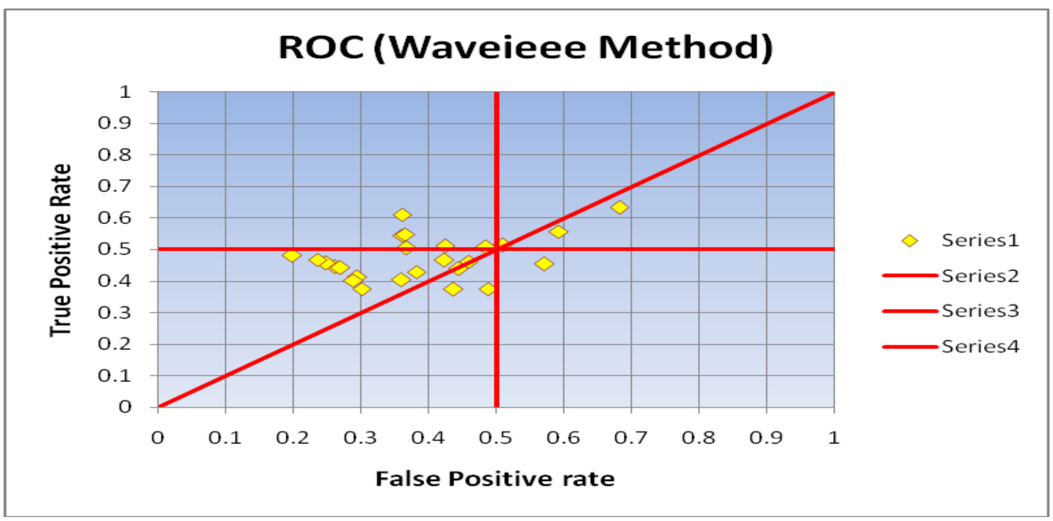

Fig 4: ROC for waveieee method [4]

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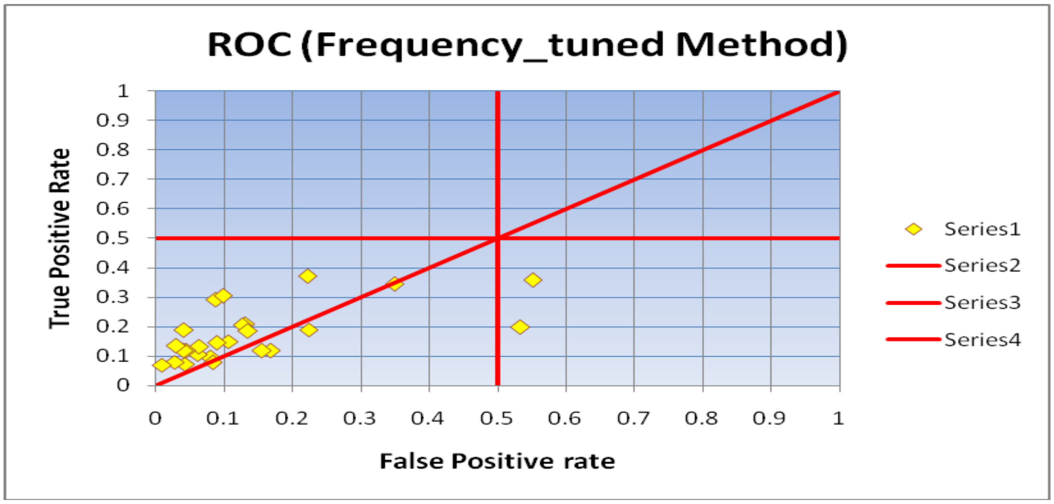

Fig 5: ROC for Frequency-tuned method [3]

It may be seen from figure 3, 4 and 5 above that about 66% values in all the three methods are above the diagonal line. It indicates that the methods are effective in locating the right salient regions in 2/3 of the cases which is acceptable. But using only the diagonal line does not concludes about the fact that which method is more effective. To deal with the problem another alternative has been proposed. In this work ROC has been divided into four quadrants. The quadrants have been numbered I, II, III and IV starting from top left in clock-wise fashion. Now it is proposed that the ranking may be given to different quadrants. Quadrant I has been given rank 1, as it is having high values for TPR and low values for FPR which is most desirable. Quadrant III has been given rank 4 as it is having low values for TPR and high values for FPR which is most undesirable. Quadrant II has been given rank 2 as although it is having high values of FPR but also having high values for TPR. Quadrant

IV has been given rank 3as it is having low values for FPR as well as for TPR. Low TPR values means it is not performing whereas high values for both TPR and FPR means the method is performing good but with high error rate which is the case with quadrant II.

According to above theory it may be seen in figure 3 above that for waveieee method [26] most of the values lies in the quadrant IV (rank 3) and very few values lies in (quadrant I, II and IV) which is not good sign for the performance of the method. Similarly in figure 4 above for frequency-tuned method [25] it may be seen that all of the values lies in the quadrant IV (rank 3) and quadrant II (rank 4) which clearly indicates the algorithm is not effective. On the other hand, if one takes a look upon the figure 2 above for proposed method it may be noticed that most of the values lies in quadrant I and II (rank 1 and 2 respectively). This clearly indicates that proposed method is much more effective than state-of-art methods for locating the correct salient regions.

6. Conclusions

In this paper an effective method for computing saliency map has been proposed. The method has been evaluated on parameters like precision, recall, F-measure, TPR, FPR and ROC. It has been found that proposed method is performing well for almost all the parameters. Further a ROC based evaluation technique has been proposed which evaluates the technique for its effectives based upon the quadrant in which most of the ROC values lies. In this evaluation technique proposed method clearly outshined the state-of-art techniques. In future the proposed saliency may be used for multiple applications like image segmentation, image summarization, image registration etc.

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