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Image Watermarking Framework using Histogram Equalization and Visual Saliency

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ABSTRACT

This paper proposes a digital image watermarking strategy using histogram equalization and visual Saliency followed by LSB (Least Significant Bit) replacement for better imperceptibility with hiding capacity. With this technique, a saliency map determines lesser-observable parts of the original image and gradually implants with increasing amounts of information based on histogram equalization information. The output from saliency is the perceptible areas within an image, which is the most notable position from the perspective of vision; as a result, any changes made other than those areas will be less noticeable to viewers. Implementing the histogram method helps identify the areas where we can hide our secret information within that image. Using the LSB replacement technique, we adaptively insert our confidential data into the original image. Here, we use the saliency map to find out the non-salient region or less perceptible region to improve the imperceptibility, and the histogram equalization technique is used to maximize the hiding capacity within those less perceptible regions. So that we can improve the imperceptibility as well as the hiding capacity.

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1. INTRODUCTION

Nowadays, digital watermarking plays a vital role for researchers in copyright protection [1, 2]. In watermarking, information is concealed inside an object so that it may taken out later to identify the owner of that object [3, 4]. Despite this, there are tradeoffs between watermarking's primary goals of robustness, imperceptibility, and hiding ability. This makes watermarking a relatively unexplored area of study.

The concept behind this suggested work is a digital watermarking approach based on histogram equalization and visual saliency. In this approach, the saliency map identifies the less observant areas of an image where we can hide our secret information. Here, the priority is data concealment in locations with low imperceptibility [5, 6].

The proposed work uses the most extensive range of pixel values, discovered using histogram equalization to enhance the hiding capacity. Histogram equalization is accomplished by adequately widening an image's intensity range and evenly distributing its most prevalent intensity levels. It can facilitate reliable information extraction from the augmented images for people and machine vision algorithms. When close contrast values express valuable information, this approach frequently enhances the overall contrast of the images. The watermark's components are inserted in at least a significant image area to increase the degree of imperceptibility [7, 8]. At various points in the original image, the proposed technique inserts the data to improve the data's hiding capacity and robustness. The adaptive least significant bit (LSB) substitution approach is employed to obscure the watermark in the original image. Inserting information into a cover image can be very simple by using the LSB approach. With portions of the hidden message, the LSB approach involves changing the pixels of an original image. In our proposed method, saliency determines the number of bits placed inside the cover image, and the LSB replacement method is employed to insert the bits into the original image, which will make the human sight system unable to detect these alterations. [9-11].

The following sections divide the remainder of this

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paper: related work and a discussion of the insertion and extraction processes for watermarks. The next section presents the result analysis, and the final section concludes the paper.

2. RELATED WORK

The execution of the digital image watermarking approach can be possible for both the spatial and frequency domains. However, spatial domain approaches offer convenience by providing lesser processing complexity, improved perceptual quality, and greater hiding capacity, whereas frequency domain techniques are more robust. Here, we present a spatial-domain watermarking approach with the help of histograms and saliency. In this part, we summarize some related works based on saliency and histogram approaches with LSB replacement techniques. Finding the strengths and weaknesses of a few existing works is the primary purpose of this section.

A technique based on the human visual system is proposed by Kundur and Hatzinakos [12] using multi-resolution fusion methods. It is a non-blind watermarking method that resists the degrading effects of additive noise, JPEG compression, and linear filtering on images. With the help of texture blocks and edge detection, the authors proposed a new digital image watermarking system in the DWT [13]. This approach can increase the digital image watermark's resistance to attacks. Khoo et al. [14] devised a resilient picture watermarking technique using the human visual system (HVS) and employed edge entropy as an HVS character to choose relevant regions to encode a binary watermark. Following the first stage of the DWT decomposition, the low-frequency sub-band is subjected to SVD to adjust the components of the U matrix following predetermined conditions. For the watermark embedding process, selecting appropriate transform algorithms is the second alternative strategy used to improve the performance of the watermarking system. There are many suggested and published watermarking schemes that employ various transformation techniques. Many watermarking applications use SVD because of its benefits [15, 16].Visual Saliency is a technique that helps us manage the information overload in our visual field by removing redundant information. The saliency map identifies the portion of an image with rich information that has given remarkable results to several signal processing methods. In the spatial domain, X. Hou et al. first retrieved the spectral residual from a picture by applying log-spectrum analysis before producing the relevant Saliency Map [17]. These are primarily various methods for determining an image's maximal rich-information area. These maps have recently been combined with digital watermarking ideas to determine the best places to implant a particular watermark. A watermark approach based on semi-blind integrated visual Saliency was proposed by L. Tian et al. [18] through the use of the discrete cosine transform (DCT) and Quantization Index Modulation (QIM). The extracted watermark has shallow correlation values against generic attacks despite the marked image having strong PSNR values. Histogram equalization is a quick and efficient method for improving contrast, which equalizes pixel values due to which it can not maintain the image's brightness. Numerous HE-based strategies address these drawbacks and improve contrast enhancement and brightness preservation. Brightness-preserving bi-histogram equalization (BBHE), the first Mean-Based Separation technique introduced by Kim[19] in 1997, enhances contrast while maintaining an image's mean brightness. It has demonstrated better outcomes than HE and somewhat accomplishes this. Dualistic Sub-Image Histogram Equalization (DSIHE), a publication by Wang et al. that is equivalent to BBHE, was presented in 1999 [20]. However, this approach demonstrated superior brightness preservation over BBHE and HE since it employed a median value rather than a means to split the input histogram. The best processing method to properly improve the image information while maintaining the original image brightness is called DSIHE. However, the photos that need a better level of brightness preservation to prevent irritating artifacts, BBHE and DSIHE, are not very appropriate.So, to preserve more, in 2003 [21, 22], Chen and Ramli introduced the Minimum Mean Brightness Error. Separation according to a threshold level and the extended version of BBHE, known as Bi-Histogram Equalization (MMBEBHE), would produce the least Absolute Mean Brightness Error (AMBE). This technique's primary objective is to enable maximal brightness conservation in Bi-Histogram Equalization to prevent undesirable artifacts and unusual enhancement caused by excessive equalization. Another goal of the study is a successful, recursive, and integer-based approach to approximating the output means as a function of threshold level. This technique divides the original image into numerous sub-images using the multi-histogram equalization approach, and each sub-histogram is then subjected to the conventional histogram equalization procedure to enhance contrast, increase brightness, and improve the original appearance of the images. Although Multi-HE approaches do not significantly increase contrast, they retain image brightness and stop the introduction of unwanted artifacts. In 2008, Abdullah-Al-Wadud et al. proposed a novel method called Spatially Controlled Histogram Equalization (SCHE), a HE-based picture contrast enhancement that takes over the functionality of conventional HE. This method uses properties of the cover image histogram and the spatial information of the pixels' surrounding areas to determine the level of control automatically. This approach can also significantly improve images without sacrificing delicate detail information or having negative consequences like blocking effects or unwanted artifacts [23]. Digital images allow for the direct insertion of information through every pixel or the careful calculation of the busier sections of an image to conceal such messages in less noticeable locations [24, 25]. Tirkel et al. came up with one of the first methods for image watermarking [26]. They provided two methods for concealing information in the spatial area of images. These techniques relied on adjustments to the pixel value's Least Significant Bit (LSB). Hao Luo et al. developed a digital image watermarking system with self-embedding [27]. They included a watermark made from the cover image in their suggested method. It creates a watermark by converting the original image into a grayscale image. The watermark is then altered and integrated into the host image's LSB. This technique searches the suspect image's LSB for the watermark, which is reverse-permuted.

It has been observed from the study that the three watermarking parameters used to evaluate the watermarking algorithm are imperceptibility, Robustness, and hiding capacity. However, balancing between these three parameters is very difficult, as increasing one factor affects the other. In this paper, we have tried to improve imperceptibility and hiding capacity by employing saliency map and histogram techniques, where saliency improves imperceptibility and histogram equalization finds the maximum hiding location within the image.

3. PROPOSED WORK

This section explains the details of the watermarking technique. The main objective of this proposed work is to strengthen the watermark. This proposed work uses the saliency method to identify the prominent points in an image, which helps reduce imperceptibility. A histogram equalization method is employed to enhance the hiding capacity of the image, which determines the hidden locations inside the images. Finally, the LSB replacement technique inserts information into the cover images.

3.1 Saliency Detection:

The term "salient" refers to a feature of an object that distinguishes it from its neighbors. A saliency map is an analytical tool that may estimate the significance of each pixel. Finding local occurrences in images is the purpose of salient feature detection. It typically uses the local differential structure of images to determine salient features. They emphasize the saliency of the surrounding area. Van.De.Weijer[28] suggested the salient region detection method used in the proposed algorithm.

Salient points are the peaks of the saliency map for an image 'P',which establish the neighborhood's derivative vectors, determined by scale.

$$s = H^{\sigma}(P_x, P_y) \quad (1)$$

In the above equation, the subscript denotes the difference with respect to the parameter, and 'H' is the saliency function. P_x and P_y indicate the information contained in an image.The vector norm 'P_x'of a derivative vector determines its influence on the local salience outcome. Thus, vectors with the same norm equally affect the local saliency.
According to the information theory, the information content of an event depends on its frequency or probability. So the relationship between the information content and its likelihood given by,

$$C(v) = -\log(u(v)) \quad (2)$$

Where'v' stands for the information content / self-information and '$u(v)$' represents the probability of the descriptor of 'v'.
If it uses the first-order derivatives and zeroth-order signal's independent probability to approximate the content, then

$$u(v) = u(P)u(P_x)u(P_y) \quad (3)$$

The probability of the derivatives '$u(P_x)$' must be less to enhance the salient point detector's information content, as indicated in Eq.1.
The goal is to obtain the transformation $h : R3 \rightarrow R3$, which provides that

$$U(p_x) = u(p'_x) \longleftrightarrow \|h(p_x)\| = \|h(p'_x)\| \quad (4)$$

In the above equation, h is defined by saliency boosting function
Finally saliency map can calculated from eq. (4) is

$$s = H^{\sigma}(h(P_x), h(P_y)) \quad (5)$$

Where 's' is, the saliency Function.
The saliency map may be categorized into multiple types based on their properties and the technique used to compute them. The popular categories are given below,

Gradient-based saliency is concerned with finding image sections with substantial intensity changes or edges. It determines saliency by detecting the gradient magnitude, or the difference in intensity, between neighboring pixels. It considers the Regions with more significant gradients or edges more prominent[45].

Fine-grained saliency: It aims to capture minor nuances and local differences in a picture. It goes beyond edge detection and considers fine-scale features like texture, patterns, and local contrast. This technique can find prominent areas that gradient-based algorithms may miss by considering fine-grained data

[46].

Spectral residual saliency: To assess saliency, spectral residual saliency analyses an image's frequency content. It decomposes an image into frequency components using spectral analysis techniques such as the Fourier Transform. After eliminating the average spectrum, this technique utilizes the leftover spectrum to determine saliency. Regions with distinct spectral fingerprints or energy changes are thought to be more prominent[47].

Center-Surround Saliency: The human visual system's receptive fields inspired center-surround saliency. It calculates saliency by examining the contrast between a central location and its surroundings. The center region is usually tiny and focuses on the focal object or location of interest, while the surrounding background is a point of comparison. Parts with a more significant difference between the center and the surrounding area are thought to be more salient[48].

We have used spectral residual saliency in our proposed approach as it provides better results than other saliency methods. We have compared the proposed method to a few existing saliency techniques.

Table 1: *Comparison of Different Saliency Method.*

Different Saliency Method	Capacity for Camera man	Capacity for Leena	Capacity for Pepper
Proposed technique	1.47	1.1	1.01
Gradient-based saliency	1.39	1.09	1.00
Fine-grained saliency	1.28	0.97	0.89
Center-Surround Saliency	0.63	0.92	0.77

3.2 Histogram Equalization

The graphic depiction of pixels in an image is called a histogram. It can be characterized as a data model that records each frequency of the pixel intensity levels in the image. The technique used in this work to identify the histogram of an image is proposed by Wei-Yen Hsu1, Ching-Yao Chou [29], where a color image is first transformed to grayscale to compute the grayscale histogram equalization by calculating the cumulative distribution function (CDF) and probability density function (PDF). The PDF value is determined as:

$$t(i) = a_i \diagup a, i = 0, 1, \dots \ E - 1 \quad (6)$$

In the above equation, 'E' stands for the amount of grayscales in the image, 'a_i' represent how many times occurs in the image, 'a'represent the overall pixels for image, and 't' for the likelihood that a pixel will appear. The image's CDF value was then determined to be:

$$C(z) = \sum_{i=0}^{z} t(i), z = 0, 1, \dots \ E - 1 \quad (7)$$

In the above equation, 'C' represents the pixel's cumulative distribution function. Using the above computed CDF value, histogram equalization is carried out on the grayscale image.

3.3 Capacity Calculation

A capacity calculation map is produced based on the calculated saliency map. Here, to improve the hiding capacity and achieve better watermark invisibility, lower perceptible saliency regions of an image are chosen for better hiding area. The size of the saliency map's measurement is equal to the original grayscale image and is described as:

$$s = P(x, y); \ 0 \leq \ x < m, 0 \leq y < n \quad (8)$$

Where $p(m, n)\varepsilon(0, 1, \dots, 255)$
Let, 'C' represent the capacity calculation Map and is determined as

$$\begin{aligned} C = I(x, y); o \leq x < m, 0 \leq y < n; \text{Where} \\ I(x, y) = 0 \text{ if } s = 0, I(x, y) = K \\ \text{If } 0 < s \leq \ E, I(x, y) = Z \\ \text{If } E < s \leq \ F, I(x, y) = Q \\ \text{If } F < s \leq \ G, I(x, y) = R \end{aligned} \quad (9)$$

$$\text{If } G < s \leq j, I(x, y) = 255 \text{ if } j < s \leq 255$$

Where 'E','F' and 'G' are the hiding parameters from saliency. It calculates the hiding bits based on those parameters and inserts watermark information.

With the help of the above capacity map, the watermark 'W'is placed in the original image utilizing the LSB replacement method.

3.4 Encoder and Decoder

Let the original grayscale cover image is denoted as 'I' with the dimensions '$m \times n$'and is shown as

$$\text{I=P(x,y)}, 0 \leq x < m, 0 \leq y < n, \ P(x, y)\varepsilon(0, 1, \dots 255) \quad (10)$$

Let 'W' be the original grayscale watermark with size of '$i \times j$' and characterized

$$\text{W=Q(x,y)}, 0 \leq x < i, 0 \leq y < j, \ Q(x, y)\varepsilon(0, 1, \dots 255) \quad (11)$$

'D_b' is the function to transform from Decimal data into Binary form and 'B_d' is the function to transform from Binary data into Decimal form. The adaptive LSB replacement watermarking is described as functions $(f_{enc}, f_{dec})u$

$$D_b\{I\} = \beta I \tag{12}$$
$$D_b\{W\} = \gamma W \tag{13}$$

Using the adaptive LSB replacement technique [30, 31], the watermark is placed into the original image several times following the capacity calculation map. Watermark embedding and Extraction are defined as:

$$\mathrm{F}_{enc} = \sum_{x=0}^{m-1}\sum_{y=0}^{n-1} I(x,y).\ F(C, t(i), D_b, \gamma W, v, B_d) = I_w \tag{14}$$

Where 'I_w'is the watermarked version of the original image with the same size.
When the watermark is extracted, the same procedure is u sed, and it is described as:

$$\mathrm{F}_{dec} = \sum_{x=0}^{m-1}\sum_{y=0}^{n-1} I_w(x,y).\ F(C, t(i), D_b, \gamma W, v, B_d) = W_w \tag{15}$$

Where 'WE' is the Extracted Watermark.
In the above equations, the function of F_{enc}, F_{dec} are used for the Encoder and Decoder of the watermark images.

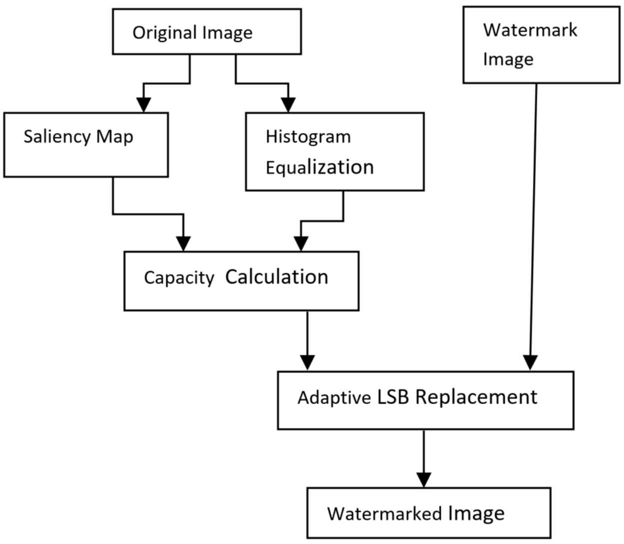

Fig.1: *Watermark Embedding.*

Figure 1 depicts the diagrammatical representation of inserting a watermark in an image. Figure 2 is the diagrammatical representation of the procedure of extracting the watermark from the watermarked image.
The watermark embedding and extraction operations utilize two test matrices, denoted by the watermark

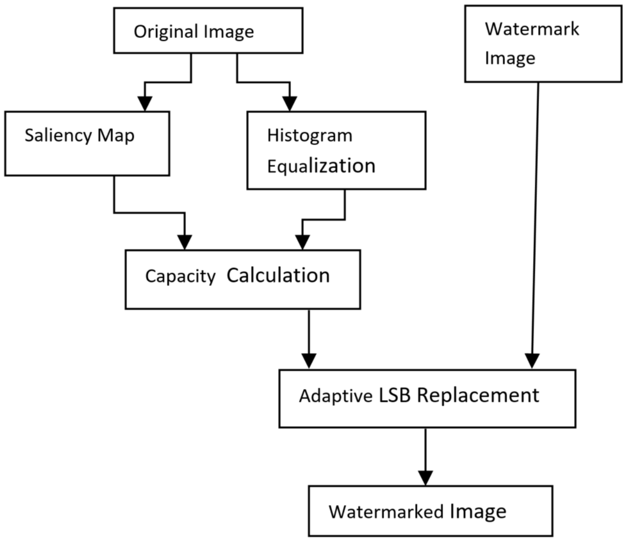

Fig.2: *Watermark Extracting.*

W and cover P. The saliency map is represented by S, Where the Histogram equalization of the image is characterized by H

$$\mathrm{P} = \begin{bmatrix} 178 & 150 & 179 & 167 & 89 \\ 174 & 164 & 174 & 188 & 55 \\ 157 & 156 & 164 & 164 & 66 \\ 158 & 151 & 163 & 33 & 38 \\ 104 & 174 & 123 & 164 & 55 \end{bmatrix} \quad \mathrm{W} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

Then, this proposed technique creates a saliency map S for P using the spectral equation (5) and the histogram equalization H for P using eq. (6) and (7). Using eq. (9), the hiding capacity map C for P is created based on the data-set values of S and H. In this case, the hiding capacity map has three unique values since Z, the maximum number of LSBs to be substituted from the most salient area, is set to four.

$$\mathrm{H} = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 3 & 4 & 3 & 1 & 2 \\ 1 & 1 & 4 & 4 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 3 & 1 & 4 & 2 \end{bmatrix} \quad \mathrm{S} = \begin{bmatrix} 23 & 45 & 57 & 214 & 67 \\ 39 & 64 & 93 & 15 & 82 \\ 45 & 65 & 102 & 18 & 97 \\ 75 & 206 & 92 & 109 & 134 \\ 79 & 44 & 124 & 234 & 215 \end{bmatrix}$$

$$\mathbf{C} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ 3 & 2 & 2 & 0 & 0 \\ 0 & 0 & 1 & 3 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 & 0 \end{bmatrix}$$

The matrices S and C show that the concealing capacity for pixels in P grows as the saliency map values for the associated pixels increase. As a result, the suggested approach calls for the last three, two, and one LSB(s) of the cover image pixels to be replaced by an instantaneous watermark bit, where the corresponding HCM values are 3, 2, and 1, respectively. As a result, the watermarked picture matrix F is created, as shown in eq. (14).

F =

178	150	179	167	89
175	164	172	188	55
157	156	165	164	66
158	151	163	33	38
104	174	123	164	55

When the watermark is extracted from the watermarked image F, this technique uses the saliency map S, Histogram equalization H, and hiding capacity map C of the original image. According to the hiding capacity of the original image, the last three, two, and one LSB(s) of the watermarked bits are extracted. Then, it performs an XOR operation between the extracted watermarked bit. Finally, extract the watermark image from our received watermarked image.

F =

178	150	179	167	89
175	164	172	188	55
157	156	165	164	66
158	151	163	33	38
104	174	123	164	55

$$W_x = \begin{bmatrix} 111 & 00 \\ 00 & 1 \end{bmatrix} \qquad W = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

4. RESULTAND ANALYSIS

The results of the suggested system are outlined in this part using the criteria of robustness, imperceptibility, and data concealment. Furthermore, the effectiveness of the proposed approach is determined using some state-of-the-art techniques.

Fig.3: *Grayscale Watermark.*

In the projected system, a series of familiar 256×256 grayscale images taken from the USC-SIPI standard image database[32], which consists of an extensive data set and one 20×20 grayscale watermark, is used to verify the effectiveness of the system. In our proposed approach, we experimented with all the images in the data set. But a few famous images have been displayed here that are globally accepted. In our proposed algorithm, first of all, we are trying to test the authenticity of our algorithm. Figure 3 and Figure 4 show the watermark image and the original images. In this paper, only five sample images are provided for simplicity of illustration and as proof of the correctness of the proposed method. Figure 5 provides the histogram of the original grayscale images to identify the high-range pixel value of each image to enhance the hiding capacity of the image. Figure 6 shows the saliency points discovered utilizing the method described in [28] to create the original grayscale image's saliency map.

In the original image, the data embedding ability for every pixel is determined using the saliency map and histogram equalization technique. It is shown

Fig.4: *Original Images.*

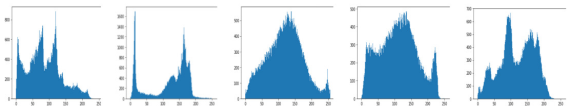

Fig.5: *Histogram of the Images.*

Fig.6: *Saliency Map of Original Images.*

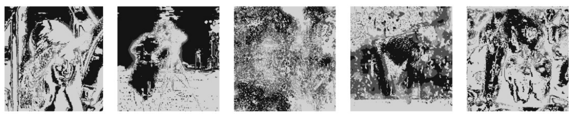

Fig.7: *Capacity Calculation Maps of Original Images.*

Fig.8: *Watermarked Images.*

in Figure- 7, where the hiding ability of an image is represented using four distinct grey colors. Finally, in Figure 8, we have illustrated the watermarked images. The capacity estimation is employed to insert the watermark into the original grayscale images using adaptive LSB replacement. The original image loses its quality due to the implantation, which is measured using various widely used quality metrics to determine the imperceptibility of the embedded watermarks. The original grayscale image and its respective watermarked image have been compared by utilizing a bar chart described below.

MSE- The MSE value represents the average difference between pixels throughout the picture. A higher MSE value indicates a more significant variation between the original and processed images.
It is represented as-

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} (X(i,j) - Y(i,j))^2$$

In the above equation, X denotes the original image's matrix data, and Y represents the degraded image's matrix data. m is the number of pixels rows in the picture, and i is the index of that row. n specifies the number of pixel columns in the picture, and j is the index of that column.

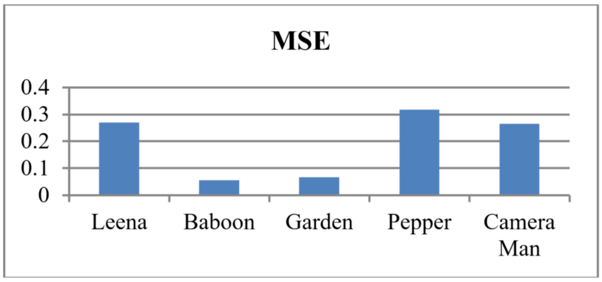

Fig.9: *Performance evaluation in terms of MSE.*

Figure 9 represents the suggested approach's MSE (Mean Square Error) value for different images. The above figure shows that the Mean Square Error provides a result range of 0.05 to 0.31, which supports a lower likelihood of quality loss and better results.

PSNR-Peak signal-to-noise ratio (PSNR) is the ratio between an image's highest conceivable power and the strength of corrupting noise that influences the quality of its representation. To calculate a picture's PSNR, compare it to an ideal clean image with the highest possible power. It can be defined as

$$PSNR = 10\log_{10}\frac{L^2}{MSE}$$

In the above equation L is the highest intensity level.

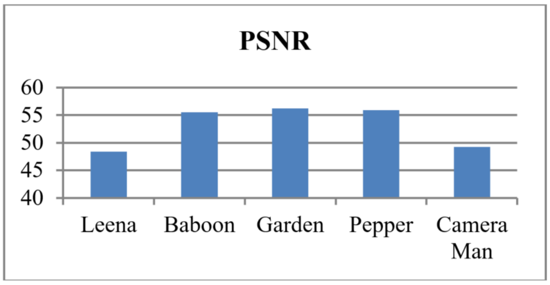

Fig.10: *Performance evaluation in terms of PSNR.*

Figure 10 provides the PSNR (Peak signal-to-noise ratio) value for different images in the proposed algorithm. The difference in PSNR between the original and watermarked images is between 49 and 56 dB, which indicates our method has attained a higher level of imperceptibility.

UIQI- The Universal Picture Quality Index (UIQI) assesses the distortion between the cover picture and its stego counterpart based on three factors: (i) luminance distortion, (ii) loss of correlation, and (iii) contrast distortion.

$$Q = \frac{4\sigma_{xy}\overline{xy}}{(\sigma_x^2+\sigma_y^2)[(\bar{x})^2+(\bar{y})^2]}$$

$$\bar{x}\frac{1}{N}\sum_{i=1}^{N} x_i, \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i$$

$$\sigma_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})^2,\ \sigma_y^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y_i-\bar{y})^2$$

$$\sigma_{xy} = \frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})(y_i-\bar{y})$$

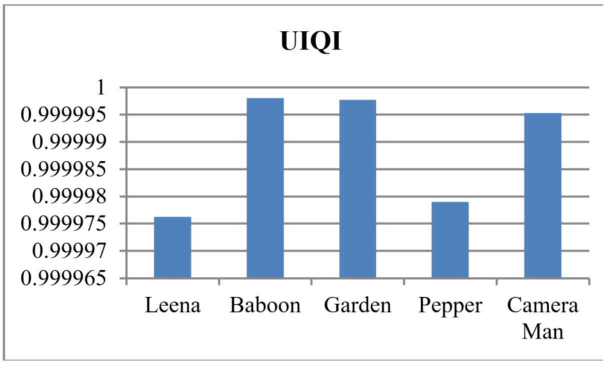

Fig.11: *Performance evaluation in terms of UIQI.*

Figure 11 represents the dissimilarity between the original and respective watermark images. From the above figure, all the values of the UIQI (Universal Image Quality Index) in the proposed method are near 1 (0.999976 to 0.999998), which shows the best result or the slightest difference between the original and watermark images.

SSIM: The (SSIM) is produced by normalizing the mean structural similarity value between the original and watermarked images.

These three terms can express it-

$$SSIM\ (x,y) = [l(x,y)]^{\alpha}.[c(x,y)]^{\beta}.[s(x,y)]^{\chi}$$

Where, $l(x,y) = \dfrac{2\mu_x\mu_y + C_1}{\mu_x^2+\mu_y^2+C_1}$

$$c(x,Y) = \frac{2\sigma_x\sigma_y + C_2}{\sigma_x^2+\sigma_y^2+C_2}$$

$$s(x,y) = \frac{\sigma_{xy}+C_3}{\sigma_x\sigma_y+C_3}$$

Where μ_x and μ_y are the local means, σ_x and σ_y are the standard deviations, σ_{xy} is the cross-covariance for images x and y sequentially, C_1 and C_2 are balancing constant.

The SSIM (Structural Similarity Index Measure) peaks at 1 for both the watermarked and the original images, and structural characteristics between both images are similar to normal. Figure 12 represents how closely the original image and each watermarked

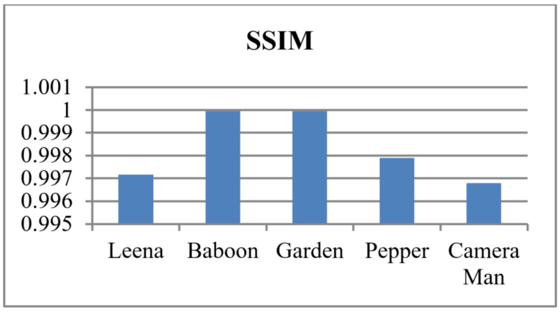

Fig.12: *Performance evaluation in terms of SSIM.*

image structurally resemble one another for the proposed technique. In all images, both values in the current scheme are getting close to one, representing the suggested approach's superiority.

The robustness of the suggested strategy with various intentional and unintentional attacks like Noise Addition, JPEG Compression, Rotation, Scaling, Translation, and others are evaluated. The proposed approach determines the result by assessing the value of widely used quality metrics such as Bit Error Rate (BER) and Normalized Cross-Correlation (NCC) using bar charts, which indicate the recovery of the inserted bits and the clarity of those bits against various types of signal impairments.

NCC: NC defines the degree of resemblance between the extracted and original watermarks, which is a critical metric for estimating the robustness of digital watermarks. The NC value ranges between 0 and 1; the closer the NC number is to 1, the more resilient the watermark. It expresses the computation as below-

$$r = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{N}(y_i - \bar{y})^2}}$$

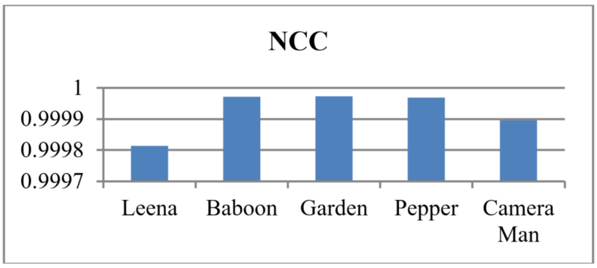

Fig.13: *Performance evaluation in terms of NCC.*

Usually, if the NCC value is equal to 0.75 or above, the system's robustness is at an appropriate standard [33]. Figure 13 presents the NCC value for the images. It indicates that the proposed algorithm gives a quality NCC result for all images greater than 0.75.

BER- BER is a typical assessment metric of watermarking resilience that reflects the ratio of the number of extracted erroneous watermark bits to the total number of implanted bits. BER has a value range of [0, 1], and the lower the value, the lower the watermark error rate.

$$BER = \frac{\sum_{m,n} |X(m,n) - Y(m,n)|}{M \times N}$$

Where X and Y represent the original Watermark and extracted watermark respectively.

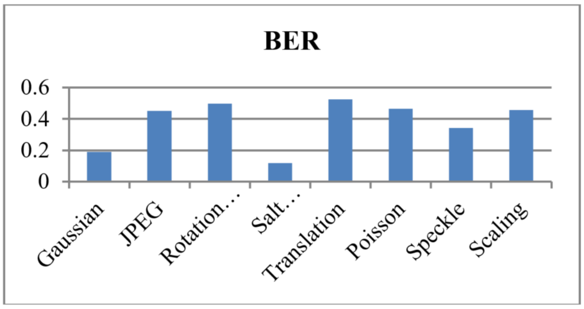

Fig.14: *Performance evaluation in terms of BER.*

Figure 14 offers the bit error rate for the proposed method, which varies from 0.11 to 0.52. The result indicates the proposed method provides a good result for different attacks on the watermarked image.

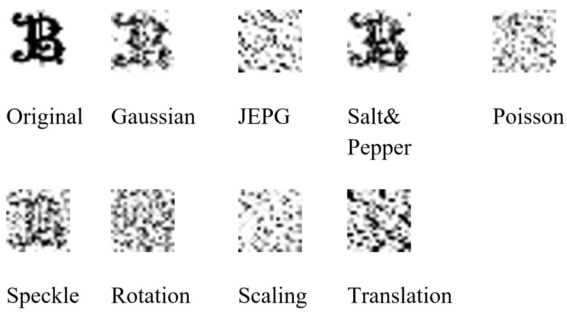

Fig.15: *Recovered Watermark After Different Attacks.*

Figure 15 delivers the decrypted watermarks recovered from various signal-processing attacks using the proposed method.

The suggested method contrasts prior methods with the average of five different images. Despite sharing a grayscale appearance, other algorithms do not use the same images. In order to compare all average outcomes, the watermark is maintained and used to display the ratio. By contrasting the suggested technique's results with those of other approaches, it is clear that it produced the highest PSNR value with a good capacity. Therefore, the proposed method has greater imperceptibility and better hiding ability.

Table 1 displays a comparative analysis of the suggested algorithm and a few other current techniques. It is clear that the watermark and cover graphics, which are employed in various algorithms, range in size and kind. An approximate average is determined by comparing the scale of the watermark to the document.

Table 2: *Comparison of the Performance Results.*

SI No.	Methods	PSNR	Avg. Capacity Inbpp.	SSIM	NCC
1	Proposed Method	56.22	1.26	0.999948	0.999973
2	LU decomposition based blind color image watermarking[34]	39.27	0.03125	0.9878	0.9966
3	Reversible Data Hiding in Encrypted Images [35]	42.995	0.0783		
4	An improved reversible watermarking scheme [36]	42.5	0.6	-	-
5	Blind watermarking using DC coefficients in the spatial domain [37]	50.0839	0.0013	0.9957	1.0000
6	Digital images data hiding technique using integer-to-integer DWT and lattice vector quantization [38]	47.22	0.37	-	-
7	Region-Based Hybrid Watermarking System [39]	45.95	0.03125	0.9728	0.9874
8	Novel color image blind watermarking algorithm with Discrete Fourier Transform in spatial domain [40]	41.7434	0.125000	0.9763	0.9496
9	A salient region watermarking scheme [41]	45.83	0.58	0.9795	-
10	Blind watermarking technique based on two-dimensional Discrete Cosine Transform [42]	38.3659	0.062500	0.9414	1
11	Quaternion wavelet transform (QWT) and discrete co-sine transform (DCT) based robust digital watermarking approach [43]	50	0.02	-	0.8861
12	Image correction and eigenvalue decompositionbased digital color image watermarking [44]	42.1475	0.250000	0.9919	1.0000

The suggested procedure computes the PSNR and maximum payload values from Table 1 by combining their corresponding figures from the pictures in the USC-SIPI image collection. This proposed system represents the payload as the average maximum concealing capacity or the most significant number of data that can be implanted; this does not imply that this amount of data is always hidden. It is noted that, compared to other systems, the suggested watermarking methodology offers a surprising capacity for data concealment and a substantially superior PSNR. In terms of capacity and imperceptibility, the majority of approaches fall short of the suggested algorithm.

5. CONCLUSION

This research proposed a spatial-domain histogram and visual saliency method for a digital watermarking system. Using the adaptive LSB replacement technique, the approach inserts watermark data in the LSB location of an image pixel. Additionally, to secure improved imperceptibility, a saliency map is used as a classifier to separate the features of an image depending on perceptibility based on picture color differentiation. The experiment results prove that the algorithm has improved robustness along with improved hiding capacity and can withstand various image impairments by combining the ideas of histogram equalization and the saliency map method. The proposed copyright protection technique is superior to other current algorithms. Further, in the future, we will implement color images and work on enhancing the robustness of watermarking. Depending on the algorithm's efficacy, another technique can be used instead of LSB Replacement.

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