MULTIPLE CAUSAL WINDOW BASED REVERSIBLE DATA EMBEDDING

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ABSTRACT

Reversible data embedding is a technique that embeds data into an image in a reversible manner. An important aspect of reversible data embedding is to find embedding area in the image and to embed the data into it. In the conventional reversible techniques, the visual quality is not taken into account which resulted in a poor quality of the embedded images. Hence the histogram modification based reversible data hiding technique using multiple causal windows is proposed which predicts the embedding level with the help of the pixel value, edge value, Just Noticeable Difference(JND) value. Using this data embedding level the data is embedded into the pixels. The pixel level adjustment considering the Human Visual System (HVS) characteristics is also made to reduce the distortion caused by data embedding. This significantly improves the data embedding capacity along with greater visual quality. The proposed method includes three phases: (i).Construction of casual window and calculation of edge and JND values in which the casual window determines the pixel values, the edge and the JND values are calculated (ii).Data embedding which is the process of embedding the data into the original image (iii). Data extractor and image recovery where the original image is recovered and the embedded bits are obtained. The experimental results and performance comparison with other reversible data hiding algorithms are presented to demonstrate the validity of the proposed algorithm. The experimental results show that the Performance of the proposed system on an average shows an accuracy of 95%.

Keywords

Data hiding, human visual system, just noticeable difference, lossless watermarking.

1. INTRODUCTION

Data embedding is a method of embedding confidential information into a set of host data, such as a photograph, television signal, or identification card. Data embedding has direct applications in data mining, data indexing and searching, information retrieval, and multimedia data processing. Data embedding on image can be implemented as a steganography technique. **STEGANOGRAPHY** is the art and science of writing hidden messages on any cover media in such a way that no one, apart from the sender and intended recipient, suspects the existence of the message. Reversible data embedding, which is often referred to as lossless or invertible data embedding, is a technique that embeds data into an image in a reversible manner. Extensive

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efforts have been devoted to increase the embedding capacity without degrading the visual quality of the embedded image.

A key of reversible data embedding is to find an embedding area in an image with the help of redundancy in the image content. The conventional reversible techniques [1] uses lossless data compression to find an extra area that can contain to-be-embedded data. In order to expand the extra space, the recent algorithms reduce the redundancy by performing pixel value prediction [1] and/or utilizing image histogram [8]. The state-of-the-art techniques [3], [8] exhibit high embedding capacity without severely degrading the visual quality of the embedded result. However the visual quality is not taken into account in the conventional methods the quality of the resultant embedded image is not satisfactory. From all data embedding techniques one common drawback is the fact that the original image is distorted by some small amount of noise due to data embedding itself.

The proposed system uses image as the input and a data embedding level is adaptively adjusted for each pixel with a consideration of the human visual system (HVS) characteristics. The conventional histogram modification methods embed a message bit into the histogram of pixel values or the histogram of the pixel differences. A multiple causal window is constructed to determine the pixel value of the given image and the edge value is determined. After the edge detection is performed, the JND value is calculated. Data embedding is the process of embedding the confidential information into the original image. The data can be embedded only in non-edge pixel positions hence the embedding level for the edge and non-edge pixel positions are obtained. After estimating the edge, JND value and the embedding level the message bit b is embedded for each pixel. At the data extractor the same values are obtained and the image is recovered.

2. RELATED WORK

C.-C. Chang, Lin, Chen Y.H [1], proposed, a reversible data-embedding scheme to embed secret information in original images. Here, an embedded pixel value is generalised according to a predetermined threshold and the difference between the predicted pixel value and its original pixel value. The results show that the proposed scheme can provide great payload capacity while preserving the quality of the stego-image D.-M. Thodi, Rodrigues J.J [2], proposed, a histogram shifting technique as an alternative to embedding the location map. This technique improves the distortion performance at low embedding capacities and mitigates the capacity control problem. Also a reversible data-embedding technique called prediction-error expansion is proposed here. This new technique better exploits the correlation inherent in the neighbourhood of a pixel than the difference-expansion scheme. Prediction-error expansion and histogram shifting combine to form an effective method for data embedding. The results show that prediction-error expansion doubles the maximum embedding capacity when compared to difference expansion. There is also a significant improvement in the quality of the watermarked image, especially at moderate embedding capacities Y. Hu, H.-K. Lee and J.Li [3], focus on improving the overflow location map. A new embedding scheme that helps us construct an efficient payload-dependent overflow location map is designed here. Such an overflow location map has good compressibility. The accurate capacity control capability also reduces unnecessary alteration to the image. Thus improves the embedding capacity with good image quality.

W. Lin, L. Dong, and P. Xue [4], proposed a method to discriminate pixel differences according to their impact toward perceived visual quality. Local contrast changes which are noticeable are formulated since contrast is the basic sensory feature in the human visual system (HVS) perception. Thus the fundamental improvement in sharpened image edges is achieved by taking the visual signal with blurring and luminance fluctuations into account.

S. Weng, Y.Zhao, J.-S. Pan, and Zhicheng Ni [9], proposed, reversible data hiding scheme which uses zero or minimum points of the histogram of the image and slightly modifies the pixel values to embed data into the image without considering the embedding level resulting with comparatively low distortion of the original image.

3. PROPOSED METHODOLOGY

The proposed scheme is based on finding embedding area in the image and to embed the data into it. This embedding area in the image is determined with the help of embedding level of each pixel. Multi causal windows are used here to determine the embedding level. The perceptual characteristic of Human Visual System is considered to improve quality degradation caused by data embedding. The flow diagram of the proposed system is as follows.

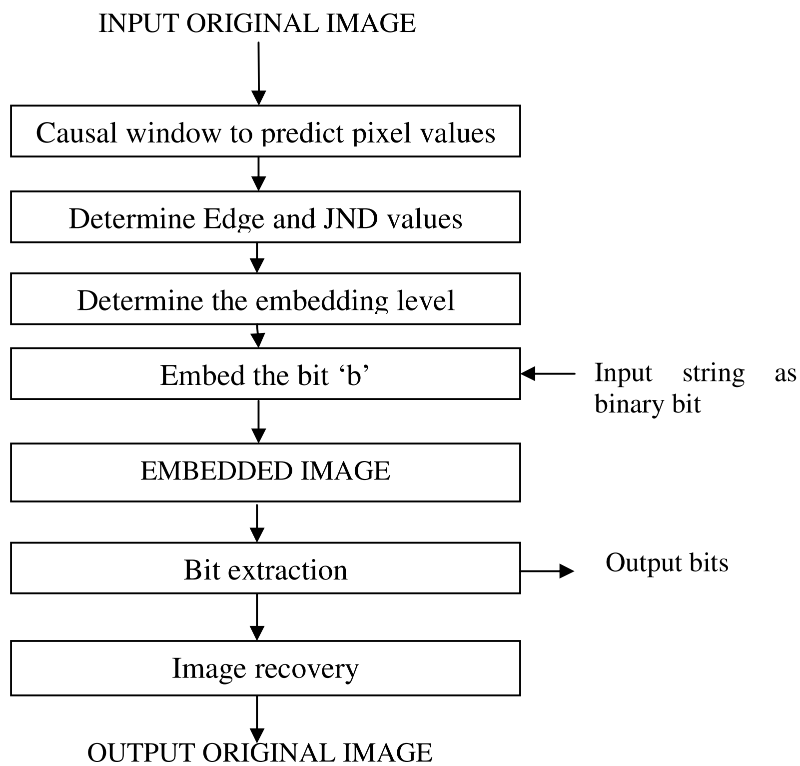


Figure 1. Overall process of Reversible Data Embedding

3.1 Construction of Multi Causal Window:

Causal window is a part of the original image with specified window size. This causal window is used to determine the pixel values, the edge values, and the JND (Just Noticeable Difference) values. Using these values the embedding level of each pixel is determined and the data is being embedded into the original image. Similarly multiple causal windows are identified in the original image and the embedding level calculation is made so that more data embedding is possible.

Algorithm:

Step-1: Calculating Pixel value:

Let (i, j) denote the pixel coordinate of the original image. Let the original image be 'x' and the embedded image be 'y'. The pixel value for each causal window is predicted.

$$x1(i,j) = 1/ N(\Omega i,j) \sum_{(m,n)\Omega i,j} x(m,n) \qquad -(1)$$

where Ωi,j denotes a single causal window surrounding x(i, j)
N(Ωi,j) denotes the cardinality of the set Ωi,j.

The size of the each causal window is specified as S. The average of the pixel values is used as the predicted value.

Step-2: Calculating Pixel Difference:

The pixel difference is calculated between the original pixel values and the predicted values as follows,

$$d(i,j)=| x(i,j)- x1 (i,j) | \qquad -(2)$$

where d(i,j) denotes the pixel difference value for each pixel. This pixel difference value is used in data embedding process.

Step-3: Calculating Edge Value:

The edge is simply estimated for each pixel as follows:

$$\text{If } var(\Omega i,j) > T_e, \ E(i,j)= 1 \qquad -(3)$$

$$\text{If } var(\Omega i,j) <= T_e, \ E(i,j)= 0 \qquad -(4)$$

where E(i,j) determines whether the pixel is edge or not.
var(Ωi,j) denotes the variance of pixel values in Ωi,j.
T_e represents the edge threshold value.

Step-4: Calculating JND Value:

The just noticeable difference value is estimated after the edge detection as follows:

$$jnd(i,j) = Tl(i,j) + \mu(Ta(i,j)/ Tl(i,j)) \qquad -(5)$$

where μ=0.5, Tl and Ta are the two thresholds representing the luminance adaptation and the activity masking of the Human Visual System characteristics respectively.

Tl is calculated by measuring the background luminance with the help of average value of local neighbourhood of a single causal window.

A piecewise linear approximation is used with three parameters, a, b, c .

$$\text{If edge } (E(i,j) = 1), \quad a=8, b=18, c=22 \qquad -(6)$$

If non-edge $(E(i,j) = 0)$, a=10, b=20, c=24 -(7)

i.e., if the background luminance is <=75 , Tl is calculated as

Tl = b-(((b-a)/75)*background luminance)

And if the background luminance is >=125 , Tl is calculated as

Tl = (((c-a)/130)*background luminance) + ((225/130)*a)-((125/130)*c)

Ta is calculated as the maximum pixel difference value in the local neighbourhood of a single causal window.

Step-5: Finding Embedding Level:

After calculating the edge and JND value, the embedding level of the image is determined. The data embedding is performed by using the difference value and finding the extra space in the image where the data can be embedded. If the embedded value exceeds a pixel value bound (0 to 255 in 8 bit images), overflow and underflow problem occurs. To solve this problem, the original image histogram is shrunk from both sides by 2^L, where L is the embedding level. The overhead information describing the pre-processing is losslessly compressed and embedded together with pure payload data to realize reversible data embedding. Compared to Tai *et al.*'s method of adopting the fixed embedding level, the embedding level here is adaptively adjusted for each pixel according to the local image characteristics. The embedding level $K_{i,j}$ is calculated as follows:

If non-edge $(E(i,j)= 0)$,

$$K_{i,j} = \arg_k \max 2^k, \text{ where } 2^k < jnd(i,j),\ k \le L \quad -(8)$$

That is the maximum possible embedding level is chosen such that the pixel value change should be lower than the JND value because the distortion above the JND in the smooth region is perceptually disturbing.

If edge $(E(i,j)= 1)$,

$$K_{i,j} = \arg_k \min 2^k, \text{ where } 2^k > jnd(i,j),\ k \le L \quad -(9)$$

That is the minimum possible embedding level above the JND is used to embed a sufficient amount of data because it is difficult to find the extra space in the image using the embedding level lower than the JND value since the difference values d(i,j) in the edge region are high. The increase of the JND value in the edge region does not reduce the visual quality. Sometimes an intentional increase of the JND in the edge region is employed for enhancement of the image.

3.2 Data Embedding:

After the estimation of the embedding level, the data in the form of binary bits are embedded into each pixel. The input data is converted into ASCII values and then converted into its respective binary values. Thus the input data bit 'b' is embedded into pixels if $d(i,j) < 2^{K_{i,j}}$ as follows:

If $x(i,j) \geq x1(i,j)$,

$$y(i,j)= x(i,j) + d(i,j) + b \quad -(10)$$

If $x(i,j) < x1(i,j)$,

$$y(i,j)= x(i,j) - d(i,j) - b \quad -(11)$$

If $d(i,j) \geq 2^{K_{i,j}}$, the bit 'b' is not embedded into pixels instead pixel level adjustment is performed as follows:

If $x(i,j) \geq x1(i,j)$,

$$y(i,j)= x(i,j) + 2^{K_{i,j}} \quad -(12)$$

If $x(i,j) < x1(i,j)$,

$$y(i,j)= x(i,j) - 2^{K_{i,j}} \quad -(13)$$

This process continues until all the bits are embedded. The overflow and underflow problem is eliminated by shifting the pixel values by 2^L at the pre-processing stage. The same is performed for multiple causal windows to embed more number of bits. The upper and left image boundaries are not modified to satisfy the reversibility. Finally the embedded image 'y' is obtained.

3.3 Data Extraction and Image Recovery:

3.3.1 Data Extraction:

Data extraction is the process of extracting the embedded data from the embedded image and to obtain the original image. Knowing the embedding level L of the image the data is extracted from the embedded image. Since the causal windows are used to determine edge, JND, and embedding level, the same values can be obtained at the extractor side.

If $| y(i,j)- x1(i,j) | < 2^{K_{i,j}+1}$, the data bit is extracted as follows:

If $| y(i,j)- x1(i,j) |$ is even, then $b=0$ -(14)

If $| y(i,j)- x1(i,j) |$ is odd, then $b=1$ -(15)

3.3.2 Pixel Recovery:

The original pixel values are recovered by the pixel recovery process as follows:

When $| y(i,j)- x1(i,j) | < 2^{K_{i,j}+1}$, the pixel values are recovered by,

If $y(i,j) < x1(i,j)$,

$$x(i,j) = y(i,j) + ((ceil(y(i,j) - x1(i,j))/2 \quad -(16)$$

If $y(i,j) \geq x1(i,j)$,

$$x(i,j) = y(i,j) - ((ceil(y(i,j) - x1(i,j))/2 \quad -(17)$$

When $| y(i,j)- x1(i,j) | \geq 2^{K_{i,j}+1}$, the pixel values are recovered by,

If $y(i,j) < x1(i,j)$,

$$x(i,j) = y(i,j) + 2^{K_{i,j}} \quad -(18)$$

If $y(i,j) > x1(i,j)$,

$$x(i,j) = y(i,j) - 2^{K_{i,j}} \quad -(19)$$

Thus the original pixel values including the overhead information bits at preprocessing are extracted and finally the original image is recovered completely.

4. EXPERIMENTAL RESULTS

The performance of the proposed system is evaluated using MATLAB. The input image is given and the causal window is identified in the input image. The pixel values of the causal window are determined and the average value of the pixel values is calculated.

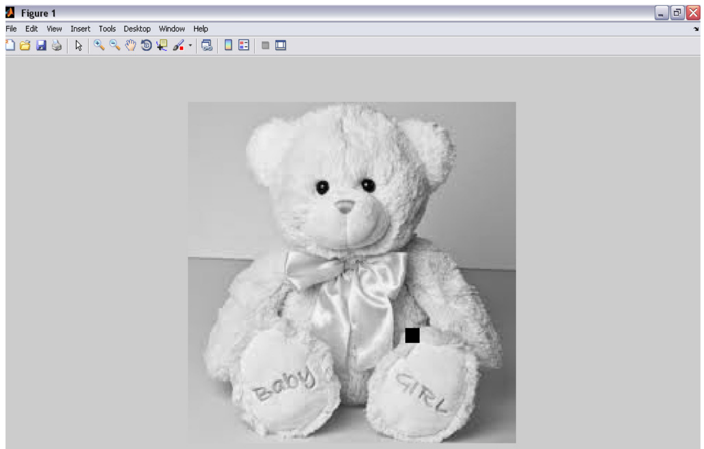


Figure 4.1.Input image showing single causal window

The difference values for each pixel are calculated and thereby edge value is calculated using the edge threshold T_e (a threshold value which lies between 0 and 1).

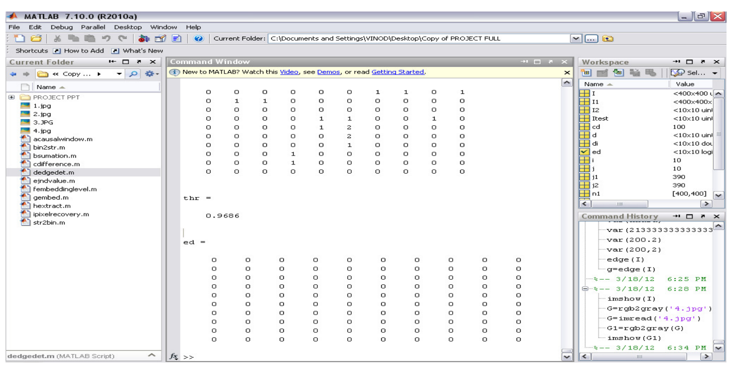


Figure 4.2.Edge Value

The Just Noticeable Difference value is calculated using two thresholds representing the luminance adaptation and the activity masking i.e., Tl and Ta (from Step-4) of the Human Visual System characteristics respectively.

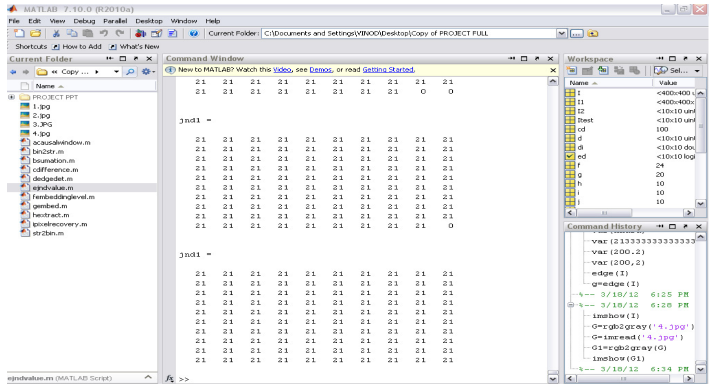


Figure 4.3.Just Noticeable Difference Value

Using the edge and JND value, the embedding level $K_{i,j}$ (from (8) and (9)) of the image is determined.

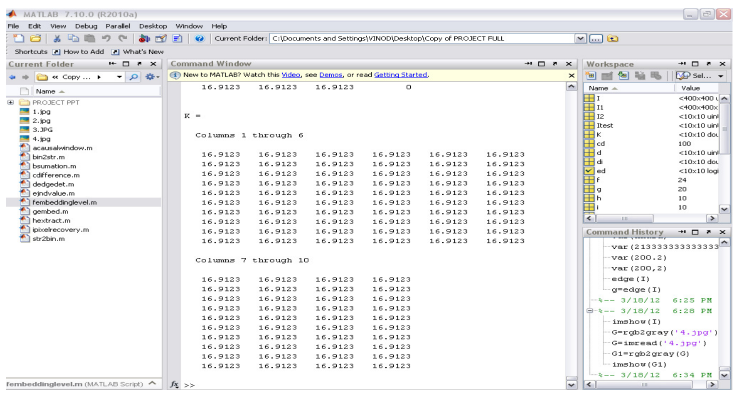


Figure 4.4.Embedding Level Value

The input string which is to be embedded is converted into its respective bits.

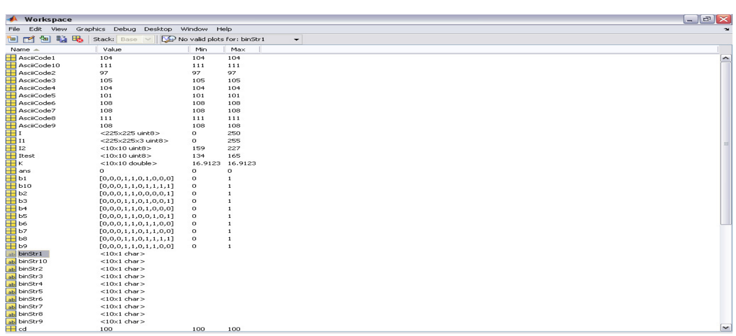


Figure 4.5.Input String to Binary Conversion

Finally the data is being embedded into the pixel values (from (10) and (11)) with respect to the embedding level and pixel level adjustment is also performed (from (12) and (13)).

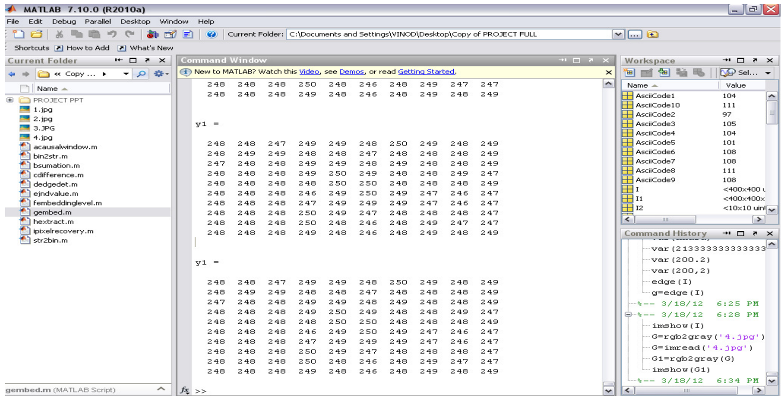


Figure 4.6.Data Embedding

Image obtained after embedding the data is displayed here.

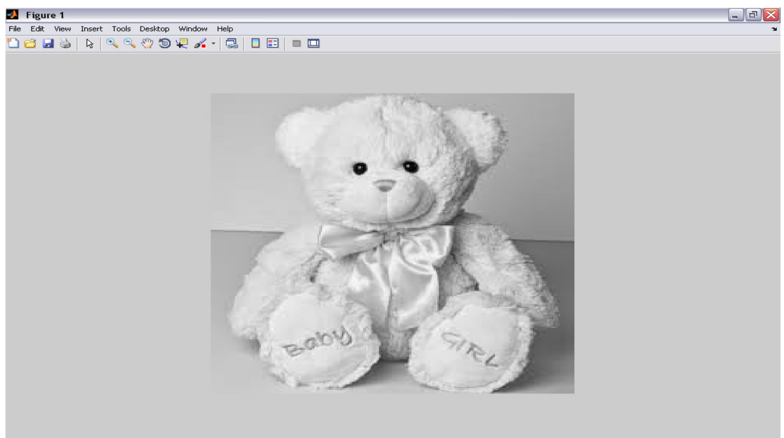


Figure 4.7.Embedded Image

Extraction of the original data that is being embedded (from (14) and (15)).

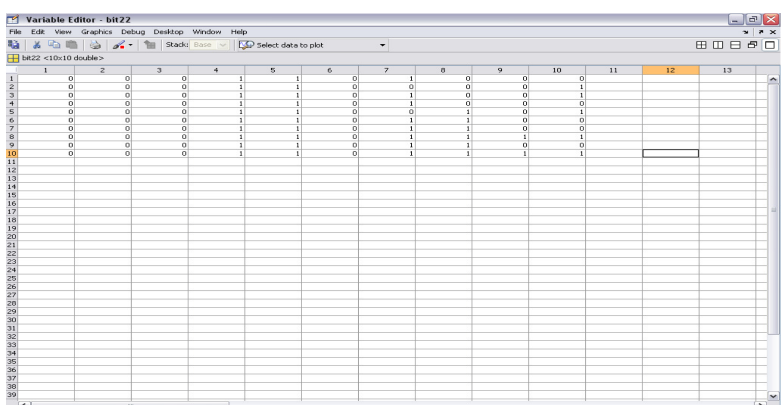


Figure 4.8.Bit extraction

Extracted bit is converted into its respective string.

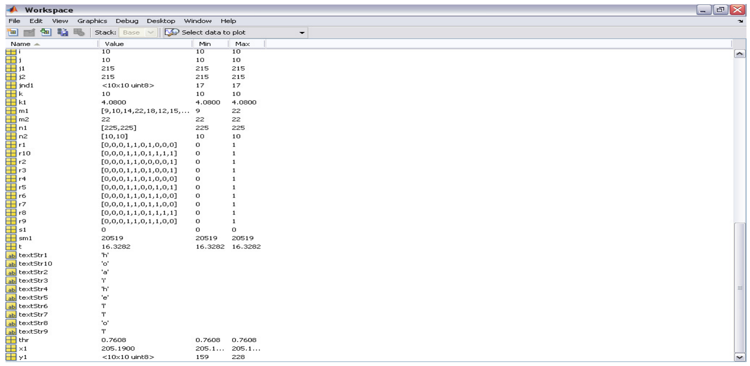


Figure 4.9.Extracted Bit to String Conversion

The original pixel values are recovered (from (16), (17), (18) and (19)).

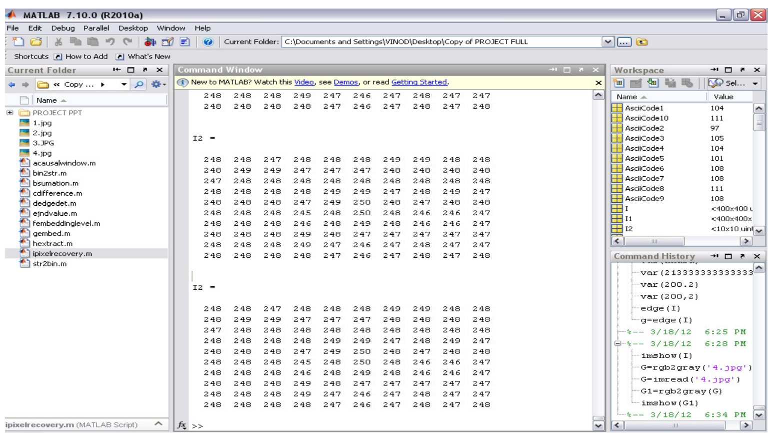


Figure 4.10.Original Pixel Recovery

The recovered original image.

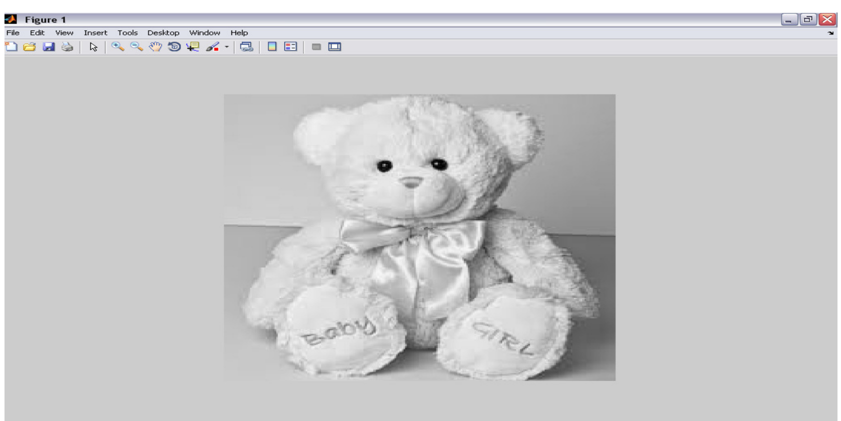
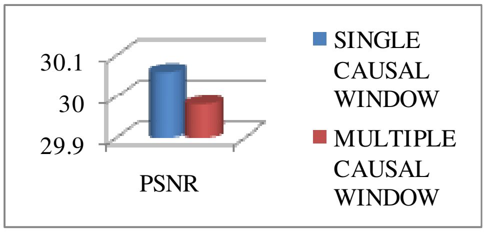
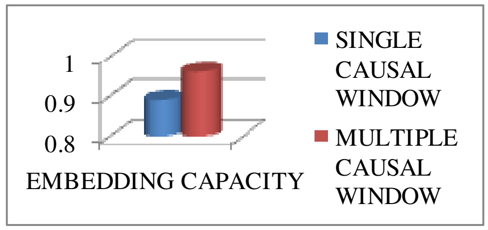


Figure 4.11.Recovered Image

Table 1. PERFORMANCE ANALYSIS BASED ON PSNR (Peak Signal to Noise Ratio), SSIM (Structural Similarity), EMBEDDING CAPACITY

SYSTEM	PSNR (in dB)	SSIM (in %)	EMBEDDING CAPACITY (in bit per pixel)
SINGLE CAUSAL WINDOW	30.06	0.861	0.89
MULTI CAUSAL WINDOW	29.98	0.921	0.96





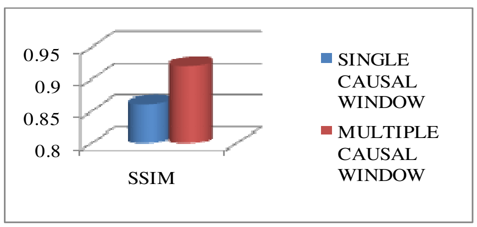


Figure 4.14 Performance of the system based on PSNR, SSIM, EMBEDDING CAPACITY.

The above graph shows the performance of the single and multi causal window based on the parameters like PSNR (in dB), SSIM (in %), EMBEDDING CAPACITY (in bit per pixel).

5. CONCLUSION

Thus an improved histogram modification based reversible data hiding technique is proposed here. Unlike the conventional reversible techniques, the HVS characteristics are considered to avoid the distortion caused by data embedding process. The edge and JND values are estimated by using the causal windows, and thus no additional overhead is required. By using the estimated values, the embedding level is adaptively adjusted for each pixel. This increases the data embedding capacity and visual quality. The experimental results show that the proposed system produces an accuracy of about 95%. Future work includes the application of the technique to reversible video data embedding, the video related HVS characteristics such as motion blur and motion sharpening can be additionally considered to produce perceptually pleasant video sequences.

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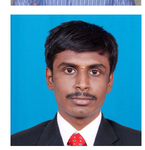

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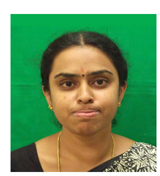

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