Interpolation Based Reversible Data Hiding using Pixel Intensity Classes

Article *in* INTERNATIONAL JOURNAL OF NEXT-GENERATION COMPUTING · November 2023

DOI: 10.47164/ijngc.v14i4.1170

2 authors:

Abhinandan Tripathi
Buddha Institute of Technology

Jay Prakash
The University of York

Interpolation Based Reversible Data Hiding using Pixel Intensity Classes

Abhinandan Tripathi
and
Jay Prakash
Department of Information Technology & Computer Application,
Madan Mohan Malaviya University of Technology,
Gorakhpur,
India

In this article, we suggest a new interpolation technique as well as a novel Reversible Data Hiding (RDH) approach for up scaling the actual image and concealing sensitive information within the up scaled/interpolated image. This data hiding strategy takes into account the features of the Human Visual System (HVS) when concealing the secret data in order to prevent detection of the private data even after extensive embedding. The private data bits are adaptively embedded into the picture cell based on its values in the suggested hiding strategy after grouping different pixel intensity ranges. As a result, the proposed approach can preserve the stego-visual image's quality. According to experimental findings, the proposed interpolation approach achieves PSNRs of over 40 dB for all experimental images. The outcomes further demonstrate that the suggested data concealing strategy outperforms every other interpolation-based data hiding scheme existing in use.

Keywords: PSNR, EC, RDH, HVS, VQ.

1. INTRODUCTION

An essential development in the area of data security is Reversible Data Hiding (RDH). The Reversible Data Hiding system's goal is to interchange personal data over a public network while concealing it in a useful cover file, preventing unauthorized eavesdropping. Even so, the dissemination or transfer of sensitive or confidential information, such as that utilized by the military and by commercial enterprises, across an open network (the Internet), and makes them susceptible to assault. Therefore, many researchers have turned their attention to the preservation of such information. To prevent sensitive information from being intercepted or altered, some methods have been devised. The RDH algorithms have primarily been applied in the fields of medicine and defense (Shi, Li, Zhang, Wu, and Ma, 2016). Particularly image-based RDH approaches are appropriate for medicinal applications to cover up a lot of patient-specific and diagnostic data inside the medicinal pictures. It assists in reducing the number of paperwork needed and encourages easier medicinal data sharing among doctors for a more accurate diagnosis of the patient's condition. Basically, there are two methods—cryptography and data embedding—that can be used to quickly determine if digital information is authentic or has been unlawfully altered. A simple definition of cryptography is the intuitive protection of sensitive data by the use of standard cryptographic techniques like DES and RSA to convert the sensitive data into a series of unintelligible codes. As a result, the secret data can only be decrypted and accessed by the valid recipient who has the key; anyone without the key is unable to access the secret data. Using the data embedding approach, tiny distortions to the cover signal are used to incorporate information bits into a host multimedia signal. These methods are frequently employed to determine authenticity, content ownership, and copyright issues. Most of the current data embedding systems inevitably introduce some degree of distortion, yet even this distortion is invisible to the human eye. Any distortion added to the content is unacceptable for various uses, including as medical, military imaging, and the preservation of artwork. In order to restore the cover pictures without any loss, RDH techniques are developed (Lin, Tai, and Chang, 2008).According to the confidential data, RDH techniques slightly alter the cover picture pixels. The updated cover picture is known as the stego image, and the procedure is known as data embedding. The stego image's

visual appeal closely resembles that of the original cover picture. Consequently, the stego image manages to deflect unnecessary attention. The extraction procedure is used at the receiver end to obtain the cover picture and secret data from the stego image. Low distortion allows it to escape an attacker's notice. Certain characteristics of reversible data concealing include transparency, payload, and security. It works well for copyright protection or image authentication. Reversible data concealment, in general, cannot resist any signal processing assaults.
Generally, image interpolation (Allebach and Wong, 1996) based RDH scheme is used for producing a high-resolution image from a low resolution. It is a procedure used to resize or remap a small image to a larger one. This method starts by interpolating the cover image using one of the common interpolation methods. Following that, interpolated picture cells are modified for data concealing while the actual pixels are retained unaltered and utilized as reference pixels for both interpolation and data hiding. The confidential data is extracted from the stego picture cells during the extraction process, and the actual cover image is then recreated by down sampling the stego image. Figure 1 depicts the precise block diagram of the interpolation-based RDH method. A tiny image is scaled or remapped to a larger one using the image interpolation (Allebach and Wong, 1996) technique, which is typically employed to create a high-quality image from a low resolution image. Here, the calculation and prediction of other pixel values are done with minimal information. Reference pixels are the known pixels or the pixels with little information, and they will remain unmodified during interpolation.

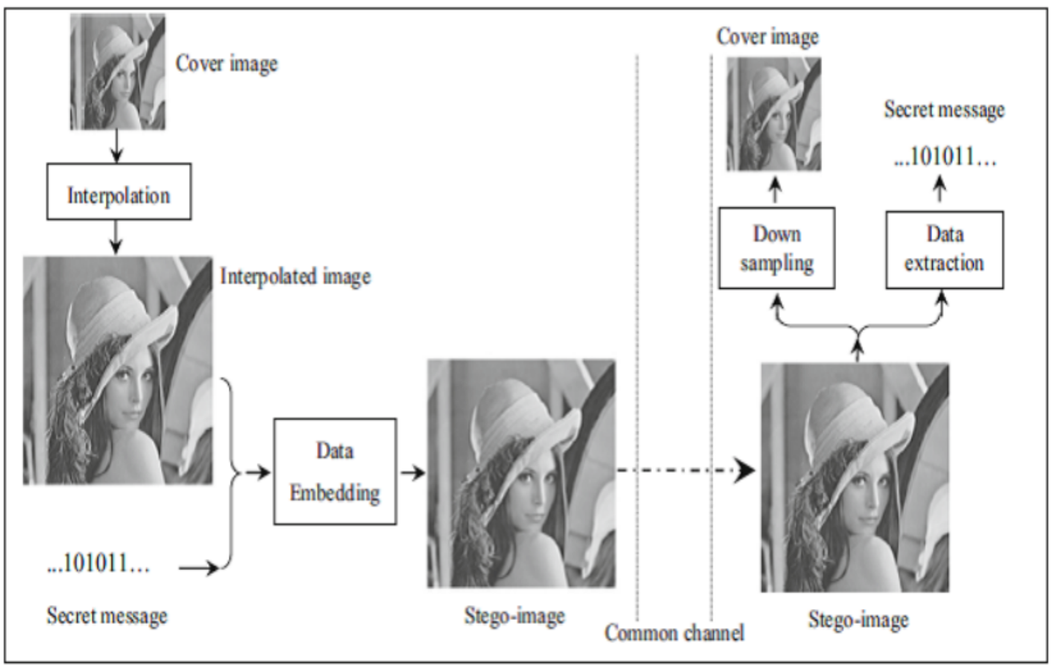


Figure 1. RDH Scheme using Interpolation Method

This paper proposed a new interpolation technique that takes into consideration of all nearby pixels by assigning them various weights based on how close they are to the projected pixel. As a result, it offers an interpolated image of high quality. A second proposal for RDH which embeds the personal information into the interpolated picture cells according to the picture cells intensity value. This method simultaneously offers a high level of information concealing capacity and a high quality stego-image. The suggested schemes have some inspiration and contribution which are as follows:

1. While estimating the value of the centre pixel, the existing interpolation techniques have not effectively taken into account all the surrounding pixels. The pixel values are estimated using a weighted manner in the suggested interpolation method. The experimental findings demonstrate

that the interpolated image's quality outperforms that of images produced by the currently used techniques.
2. The proposed data concealing strategy considers how the Human Visual System (HVS) functions to conceal the personal data in the picture cells of the cover image. The approach alters the pixel values in a way that is adaptable and invisible to the human eye.
3. The experimental findings further demonstrate that the suggested approach performs best in terms of the capacity to hide data and the caliber of the produced images for all test shots. The suggested hiding strategy is also one of the easiest data hiding approach since it merely substitutes the personal data bits for the LSBs.
4. The suggested data hiding method is also reversible because it merely alters the interpolated picture cell values while concealing the private data. At the receiving end, the suggested interpolation approach can restore the interpolated pixel values.
The remaining of the article is structured as follows. The associated works are discussed in Section 2. The proposed approach is covered in Section 3, and the experimental findings are covered in Section 4. At last, section 5 contains conclusions of this article.

2. BACKGROUND AND RELATED WORK

For more than ten years, reversible data concealment has been a topic of ongoing research in the field of information and data security. Various strategies and approaches, including histogram shifting (HS) (Coatrieux, Pan, Cuppens-Boulahia, Cuppens, and Roux, 2012), difference expansion (DE)(Kim, Sachnev, Shi, Nam, and Choo, 2008), least significant bit (LSB) compression (Mohammad, Al-Haj, and Farfoura, 2019a), interpolation (Jung, 2018)(Jung and Yoo, 2015b)(Ren, Liu, Zhang, and Li, 2023)(Fan, Zhong, and Xiong, 2023)(Huang, Lin, and Chen, 2023)(Qi, Zhang, Li, Ma, and Guo, 2023) , and others, have been proposed to achieve reversible data concealing. Due to their simplicity, numerical efficiency, and ability to offer comparatively larger data hiding capacity, interpolation-based data hiding algorithms continue to draw researchers' interest. The strategies based on interpolation will be briefly described in this section and summary is shown in Table I.
A new data concealing method based on NMI was suggested by Jung in 2018 (Jung, 2018) and by Jung and Yoo in 2009 (Jung and Yoo, 2015c). The mean is computed by the NMI method utilizing values from nearby pixels and is then inserted into unallocated pixels. PT'(0, 1) = PT(0, 0) + PT(0, 2)/2, PT'(1, 0) = PT(0, 0) + PT(2, 0)/2, and PT'(1, 1) = PT(0, 0) + PT'(0, 1) + PT'(1,0))/3 are the formulas used to compute the NMI for a 3×3 sub-block. Due to its straightforward computation, data hiding strategies based on the NMI enable the embedding of significant amounts of personal data while sustaining high-quality images. This approach (NMI) have little temporal complexity and quick calculation time. The input image, sometimes referred to as the original image, is initially scaled down to Quarter of its original size. The actual image is enlarged using the NMI approach to create a cover image that is the identical size to the source picture. Finally, the enlarged cover image contains hidden details. A better variation of the Jung and Yoo system (Jung and Yoo, 2015c) is the ENMI technique (Chang, Huang, Lee, and Wang, 2013). Chang et al (Chang et al., 2013) suggested a data concealing strategy based on picture interpolation and histogram pixel shifting in 2013. This scheme uses a two-step data concealing technique. In first step, A high-quality cover pic is created using ENMI, and secret data is then embedded using difference values obtained from the input and cover pel. During second step, the difference image is modified using a histogram modification to increase payload even further while preserving distortion-free image quality. The improved neighbor mean interpolation is demonstrated in an example where the pixel values for PT'(0, 1), PT'(1, 0), PT'(1, 1), PT'(1, 2), and PT'(2, 1) are calculated by weighting the pixels of their reference neighbors.
Using the HS approach, Hong et. al. in 2011,(Hong and Chen, 2011) discussed a RDH scheme that splits the cover image into smooth and complicated sections. The locations of the reference

pixels are represented by a binary picture that is created. Initially, fewer bits of the unknown data is incorporated into the complicated zone because extra reference pixels are selected therefore it minimizes the image distortion. Secondly, it conceals a number of hidden data bits in the smooth and shiny areas because few reference pel are used. As a result, it can effectively manage a high level of data concealment while retaining stego-image quality. In order to enhance the performance of the data concealing approach proposed by Jung and Yoo (Jung and Yoo, 2015c), In 2012, Lee et al.(Lee and Huang, 2012) suggested a high-capacity image hiding scheme that makes use of an interpolating technique known as INP on Maximum Difference Values. The merits of the suggested technique include good image quality, minimal computing complexity, and great embedding capacity. According to the experimental findings, the suggested technique performs well for payload up to 2.28 bpp. Additionally, compared to other interpolating techniques like NMI, NNI, and BI, the INP produces greater PSNRs. A RDH approach based on interpolation and a movement order mechanism was suggested by Wang et al.(Wang, Chang, Nguyen, and Li, 2013). All pixels in this scheme are split into two groups: boundary picture cells and non-boundary picture cells. The interpolation error is calculated and utilized to embed hidden data in the case of boundary picture cells. When using non-boundary picture cells, the direction order determines the difference value between the non-boundary picture cells and its parent picture cell, which is used to hide confidential data through histogram shifting.

In order to improve the effectiveness of information hiding systems, Tang et al. (Tang, Hu, and Song, 2014) suggests a large capacity steganography that uses multi layer embedding (CRS) in 2014. The experimental findings demonstrate that the suggested CRS method performs better than alternatives. Additionally, the suggested CRS approach can demonstrate the benefits of high-quality images and minimal computational complexity. This approach is modified the work done by Lee et al. (Lee and Huang, 2012). Hong and Chen's(Hong and Chen, 2011) strategy was improved by Lu and Huang's (Lu, Chang, and Huang, 2014) proposal for an improved concealment technique. In their approach, a hidden message is embedded in the reference pixels to increase the hiding capacity using the DE, HS, and bi linear interpolation procedures. In 2015, Hu & Li (Hu and Li, 2015) proposes an upgraded interpolating method-based high payload image steganographic technique. Their proposed technique enhances capacity in the assumption of image quality assurance by enhancing the disparity between nearby pixels. It is also simple to use and maintains high image quality. Jung & Yoo (Jung and Yoo, 2015d) in 2015 proposed a least substantial substitution strategy and interpolation are used to create a semi-reversible data abstracting method. Initially, secret data is hidden before scaling up and down the cover image using interpolation techniques to increase capacity and quality. Secondly, secret data is embedded using the LSB substitution technique. A method for pixel value difference based on an index was proposed by Jung and Yoo (Jung and Yoo, 2015a). The base pixel is determined for non-overlapping sub blocks using an index function. The picture cell-value difference method is used for other picture cell-pairs in the sub-block to determine the number of embedding bits. The results of the experiments showed that the suggested approach had a better bit-embedding capacity while maintaining good visual quality and also robust against histogram attacks. A RDH approach using image interpolation and the picture cell value modifying feature is projected by Malik et al. (Malik, Sikka, and Verma, 2017b).The two levels of this approach are image interpolation and data concealment. Similar to the NMI method, the interpolation method consider every nearby pixel. However, it adjusts the weight-age according on their proximity. As a result, it offers an interpolated image of superior quality. Confidential information is inserted into the interpolated pixels twice during the data concealment step. The secret data is initially embedded into the odd-valued pixels, and then in the secondly, it is embedded into the even-valued pixels. In 2016, Malik et al.(Malik, Sikka, and Verma, 2017a) suggested a high capacity, RDH method using image interpolation. This data hiding scheme abstracts the confidential data in the interpolated picture cell by considering the HVS in order to maintain the quality of the final image.

Table I: **Summary of various existing interpolation scheme**

References	**Concepts Used**	**Features**
(Jung and Yoo, 2015c)	NMI Method	High PSNR
(Chang et al., 2013)	Enhanced NMI Method	Improve PSNR as Compared to (Jung and Yoo, 2015c)
(Hong and Chen, 2011)	HS	Least Image distortion
(Lee and Huang, 2012)	INP on MDV Method	Payload upto 2.28 bpp & higher PSNR than (Jung and Yoo, 2015c)
(Wang et al., 2013)	Pixels are divided in to boundary and non-boundary picture cells	Performance is stable for various images
(Tang et al., 2014)	Uses larger capacity steganography that uses multilayer embedding (CRS)	Better performance than (Lee and Huang, 2012) and less computational cost
(Lu et al., 2014)	DE, HS & bilinear interpolation method	Greater hiding capacity as compared to (Hong and Chen, 2011)
(Hu and Li, 2015)	IMNP method	Increases capacity and payload up to 246% from 74% (Lee and Huang, 2012) and 35% from14% (Lee and Huang, 2012) respectively
(Jung and Yoo, 2015d)	Semi-RDH & LSB substitution method	Average PSNR is 37
(Jung and Yoo, 2015a)	Pixel value differencing based on an index	High PSNR and least distortion
(Malik et al., 2017b)	Confidential data are hide in to odd valued and even valued pixel	High PSNR and capacity, less complexity
(Malik et al., 2017a)	Modified NMI	Better PSNR & capacity as compared to (Chang et al., 2013)
(Malik, Singh, and Kumar, 2018)	Location map is used to hide the data	Good hiding capacity and visual quality
(Meikap and Jana, 2018)	DPVO having variable block size	Higher capacity than other PVO based schemes with good visual quality
(Lu, 2018)	Modulus function and re-encoding technique	Better performance than (Jung and Yoo, 2015c)(Lee and Huang, 2012)(Tang et al., 2014) in terms of capacity & payload
(Kumar, Chand, and Singh, 2018)	Splits images into pairs of embeddable picture cells and concealed the confidential bits of data in every pair	High capacity, efficiency and visual quality
(Wahed and Nyeem, 2019)	Uses a bit-wise correlation between the embedded pixel and estimated versions of an embedded pixel.	Good embedding rate and less distortion
(Mohammad, Al-Haj, and Farfoura, 2019b)	Adjustable data hiding algorithm	Achieved high PSNR, Weighted PSNR & SSIM

(Zhang, Sun, Tang, Yu, and Wang, 2017)	Parabolic interpolation method	High embedding capacity & visual quality
(Shaik and V, 2019)	2D-Parabolic interpolation method	High embedding capacity & visual excellence as compared to 1D-Parabolic interpolation method (Zhang et al., 2017)
(Bai, Chen, Duan, Feng, and Zhang, 2022)	Interpolated values calculated by different functions are selected as the actual interpolation according to different secret data.	Stable embedding capacity & visual effects
(Xiong, Chen, Fan, and Zhong, 2022)	Adaptive Interpolation based RDH algorithm	Higher PSNR and resist histogram and regular singular steganalysis attacks
(Xiong, Wang, Li, Ye, Chen, Fan, and Zhu, 2022)	Location-dependent weighted image interpolation method	No pixel overflow or underflow problem and resist steganalysis attacks
(Benseddik, Zebbiche, Azzaz, and Sadoudi, 2022)	Used in the transform domain for fingerprint images	No pixel overflow or underflow problem, high embedding capacity and embedding rate is around 0.5 bpp.
(Jana, Jana, Lu, and Vo, 2022)	Used image interpolation by exploiting center folding with fuzzy weight strategy (FWS).	Achieved high PSNR value around 30 dB and resist steganalysis attacks
(Malik, Sikka, and Verma, 2020)	Number of bits to be concealed in the confidential data in a picture cell is decided on the basis of its pixel's value.	Higher PSNR & capacity as compared to (Jung and Yoo, 2015c)
(Jung and Yoo, 2015b)	NNMI Method	High PSNR& good visual quality
(Ren et al., 2023)	Adaptive interpolation between neighbor pixels (AIA) technique	Good capacity, PSNR & SSIM
(Fan et al., 2023)	Modulo operation and prediction-error expansion	Higher PSNR, bpp and resisting histogram analysis
(Huang et al., 2023)	Block-based adaptive high fidelity RDH approach	High EC, visual quality, No pixel overflow or underflow problem

To produce an interpolated image of higher quality, this suggested interpolation technique takes into account all nearby picture cells as well as their influence on the reference pixels. The cover picture is separated into several blocks in this proposed data concealing strategy in order to identify the smooth and complex regions. Then, it incorporates extra bits into the complex areas of the image to improve both the image quality and data embedding capabilities. Malik et al.(Malik et al., 2018) suggested a high competency recovery strategy-based data concealing approach. In this scheme secret data are incorporated into a cover picture using two passes. The cover picture is scanned in the first pass according to a predetermined scan order and creating a location map where even-valued pixels are represented by a "1" and odd-valued pixels by a "0". It inserts the private information into each pixel of the picture by altering each pixel's value by not more than 1. Embedding technique which is used in first pass is repeated in the second pass in order to return some of the pixels to their original state and to further embed the private data. Even though the private data is concealed behind layers, it can nevertheless maintain image quality. A generalized directional picture cell value ordering (DPVO) having variable block sizes is proposed by Meikap et al. in 2018 (Meikap and Jana, 2018). After the actual image is separated into blocks, image interpolation is used to enlarge it. The horizontal, plumb and diagonal directions of every block have been explored for overlapping embedding in order to increase data concealing capacity. The modulus function and re-encoding technique are used in Lu's interpolation-based concealment approach (Lu, 2018). It looks at the location values' probabilities before re-encoding the value in accordance with how often that occurrence occurs. To determine the rank of the position value in descending order, a re-encode function is utilized. The position value that occurs most frequently is re coded to zero. The re-encoded codes still have large values and are positive numbers. The value is reduced by ciphering the re-encoded codes to create mapping codes that have negative and positive numbers. The re-encoded code will be mapped to the mapping code using a specified mapping function. To reduce image distortion, the code which is used in mapping is split in half from the re-encoded code.

A new RDH scheme with high concealing capacity of data and very little distortion is discovered by Kumar et al. [(Kumar et al., 2018),(Kumar, Chand, and Singh, 2015)]. It uses a combinatorial strategy. Before identifying the embeddable pixels, it first creates a position map for the pel in the cover snaps. To hide the secret data bits, it divides each photo into two encapsulated pixel pairs. The embeddable pixels' values are modified in accordance with predefined guidelines. At most one of the pixel values is modified, and some of them might stay the same. A new interpolation-based RDH strategy is discussed by Wahed et al. (Wahed and Nyeem, 2019). This strategy focuses on using the formula to establish a minimal number of encapsulated bits in a picture element. An efficient interpolation-based data concealing technique for high payload is presented by Mohammad et al. (Mohammad et al., 2019b). The objective of this strategy is to retain stego-image quality while enhancing data hiding capacity. In order to create high quality interpolated images that are helpful for medicinal applications, Zhang et al. (Zhang et al., 2017) propose parabolic interpolation-based data concealment. The confidential data is inserted using both the original and interpolated pixels in the technique. Data concealing efficiency is increased while good visual quality is maintained by using more original pixels in the process. Another large capacity reversible data concealing technique employing 2D parabolic interpolation is discussed by Shaik et al.(Shaik and V, 2019).This study seeks to build a large capability RDH approach using a 2D-parabolic interpolation and a advanced embedding scheme that is ideal for interpolation-based methods. The findings of this investigation demonstrated that the suggested 2D parabolic interpolation optimized the up sampling's use of the pixels from the cover image. Compared to the 1D parabolic interpolation method, this approach generated interpolated snaps of a superior quality. Additionally, the suggested data hiding approach took advantage of local redundancy to achieve large EC with observable picture quality. In 2022, X Bai et al. (Bai et al., 2022) suggested a scheme in which encode secret data utilizing the differences between the interpolated values acquired by surrounding points using several interpolation methods. In the best scenario, there are 2k different interpolated values produced by 2k distinct interpolation methods, and they are numbered in ascending order to match the k bits of private data contained in every interpolated pixel. Based on the comparison of these interpolation values' sorting results with those of the accepted interpolation values at the receiver's end, the secret data may be acquired. X Xiong et al. (Xiong et al., 2022) suggested an adaptive interpolation based RDH method in 2022. In this method, the amount of bits that can be incorporated into every interpolated pel is first adaptively determined, then the picture is separated into 2×2 non-overlapping blocks, and they are sorted in ascending order. Second, the confidential data are successively incorporated using the index that was obtained after sorting. Prior to embedding, the secret data are re-encoded to further minimize the distortion of the cover pel.

A brand-new adaptive high capacity RDH algorithm is suggested in 2022 by X Xiong et al.(Xiong et al., 2022). In this approach, firstly a location-dependent weighted image interpolation method is suggested to enhance the interpolated image's VQ. The interpolated image is then split into overlapping blocks that are sorted in increasing order based on their standard deviations. Confidential data is preferably placed in the blocks with minimal deviation so that image quality is not excessively distorted. The amount of confidential data bits that can be embedded in non-reference picture cell is finally adaptively computed to maximize embedding capacity. The authors demonstrate that there is no pixel overflow or underflow issue and that the embedded secret data may be recovered appropriately. For fingerprint images, an RDH strategy is proposed by M L Benseddik et al.(Benseddik et al., 2022) in 2022 that combines the benefits of transform-based data concealing strategies and image interpolation approaches. The suggested technique relies on resetting the reference picture cell to their initial values to conserve cover picture reversibility because the private data is concealed within the transform coefficients. The author modified the DM-QIM embedding approach, created an improved perceptual masking model for fingerprint images, and created a advanced iterative correction algorithm to address the distortions brought on by the abovementioned procedure. This suggested approach enables error-free embedding without the need for additional information for picture or secret data recovery.

In 2022, S Jana et al. (Jana et al., 2022) proposed a picture interpolation using the centre folding with fuzzy weight technique (FWT) has been followed by the development of a unique efficient reversible data concealing scheme. By taking into account the fuzzy weight of each pair of pixels in a chosen image block, the interpolated pixel values are produced. Each input pixel pair's fuzzy membership values have been taken to represent the range between that block's minimum and maximum value. The input membership value is fed into the fuzzy output function, which calculates the fuzzy rule's strength using the Max-Min composite principle. Then, through a de-fuzzification process, interpolated pixel values are calculated from the fuzzy output function dependent on the strength of the fuzzy rule. Then, using a centre folding method and a comparison with the signal of the secret data, data hiding operations were carried out in each interpolated pixel. The suggested approach reverses the folded value to match the secret data if the signal of the secret data differs from that of the interpolated pixel, therefore reducing the difference in image distortion between the interpolated picture and the stego-image. Based on the difference between the outcomes of these interpolated values and the centre folding approach (CFA), the confidential data can be retrieved at the receiver's end. A Malik et al. (Malik et al., 2020) proposed a model in which the private data bits are adaptively embedded into the picture cell based on the picture cell intensity values after grouping different pixel intensity ranges. As a result, the proposed approach can preserve the stego-visual image's quality.

To acquire seed and non-seed pixels, Ren et al.(Ren et al., 2023) proposed an adaptive interpolation between neighbor pixels (AIA) technique is employed, which ensures the scheme's reversibility while balancing the embedding capacity and the quality of the tagged image. The region of interest (ROI) and the region of non-interest are then separated from the image (NROI).Fan et al. (Fan et al., 2023) provide an RDH technique based on modulo operation and prediction-error expansion for interpolated pictures (PEE). In this scheme image is divided into several blocks & by using the modulo operation on interpolated pixels and the PEE on reference pixels, secret data is embedded in each block. Block-based adaptive high fidelity RDH approach is suggested by Huang et al. (Huang et al., 2023). In this scheme, firstly the reference pixel values are used to construct the interpolated image. The interpolated image is then divided into overlapping blocks, with the secret information being preferentially inserted into interpolated pixels with low noise levels. Prediction-error value ordering and multiple embedding are used by Qi et al. (Qi et al., 2023) to provide a brand-new high-fidelity reversible embedding system. The difference between the top two greatest prediction-errors inside each image block is used to calculate a prediction-error.

In conclusion, much work has been done to enhance the performance of interpolation-based data concealing, but we think that most of the gains in capacity and image quality have been achieved at the expense of numerical simplicity and minimal computing overhead. Our suggested interpolation-based method aims to improve PSNR, embedding time and speed & data concealing capacity while retaining computational simplicity. This has been accomplished, as will be shown in section 4, where the performance of the suggested technique has been assessed and thoroughly compared with the performance of [(Zhang et al., 2017),(Shaik and V, 2019),(Bai et al., 2022),(Malik et al., 2020), and (Jung and Yoo, 2015b)].

3. PROPOSED SCHEME

In this part, we suggest a pixel intensity class-based RDH strategy for interpolated images. The algorithm for the suggested data hiding strategy is given in Section 3.1.Section 3.2 explain the example of suggested interpolation technique and embedding phase algorithms is covered in section 3.3. In Section 3.4, the algorithm for extracting sensitive data and restoring images is covered, and in Section 3.5, a demonstration of extraction process using the suggested algorithm is provided.

3.1 Proposed Data Hiding Strategy

Input: Actual Image A having size I×I.
Output: Stego-image S'
Step-1(Interpolation Phase): The actual image A should be interpolated to cover image A' as follows:
For t = 0 to I-1 do
For k= 0 to I-1 do

$$A'(t,k) = \begin{cases} A(t,k) \quad if \quad t \mod 2 = 0, k \mod 2 = 0 \text{ and } k < I-1 \\ A(t,k) \quad if \ t \mod 2 = 0 \text{ and } k = I-1 \\ A(t,k) \quad if \quad k \mod 2 = 0 \text{ and } t = I-1 \\ \frac{A(t,k-1)*2+A(t,k+1)*2+A(t-1,k-2)+A(t+1,k-2)}{6} \ if \ t \mod 2 = 1 \ \& \ k = I-1 \\ \frac{A(t,k-1)*2+A(t,k+1)+2+A(t-2,k-1)+A(t-2,k+1)}{6} \ if \ k \mod 2 = 1 \ \& \ t = I-1 \\ \frac{A(t,k-1)+A(t,k+1)+A(t,k+3)+A(t+2,k-1)+A(t+2,k+1)+A(t+2,k+3)}{6} \ if \ t \mod 2 = 0, k \mod 2 = 1 \ \& \ t < I-2 \\ \frac{A(t-1,k)+A(t+1,k)+A(t+3,k)+A(t-1,k+2)+A(t+1,k+2)+A(t+3,k+2)}{6} \ if \ t \mod 2 = 1, k \mod 2 = 0 \ \& \ t < I-2 \\ \frac{A(t,k-1)*2+A(t,k+1)*2+A(t+2,k-1)+A(t+2,k+1)}{6} \quad if \ t \mod 2 = 0, k \mod 2 = 1 \ \& \ k = I-2 \\ \frac{A(t-1,k)*2+A(t+1,k)*2+A(t-1,k+2)+A(t+1,k+2)}{6} \ if \ t \mod 2 = 1, k \mod 2 = 0 \ \& \ t < I-2 \\ \frac{A(t-1,k-1)+A(t-1,k+1)+A(t+1,k-1)+A(t+1,k+1)}{4} Else \end{cases} \tag{1}$$

End For
End For
Step-2 (Encryption Phase): Choose a 8-bit secret key and take Ex-OR this all bytes of confidential message (CM).
Step-3 (Group Formation Phase): Divide the pixel range into four different classes as the first class (0-15), second class (16-31), third class (32-191) and fourth class (192-255).
Step-4 (Guarantee of Reversibility Phase): Embed the confidential message after identifying pixels from the cover picture that have been interpolated.
Step-5 (Data Embedding Phase): If the value of identified pixel is lies between 0 to 15 then 4 LSBs of the recognized pixel should be replaced with the 4 bits of the confidential message through a normal LSB substitution scheme.
Else if the value of identified pixel is lies between 16 to 31 then substitute 3 LSBs of the identified pixel with the 3 bits of confidential message through a normal LSB substitution scheme.
Else if the value of pixel that has been identified is lies between 32 to 191 then substitute 2 LSBs of the identified pixel with the 2 bits of confidential message through a normal LSB substitution scheme.
Else substitute 1 LSBs of the identified pixel with the 1 bits of private message through a normal LSB substitution scheme.
Step-6: For each of the interpolated pel, repeat above step 4 and step 5 again. So, by continuing in the same manner, the stego image A' is obtained.

3.2 Illustration of Modification in Neighbour Mean Interpolation (MNMI)

Figure 2 provides an illustration of how our suggested modified neighbor means interpolation method for scaling the original image of size 5×5. As illustrated in Figure 2 (b), we first put a vacant row and a vacant column between two neighboring rows and columns, respectively. We next assign values of actual picture cell to the previous places as follows: A'(0,0) =A(0,0), A'(0,2) = A(0,2), A'(0,4) = A(0,4), A'(0,6) = A(0,6), A'(0,8) = A(0,8), A'(2,0) = A(2,0), A'(2,2) = A(2,2), A'(2,4) = A(2,4), A'(2,6) = A(2,6), A'(2,8) = A(2,8), A'(4, 0) = A(4,0), A'(4,2) = A(4,2), A'(4,4) = A(4,4), A'(4,6) = A(4,6), A'(4 8) = A(4,8), A'(6,0) = A(6,0), A'(6,2) = A(6,2), A'(6,4) = A(6,4), A'(6,8) = A(6,8), A'(8,0) = A(8,0), A'(8,2) = A(8,2), A'(8,4) = A(8,4), A'(8,6) = A(8,6) and A'(8,8) = A(8,8), The centre pixels of A'(1,1), A'(1,3), A'(1,5), A'(1,7), A'(3,1), A'(3,3), A'(3,5), A'(3,7), A'(5,1), A'(5,3), A'(5,5), A'(5,7), A'(7,1), A'(7,3), A'(7,5) and A'(7,7), are then determined using the real picture cell and Equation (1). Basically, it is the mean of all the picture cell in its close surroundings. The values of the other pixels, such as A'(0,1), A'(1,0), A'(0,3), A'(1,2), A'(0,5), A'(1,4), A'(0,7), A'(1,6), A'(1,8), A'(2,1), A'(3,0), A'(2,3), A'(3,2), A'(2,5), A'(3,4), A'(2,7),A'(3,6), A'(3,8), A'(4,1), A'(5,0), A'(4,3), A'(5,2), A'(4,5), A'(5,4), A'(4,7), A'(5,6), A'(5,8), A'(6,1),A'(7,0), A'(6,3), A'(7,2), A'(6,5), A'(7,4), A'(6,7), A'(7,6), A'(7,8), A'(8, 1), A'(8,3), A'(8,5), and A'(8,7) are calculated as 23,25,31,29,31,32,27,34,29,33,36,40,38,40,38,44,37,41,37,47,34,43,32,33,34,30,33,50,53,41,50,33,38, 26,26,27,55,51,36 and 27 respectively after calculating the values of the centre pixels. According to Figure 4, the scaled-up picture cell of the final row and column are calculated using the pixel values of the respective prior rows and columns. To obtain the final scaled-up picture, repeat this procedure for the complete image.

3.3 Example of Interpolating the Actual Image and Data Embedding Procedure

Figure 2 provides a visual representation of the embedding and interpolating processes. A 5×5 sub-block of the original image A is shown in figure 2(a) has taken into consideration, and the proposed interpolating function A'(t,k) is used to scale the image. The 5×5 sub-block of the original image A is converted into a new 9×9 sub-block of the image A'(Cover Image) by applying the function A'(t,k) which is shown in figure 2. Since the value of the picture cell is more likely to be close to the nearby pixels, this proposed interpolation algorithm gives weight to the closeness of the present pixel when predicting the same. However, nearby pixels also have an impact on the picture cell values. Now, the computed cover image (A') is used to hide the confidential data. Assume that the ciphered restricted data bit stream is T_{db} =”10111000101010010110110001011110001010011111011011111011110111101101100100011 0001000100101111101111001110011010100111110000011 1110”.To add an additional layer of security, secret data is encrypted. Secret information will be concealed using this technique only within the interpolated pixels that are (23,31,31,26,25,20,29,27,32,34,33,31,29,33,39,40,43,36,32,38,36,37, 40,36,42,41,37,34,32,33,46,39,43,37,33,30,30,31,33,50,40,32,26,52,52,50,49,38,35,25,26,27,55,51,36, 26). The intensity of each detected pixel determines how many bits need to be hidden in every pixel, in accordance with the data hiding rule. We may conceal three bits in the pixel in this example since the initial interpolated pixel 23, falls inside the range of 16 to 31. The binary code for 23 is ”00010111,” and the first three bits of the T_{db} are ”101.” The pixel value will be $'00010111'$ = 21 after the unknown data bits have been replaced. Further, we can conceal three bits in the pixel since the next interpolated pixel 31, again falls inside the range of 16 and 31. After the unknown data bits are replaced, the pixel value will be $'00011110' = 30$ since the next three bits of the $T_{db}$are $'110'$ and the binary equivalent of 31 is $'00011111'$. Similarly, we can substitute 3 LSB bits of binary equivalent of 31,26,25,20,29, and 27 (since all values lies between 16 to 31) by next T_{db} value $'001','010','100','101','101'$, and $'100'$ respectively and finally these 31,26,25,20,29 and 27 pixel values are converted in to 25,26,28,21,29,28 respectively. Further, we may conceal two bits in the pixel because the next interpolated picture cell, 32, is lies in the class of 32–91. The binary code for 32 is "00100000," and the next two bits of the T_{db} are "01." The pixel value after the secret data bits have been replaced is "00100001" = 33. So, continuing in the same way, the interpolated pixels contain the hidden information as shown in table II. Figure 3 depicts the entire procedure for the entire block.

3.4 Data Extraction Process

At receiver side, extraction of data has been executed.The receiver in this instance reverses the embedding step to put back the real image and to retrieve the hidden data. In order to regenerate the original message, an 8 bit private key containing XOR operations is ultimately applied to the retrieved message. The receiver can quickly obtain the actual image by eliminating all interpolated pixel or any picture cell carrying confidential data. The following is a description of the entire extraction algorithm:
Input: Stego Image (S')
Output: Private Data
Step-1: In the stego-image, locate the interpolated pixels

$$\begin{array}{|c|c|}\hline A'(0,0) = 8 & A'(0,1) \\ \hline A'(1,0) & A'(1,1) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(0,0) = A(0,0) = 8 \\ A'(0,1) = \frac{A(0,0)+A(0,2)+A(0,4)+A(2,0)+A(2,2)+A(2,4)}{6} = 23 \\ A'(1,0) = \frac{A(0,0)+A(2,0)+A(4,0)+A(0,2)+A(2,2)+A(4,2)}{6} = 25 \\ A'(1,1) = \frac{A(0,0)+A(0,2)+A(2,0)+A(2,2)}{4} = 20 \end{cases}$$

$$\begin{array}{|c|c|}\hline A'(0,2) = 12 & A'(0,3) \\ \hline A'(1,2) & A'(1,3) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(0,2) = A(0,2) = 12 \\ A'(0,3) = \frac{A(0,2)+A(0,4)+A(0,6)+A(2,2)+A(2,4)+A(2,6)}{6} = 31 \\ A'(1,2) = \frac{A(0,2)+A(2,2)+A(4,2)+A(0,4)+A(2,4)+A(4,4)}{6} = 29 \\ A'(1,3) = \frac{A(0,2)+A(0,4)+A(2,2)+A(2,4)}{4} = 27 \end{cases}$$

$$\begin{array}{|c|c|}\hline A'(0,4) = 16 & A'(0,5) \\ \hline A'(1,4) & A'(1,5) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(0,4) = A(0,4) = 16 \\ A'(0,5) = \frac{A(0,4)+A(0,6)+A(0,8)+A(2,4)+A(2,6)+A(2,8)}{6} = 31 \\ A'(1,4) = \frac{A(0,4)+A(2,4)+A(4,4)+A(0,6)+A(2,6)+A(4,6)}{6} = 32 \\ A'(1,5) = \frac{A(0,4)+A(0,6)+A(2,4)+A(2,6)}{4} = 33 \end{cases}$$

$$\begin{array}{|c|c|}\hline A'(0,6) = 15 & A'(0,7) \\ \hline A'(1,6) & A'(1,7) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(0,6) = A(0,6) = 15 \\ A'(0,7) = \frac{A(0,6)*2+A(0,8)*2+A(2,6)+A(2,8)}{6} = 26 \\ A'(1,6) = \frac{A(0,6)+A(2,6)+A(4,6)+A(0,8)+A(2,8)+A(4,8)}{6} = 33 \\ A'(1,7) = \frac{A(0,6)+A(0,8)+A(2,6)+A(2,8)}{4} = 31 \end{cases}$$

$$\begin{array}{|c|}\hline A'(0,8) = 18 \\ \hline A'(1,8) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(0,8) = A(0,8) = 18 \\ A'(1,8) = \frac{A(0,8)*2+A(2,8)*2+A(0,6)+A(2,6)}{6} = 29 \end{cases}$$

$$\begin{array}{|c|c|}\hline A'(2,0) = 20 & A'(2,1) \\ \hline A'(3,0) & A'(3,1) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(2,0) = A(2,0) = 20 \\ A'(2,1) = \frac{A(2,0)+A(2,2)+A(2,4)+A(4,0)+A(4,2)+A(4,4)}{6} = 33 \\ A'(3,0) = \frac{A(2,0)+A(4,0)+A(6,0)+A(2,2)+A(4,2)+A(6,2)}{6} = 36 \\ A'(3,1) = \frac{A(2,0)+A(2,2)+A(4,0)+A(4,2)}{4} = 32 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(2,2) = 39 & \mathrm{A}'(2,3) \\ \hline \mathrm{A}'(3,2) & \mathrm{A}'(3,3) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(2,2) = A(2,2) = 39 \\ A'(2,3) = \frac{A(2,2)+A(2,4)+A(2,6)+A(4,2)+A(4,4)+A(4,6)}{6} = 39 \\ A'(3,2) = \frac{A(2,2)+A(4,2)+A(6,2)+A(2,4)+A(4,4)+A(6,4)}{6} = 38 \\ A'(3,3) = \frac{A(2,2)+A(2,4)+A(4,2)+A(4,4)}{4} = 36 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(2,4) = 42 & \mathrm{A}'(2,5) \\ \hline \mathrm{A}'(3,4) & \mathrm{A}'(3,5) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(2,4) = A(2,4) = 42 \\ A'(2,5) = \frac{A(2,4)+A(2,6)+A(2,8)+A(4,4)+A(4,6)+A(4,8)}{6} = 40 \\ A'(3,4) = \frac{A(2,4)+A(4,4)+A(6,4)+A(2,6)+A(4,6)+A(6,6)}{6} = 37 \\ A'(3,5) = \frac{A(2,4)+A(2,6)+A(4,4)+A(4,6)}{4} = 40 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(2,6) = 62 & \mathrm{A}'(2,7) \\ \hline \mathrm{A}'(3,6) & \mathrm{A}'(3,7) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(2,6) = A(2,6) = 62 \\ A'(2,7) = \frac{A(2,6)*2+A(2,8)*2+A(4,6)+A(4,8)}{6} = 43 \\ A'(3,6) = \frac{A(2,6)+A(4,6)+A(6,6)+A(2,8)+A(4,8)+A(6,8)}{6} = 36 \\ A'(3,7) = \frac{A(2,6)+A(4,6)+A(2,8)+A(4,8)}{4} = 42 \end{cases}$$

$$\begin{array}{|c|}\hline A'(2,8) = 30 \\ \hline A'(3,8) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(2,8) = A(2,8) = 30 \\ A'(3,8) = \frac{A(2,8)*2+A(4,8)*2+A(2,6)+A(4,6)}{6} = 41 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(4,0) = 32 & \mathrm{A}'(4,1) \\ \hline \mathrm{A}'(5,0) & \mathrm{A}'(5,1) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(4,0) = A(4,0) = 32 \\ A'(4,1) = \frac{A(4,0)+A(4,2)+A(4,4)+A(6,0)+A(6,2)+A(6,4)}{6} = 37 \\ A'(5,0) = \frac{A(4,0)+A(6,0)+A(8,0)+A(4,2)+A(6,2)+A(8,2)}{6} = 46 \\ A'(5,1) = \frac{A(4,0)+A(4,2)+A(6,0)+A(6,2)}{4} = 39 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(4,2) = 36 & \mathrm{A}'(4,3) \\ \hline \mathrm{A}'(5,2) & \mathrm{A}'(5,3) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(4,2) = A(4,2) = 36 \\ A'(4,3) = \frac{A(4,2)+A(4,4)+A(4,6)+A(6,2)+A(6,4)+A(6,6)}{6} = 34 \\ A'(5,2) = \frac{A(4,2)+A(6,2)+A(8,2)+A(4,4)+A(6,4)+A(8,4)}{6} = 43 \\ A'(5,3) = \frac{A(4,2)+A(4,4)+A(6,2)+A(6,4)}{4} = 37 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(4,4) = 28 & \mathrm{A}'(4,5) \\ \hline \mathrm{A}'(5,4) & \mathrm{A}'(5,5) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(4,4) = A(4,4) = 28 \\ A'(4,5) = \frac{A(4,4)+A(4,6)+A(4,8)+A(6,4)+A(6,6)+A(6,8)}{6} = 32 \\ A'(5,4) = \frac{A(4,4)+A(6,4)+A(8,4)+A(4,6)+A(6,6)+A(8,6)}{6} = 33 \\ A'(5,5) = \frac{A(4,4)+A(4,6)+A(6,4)+A(6,6)}{4} = 30 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(4,6) = 29 & \mathrm{A}'(4,7) \\ \hline \mathrm{A}'(5,6) & \mathrm{A}'(5,7) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(4,6) = A(4,6) = 29 \\ A'(4,7) = \frac{A(4,6)*2+A(4,8)*2+A(6,6)+A(6,8)}{6} = 33 \\ A'(5,6) = \frac{A(4,6)+A(6,6)+A(8,6)+A(4,8)+A(6,8)+A(8,8)}{6} = 30 \\ A'(5,7) = \frac{A(4,6)+A(4,8)+A(6,6)+A(6,8)}{4} = 31 \end{cases}$$

$$\begin{array}{|c|}\hline A'(4,8) = 46 \\ \hline A'(5,8) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(4,8) = A(4,8) = 46 \\ A'(5,8) = \frac{A(4,8)*2+A(6,8)*2+A(4,6)+A(6,6)}{6} = 33 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(6,0) = 43 & \mathrm{A}'(6,1) \\ \hline \mathrm{A}'(7,0) & \mathrm{A}'(7,1) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(6,0) = A(6,0) = 43 \\ A'(6,1) = \frac{A(6,0)*2+A(8,0)*2+A(6,2)+A(8,2)}{6} = 50 \\ A'(7,0) = \frac{A(6,0)*2+A(8,0)*2+A(6,2)+A(8,2)}{6} = 52 \\ A'(7,1) = \frac{A(6,0)+A(6,2)+A(8,0)+A(8,2)}{4} = 52 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(6,2) = 45 & \mathrm{A}'(6,3) \\ \hline \mathrm{A}'(7,2) & \mathrm{A}'(7,3) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(6,2) = A(6,2) = 45 \\ A'(6,3) = \frac{A(6,2)+A(6,4)+A(6,6)+A(8,2)+A(8,4)+A(8,6)}{6} = 40 \\ A'(7,2) = \frac{A(6,2)*2+A(8,2)*2+A(6,4)+A(8,4)}{6} = 50 \\ A'(7,3) = \frac{A(6,2)+A(6,4)+A(8,2)+A(8,4)}{4} = 49 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(6,4) = 37 & \mathrm{A}'(6,5) \\ \hline \mathrm{A}'(7,4) & \mathrm{A}'(7,5) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(6,4) = A(6,4) = 37 \\ A'(6,5) = \frac{A(6,4)+A(6,6)+A(6,8)+A(8,4)+A(8,6)+A(8,8)}{6} = 32 \\ A'(7,4) = \frac{A(6,4)*2+A(8,4)*2+A(6,6)+A(8,6)}{6} = 38 \\ A'(7,5) = \frac{A(6,4)+A(6,6)+A(8,4)+A(8,6)}{4} = 35 \end{cases}$$

$$\begin{array}{|c|c|}\hline \mathrm{A}'(6,6) = 26 & \mathrm{A}'(6,7) \\ \hline \mathrm{A}'(7,6) & \mathrm{A}'(7,7) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(6,6) = A(6,6) = 26 \\ A'(6,7) = \frac{A(6,6)*2+A(6,6)*2+A(8,6)+A(8,8)}{6} = 26 \\ A'(7,6) = \frac{A(6,6)*2+A(8,6)*2+A(6,8)+A(8,8)}{6} = 25 \\ A'(7,7) = \frac{A(6,6)+A(6,8)+A(8,6)+A(8,8)}{4} = 26 \end{cases}$$

$$\begin{array}{|c|}\hline A'(6,8) = 24 \\ \hline A'(7,8) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(6,8) = A(6,8) = 24 \\ A'(7,8) = \frac{A(6,8)*2+A(8,8)*2+A(6,6)+A(8,6)}{6} = 27 \end{cases}$$

$$\begin{array}{|c|}\hline A'(8,0) = 62 \\ \hline A'(8,1) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(8,0) = A(8,0) = 62 \\ A'(8,1) = \frac{A(8,0)*2+A(8,2)*2+A(6,0)+A(6,2)}{6} = 55 \end{cases}$$

$$\begin{array}{|c|}\hline A'(8,2) = 59 \\ \hline A'(8,3) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(8,2) = A(8,2) = 59 \\ A'(8,1) = \frac{A(8,2)*2+A(8,4)*2+A(6,2)+A(6,4)}{6} = 51 \end{cases}$$

$$\begin{array}{|c|}\hline A'(8,4) = 53 \\ \hline A'(8,5) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(8,4) = A(8,4) = 53 \\ A'(8,5) = \frac{A(8,4)*2+A(8,6)*2+A(6,4)+A(6,6)}{6} = 51 \end{cases}$$

$$\begin{array}{|c|}\hline A'(8,6) = 22 \\ \hline A'(8,7) \\ \hline \end{array} \Longrightarrow \begin{cases} A'(8,6) = A(8,6) = 22 \\ A'(8,7) = \frac{A(8,6)*2+A(8,8)*2+A(6,6)+A(6,8)}{6} = 27 \end{cases}$$

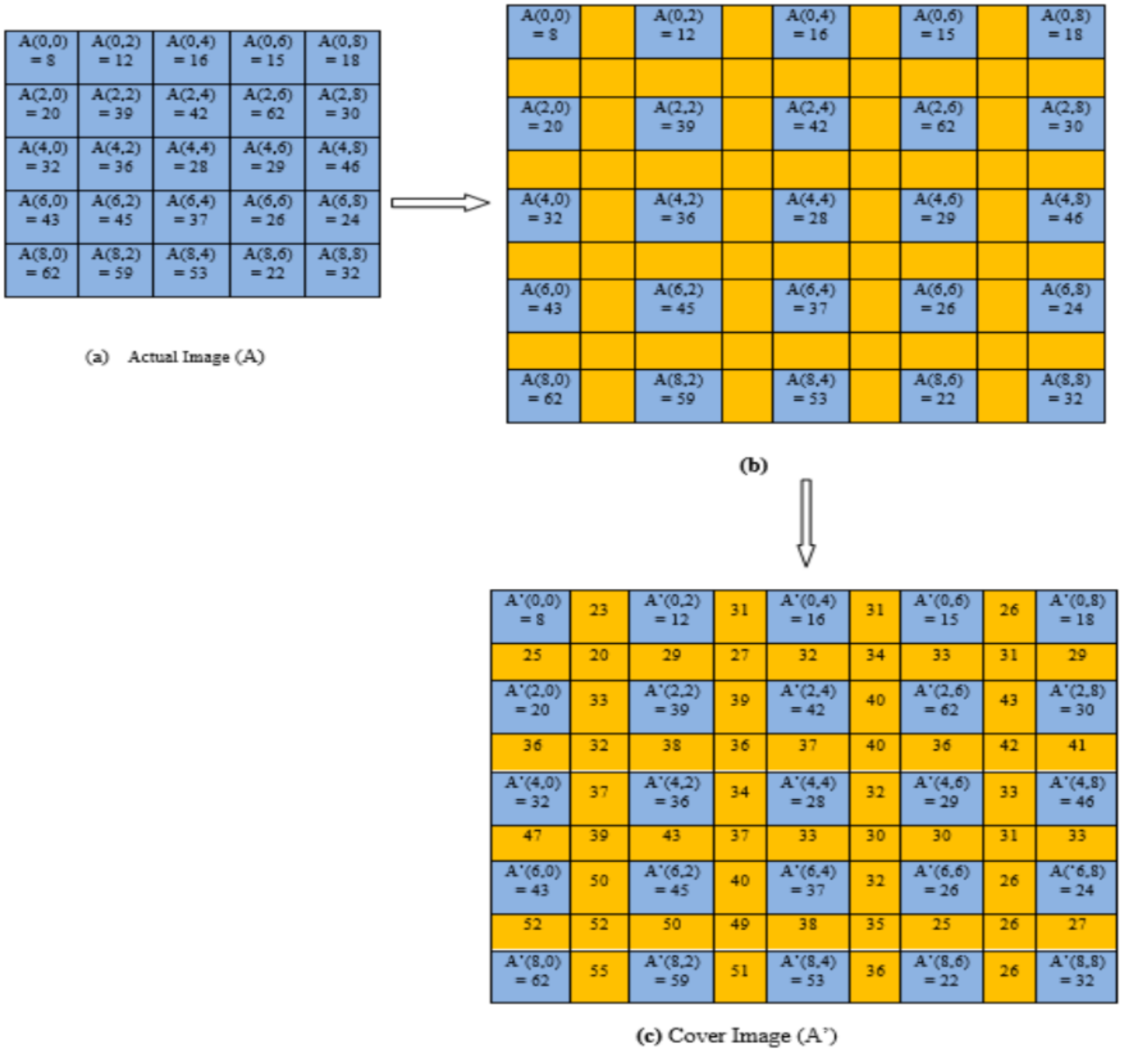


Figure 2. An Illustration of Modification in Neighbour Mean Interpolation (MNMI)

Step-2: Extract 4 LSBs from the detected picture cell and add them to the confidential data stream if the value picture cell lies between 0 to 15.
If not, the recognised pixel's 3 LSBs are extracted and added to the unknown data stream if its pixel value lies between 16 to 31.
Else if the picture cell value of the identified pixel is lies between 32 to 191 then extracts 2 LSBs of the picture cell and adds it to the unknown data stream.
Otherwise extract 1 LSBs of the pixel and adds it to the unknown data stream.
Step-3: For every interpolated pixel, repeat above step 2.
Step-4: To recover the original secret data bit stream, XOR the obtained secret data in the bytes using the secret key.
Step-5: Get the actual cover image by removing the interpolated pixels.

3.5 Examples of Extraction Process

Assuming we have a 9×9 sub-block of stego-image, the interpolated pixels in the stego-image that are 21,30,25,26,28,21,29,28,33,33,35,28,26,34,37,37,43,37,34,39,39,38,43,39,41,43,38,35,33,34, 45,36,41,38,32,28,26,26,35,51,42,35,30,53,55,48,51,37,33,25,31,28,52,49,39 and 30 are first detected in order to extract the confidential data from the stego-image. The initial interpolating pixel, 21, is in the second group, or the group starting with 16 to 31. Therefore, in accordance with this proposed algorithm, 3 LSB will be extracted and added to the confidential data if the interpolating picture cell belongs to the second class. This interpolating pixel is then converted to binary form, which equals (00010101)2 ,from which the 3 LSB, or 101, is retrieved and added to the secret data bit stream. As a result, the first three bits of the secret data are 101. Next, we look for the pixel 30, which is also in the second group (16–31); similarly, the 3-LSB or 110, will be retrieved and added to the private data bit stream. As a result, by continuing in this technique, we obtain the entire private data bit stream as 10111000101010010110110001011110001010011111011011111011110111 1011011001000110001000100101111101111001110011010100111110000011111."

Table II: **Procedure of secret data embedding in to interpolated image**

$23=(00010111)_2 \Longrightarrow (00010101)_2 = (21)_{10}\ [T_{db} = 101]$	$32 = (00100000)_2 \Longrightarrow (00100001)_2 = (33)_{10}[T_{db} = 01]$
$31=(00011111)_2 \Longrightarrow (00011110)_2 = (30)_{10}\ [T_{db} = 110]$	$33 = (00100001)_2 \Longrightarrow (00100010)_2 = (34)_{10}[T_{db} = 10]$
$31=(00011111)_2 \Longrightarrow (00011001)_2 = (25)_{10}\ [T_{db} = 001]$	$46 = (00101110)_2 \Longrightarrow (00101101)_2 = (45)_{10}[T_{db} = 01]$
$26=(00011010)_2 \Longrightarrow (00011010)_2 = (26)_{10}\ [T_{db} = 010]$	$39 = (00100111)_2 \Longrightarrow (00100100)_2 = (36)_{10}[T_{db} = 00]$
$25=(00011001)_2 \Longrightarrow (00011100)_2 = (28)_{10}\ [T_{db} = 100]$	$43 = (00101011)_2 \Longrightarrow (00101001)_2 = (41)_{10}[T_{db} = 01]$
$20=(00010100)_2 \Longrightarrow (00010101)_2 = (21)_{10}\ [T_{db} = 101]$	$37 = (00100101)_2 \Longrightarrow (00100110)_2 = (38)_{10}[T_{db} = 10]$
$29=(00011101)_2 \Longrightarrow (00011101)_2 = (29)_{10}\ [T_{db} = 101]$	$33 = (00100001)_2 \Longrightarrow (00100000)_2 = (32)_{10}[T_{db} = 00]$
$27=(00011011)_2 \Longrightarrow (00011100)_2 = (28)_{10}\ [T_{db} = 100]$	$30= (00011110)_2(\Longrightarrow 00011100)_2 = (28)_{10}\ [T_{db} = 100]$
$32=(00100000)_2 \Longrightarrow (00100001)_2 = (33)_{10}\ [T_{db} = 01]$	$30 = (00011110)_2 \Longrightarrow (00011010)_2 = (26)_{10}[T_{db} = 010]$
$34=(00100010)_2 \Longrightarrow (00100001)_2 = (33)_{10}\ [T_{db} = 01]$	$31 = (00011111)_2 \Longrightarrow (00011010)_2 = (26)_{10}[T_{db} = 010]$
$33=(00100001)_2 \Longrightarrow (00100011)_2 = (35)_{10}\ [T_{db} = 11]$	$33 = (00100001)_2 \Longrightarrow (00100011)_2 = (35)_{10}[T_{db} = 11]$
$31=(00011111)_2 \Longrightarrow (00011100)_2 = (28)_{10}\ [T_{db} = 100]$	$50 = (00110010)_2 \Longrightarrow (00110011)_2 = (51)_{10}[T_{db} = 11]$
$29=(00011101)_2 \Longrightarrow (00011010)_2 = (26)_{10}\ [T_{db} = 010]$	$40 = (00101000)_2 \Longrightarrow (00101010)_2 = (42)_{10}[T_{db} = 10]$
$33=(00100001)_2 \Longrightarrow (00100010)_2 = (34)_{10}\ [T_{db} = 10]$	$32 = (00100000)_2 \Longrightarrow (00100011)_2 = (35)_{10}[T_{db} = 11]$
$39=(00100111)_2 \Longrightarrow (00100110)_2 = (37)_{10}\ [T_{db} = 01]$	$26 = (00011010)_2 \Longrightarrow (00011110)_2 = (30)_{10}\ [T_{db} = 110]$
$40=(00101000)_2 \Longrightarrow (00101011)_2 = (37)_{10}\ [T_{db} = 11]$	$52 = (00110100)_2 \Longrightarrow (00110101)_2 = (53)_{10}[T_{db} = 01]$
$43=(00101011)_2 \Longrightarrow (00101011)_2 = (43)_{10}\ [T_{db} = 11]$	$52 = (00110100)_2 \Longrightarrow (00110111)_2 = (55)_{10}[T_{db} = 11]$
$36=(00100100)_2 \Longrightarrow (00100101)_2 = (37)_{10}\ [T_{db} = 01]$	$50 = (00110010)_2 \Longrightarrow (00110000)_2 = (48)_{10}[T_{db} = 00]$

$32{=}(00100000)_2 \Longrightarrow (00100010)_2 = (34)_{10}\ [T_{db} = 10]$	$49 = (00110001)_2 \Longrightarrow (00110011)_2 = (51)_{10}[T_{db} = 11]$
$38{=}(00100110)_2 \Longrightarrow (00100111)_2 = (39)_{10}\ [T_{db} = 11]$	$38 = (00100110)_2 \Longrightarrow (00100101)_2 = (37)_{10}[T_{db} = 01]$
$36{=}(00100100)_2 \Longrightarrow (00100111)_2 = (39)_{10}\ [T_{db} = 11]$	$35 = (00100011)_2 \Longrightarrow (00100001)_2 = (33)_{10}[T_{db} = 01]$
$37{=}(00100101)_2 \Longrightarrow (00100110)_2 = (38)_{10}\ [T_{db} = 10]$	$25 = (00011001)_2 \Longrightarrow (00011001)_2 = (25)_{10}[T_{db} = 001]$
$40{=}(00101000)_2 \Longrightarrow (00101011)_2 = (37)_{10}\ [T_{db} = 11]$	$26 = (00011010)_2 \Longrightarrow (00011111)_2 = (31)_{10}[T_{db} = 111]$
$36{=}(00100100)_2 \Longrightarrow (00100111)_2 = (39)_{10}\ [T_{db} = 11]$	$27 = (00011011)_2 \Longrightarrow (00011100)_2 = (28)_{10}[T_{db} = 100]$
$42{=}(00101010)_2 \Longrightarrow (00101001)_2 = (41)_{10}\ [T_{db} = 01]$	$55 = (00110111)_2 \Longrightarrow (00110100)_2 = (52)_{10}[T_{db} = 00]$
$41{=}(00101001)_2 \Longrightarrow (00101011)_2 = (43)_{10}\ [T_{db} = 11]$	$51 = (00110011)_2 \Longrightarrow (00110001)_2 = (49)_{10}[T_{db} = 01]$
$37{=}(00100101)_2 \Longrightarrow (00100110)_2 = (38)_{10}\ [T_{db} = 10]$	$36 = (00100100)_2 \Longrightarrow (00100111)_2 = (39)_{10}[T_{db} = 11]$
$34{=}(00100010)_2 \Longrightarrow (00100011_)2 = (35)_{10}\ [T_{db} = 11]$	$26 = (00011010)_2 \Longrightarrow (00011110)_2 = (30)_{10}[T_{db} = 110]$

A' (0,0) = 8	21	A' (0,2) = 12	30	A' (0,4) = 16	25	A' (0,6) = 15	26	A' (0,8) = 18
28	21	29	28	33	33	35	28	26
A' (2,0) = 20	34	A' (2,2) = 39	37	A' (2,4) = 42	47	A' (2,6) = 62	43	A' (2,8) = 30
37	34	39	39	38	43	39	41	43
A' (4,0) = 32	38	A' (4,2) = 36	35	A' (4,4) = 28	33	A' (4,6) = 29	34	A' (4,8) = 46
45	36	41	38	32	28	26	26	35
A' (6,0) = 43	51	A' (6,2) = 45	42	A' (6,4) = 37	35	A' (6,6) = 26	30	A' (6,8) = 24
53	55	48	51	37	33	25	31	28
A' (8,0) = 62	52	A' (8,2) = 59	49	A' (8,4) = 53	39	A' (8,6) = 322	30	A' (8,8) = 32

Stego Image (S')

Figure 3. An illustration of suggested method for interpolating image and embedding private bit stream

4. RESULTS & DISCUSSION

This section compares and contrasts the performance of this suggested approach with that of other well-known and current schemes. In order to cover the widest range of image attributes, we have chosen twelve photographs as the cover media. Lena, Airplane, House, Peppers, Tiffany, and Splash are six different images having size 512×512 each are shown in figure 4 (a)-(f) respectively. We have used MATLAB tool for implementing the suggested strategy. A pseudo-random number generator is employed to create the private data used in the investigations. Four frequently used parameters—EC, PSNR, embedding speed, and embedding time are used to analyze how well existing and proposed methods work. The PSNR measures the stego-image quality in relation to the cover picture, and the concealing capacity refers to the quantity of confidential data bits embedded in the cover image. It is a widely used metric to assess the consistency or dependability of an image. The following equation can be used to determine the PSNR value:

$$PSNR = 10\log_{10}\frac{(255)^2}{\sigma}$$

Where σ = Mean Square Error which is defined as follows:

$$\sigma = \frac{1}{I \times I}\sum_{m=1}^{I}\sum_{n=1}^{I}\left(IM_{mn} - IM'_{mn}\right)^2$$

Where, IM_{mn} and IM'_{mn} stand for the pixels in the mth row and nth column of the I×I sized cover picture IM and stego-image IM' respectively.

The higher visual quality of the stego-image is generally indicated by a higher PSNR score.A new data hiding technique for interpolated images as well as a advanced interpolation method that is an improvement over the current NMI approach are both included in this proposed scheme. The following discussion examines how well this changed NMI approach performed and how the data concealing method worked.

4.1 Performance Assessment of Proposed Scheme

In this part, Table III and Table IV provide experimental findings for our suggested and current interpolation methods for all test snaps. In order to conduct a critical analysis, we contrasted the effectiveness of our proposed method with those of other approaches which is proposed by Zung (Jung and Yoo, 2015b), Zhang (Zhang et al., 2017), Shaik (Shaik and V, 2019), Bai (Bai et al., 2022) and Malik (Malik et al., 2020). Table III makes it very clear that, in terms of PSNR value, the suggested method outperforms than existing methods. The PSNR value is increased by a minimum 10.41% and a maximum 25.68% as compared to Malik et. al. work (Malik et al., 2020) by using this proposed interpolation approach, which is the best of the available techniques. This proposed method uses all the nearby picture cell while predicting the centre picture cell, which is the primary factor in our method's ability to produce improved PSNR values.

Table IV shows the EC in bits for various images. EC computed in various author's work such as Jung(Jung and Yoo, 2015b), Zhang (Zhang et al., 2017), Shaik (Shaik and V, 2019), Bai (Bai et al., 2022) and Malik (Malik et al., 2020) and compared with proposed scheme. It is clear that the EC is increased by a minimum 09.99% and maximum 31.00% as compared to Malik et. al. work (Malik et al., 2020) and proposed work.

The output image has higher quality in suggested approach because this suggested hiding approach consider the features of the HVS before embedding the confidential data in the picture cell of the cover image. Additionally, it essentially makes fewer changes to the low-intensity pixels and more changes to the high-intensity pixels because a low-intensity pixel's intensity value may change significantly with more change, which will raise suspicion, whereas there is no chance of such suspicion among intruders if the same amount of change is made to a high-intensity pixel. It also carries over the excellent interpolated/cover image, which is quite beneficial in achieving performance objectives. As a result, the suggested approach can deliver a high-quality stego-image with a high capacity for data concealing. The suggested strategy is also reversible because it simply adjusts the interpolated picture cell to hide the confidential data, which can be retrieved at the receiver side using the suggested interpolation technique.

(a) Lena (b) Airplane (c) House

(d) Peppers (e) Tiffany (f) Splash

Figure 4. Cover Image

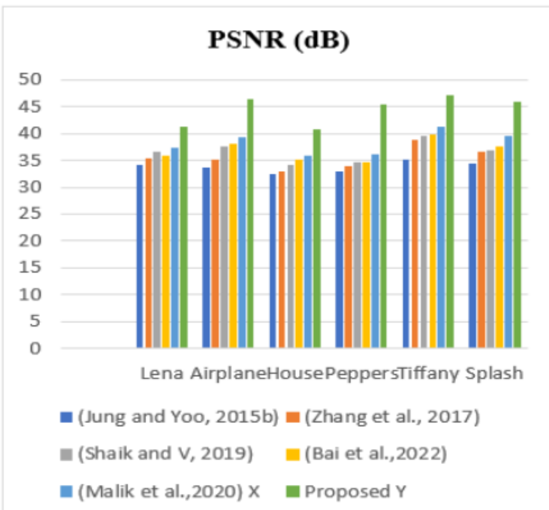
Figure 6 & 7 shown the embedding time and embedding speed results for the suggested technique as well as alternative interpolation-based data hiding schemes that are currently in use, such as Jung (Jung and Yoo, 2015b), Zhang (Zhang et al., 2017), Shaik (Shaik and V, 2019), Bai (Bai et al., 2022) and Malik (Malik et al., 2020). The suggested approach has the best embedding speed and the least embedding time, as shown in Figure 6 & 7 . Due to simplicity in suggested scheme as we just substitutes the secret data bits for the LSBs of the pixels instead of the complicated calculations used by other methods [(Jung and Yoo, 2015b)(Zhang et al., 2017)(Shaik and V, 2019)(Bai et al., 2022)(Malik et al., 2020)] is the primary factor in its higher performance.
The lesser discrepancy between the stego-image and the cover image, as indicated by the lower failure rate, suggests that the SPAM assault cannot find the hidden secret data. According to the intensity levels of the picture cells, the suggested system selectively embeds the secret data to reduce error rates. Consequently, we can conclude that the suggested strategy is sufficiently resistant to the SPAM assault.

Table III: Comparison of PSNR of various existing and suggested interpolation scheme

Image	(Jung and Yoo, 2015b)	(Zhang et al., 2017)	(Shaik and V, 2019)	(Bai et al., 2022)	(Malik et al., 2020) X	Proposed Y	Improvement % (X/Y)*X
Lena	34.23	35.46	36.53	35.98	37.34	41.23	10.41
Airplane	33.69	35.12	37.62	38.20	39.43	46.41	17.70
House	32.51	32.87	34.21	35.16	35.78	40.67	13.66
Peppers	32.86	33.89	34.69	34.76	36.21	45.51	25.68
Tiffany	35.23	38.78	39.50	39.87	41.35	47.20	14.14
Splash	34.36	36.64	36.94	37.67	39.60	45.91	15.93

Table IV: Comparison of EC of various existing and suggested interpolation scheme

Image	(Jung and Yoo, 2015b)	(Zhang et al., 2017)	(Shaik and V, 2019)	(Bai et al., 2022)	(Malik et al., 2020) X	Proposed Y	Improvement % (X/Y)*X
Lena	142602	158925	158995	167932	189265	226729	19.79
Airplane	130875	139872	143267	164269	192345	251974	31.00
House	147268	148923	156782	178425	198725	227459	14.45
Peppers	154828	178527	168942	175289	198267	236532	19.29
Tiffany	136871	158432	172678	179267	208715	229567	09.99
Splash	142143	148952	162987	182654	219452	269436	22.78



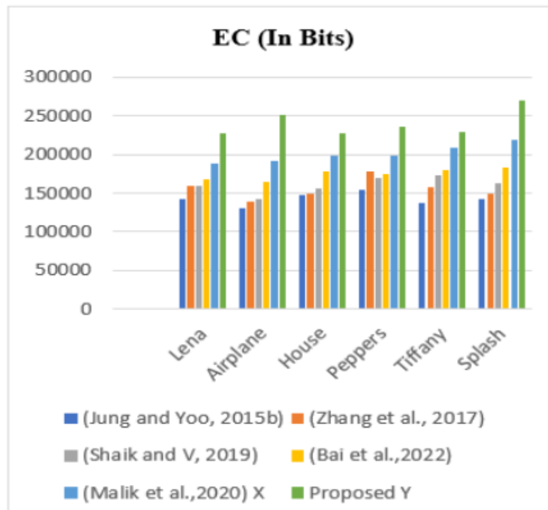


Figure 5. Comparative study of PSNR & EC of several existing and proposed scheme

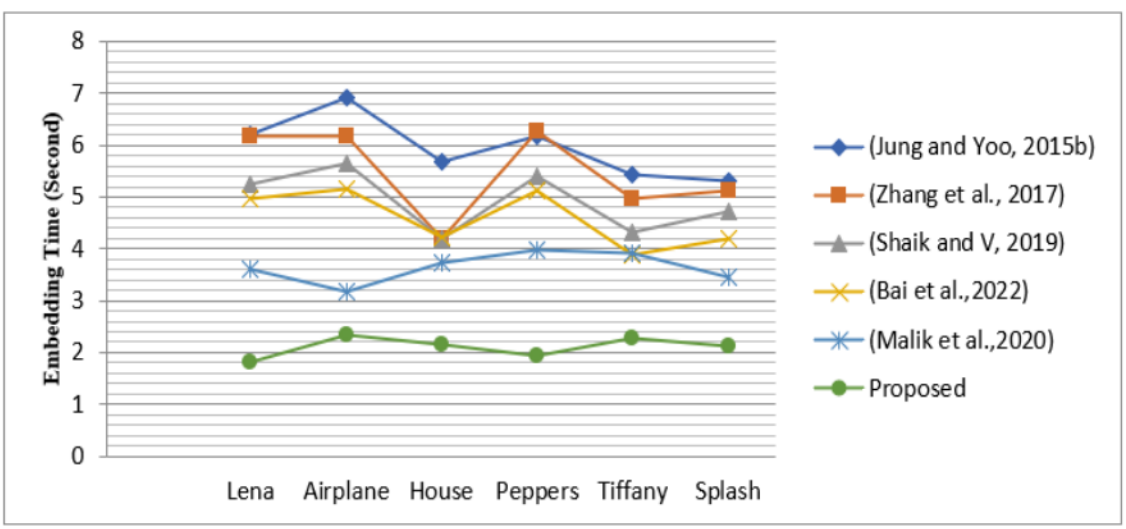


Figure 6. Embedding Time for the current techniques and the suggested approach for taking various images

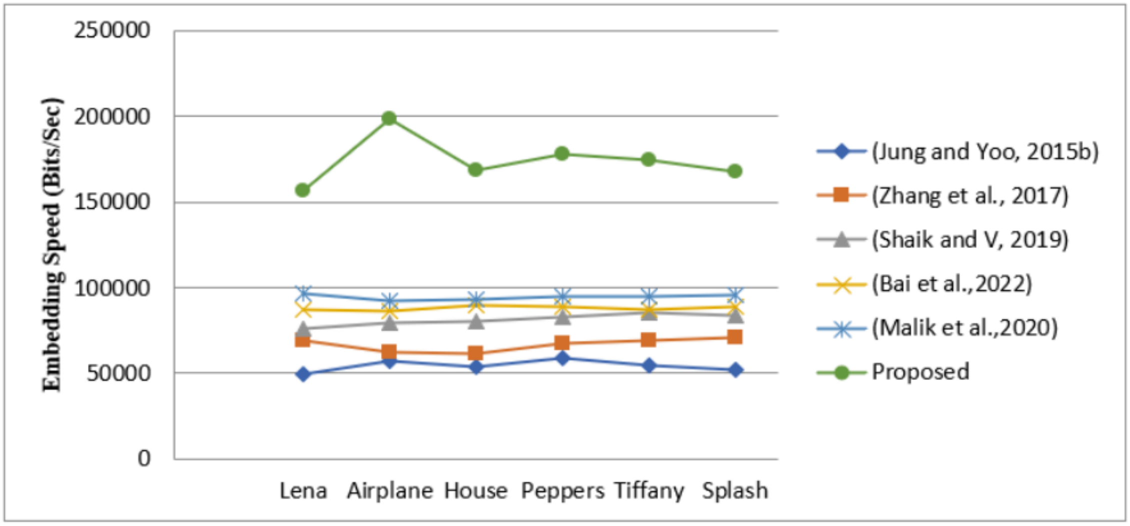


Figure 7. Embedding Speed for the current techniques and the suggested approach for taking various images

5. CONCLUSION

In this article, a new RDH system and innovative interpolation approach are suggested. The interpolation approach enhances the NMI method already in use to produce interpolated images of higher quality. For t embedding the private data into the interpolated picture cell and achieving high concealing capacity with high-quality stego-images, the suggested data hiding technique considers the features of the HVS. The value of a pixel's intensity determines how many bitswill be included in the confidential data. The cover image is guaranteed to be reversible because the confidential data is only concealed in the interpolated picture cell. According to experimental findings, the suggested data hiding strategy outperforms by an average of 16.25% and19.55% increases in PSNR value and EC, respectively as compared to (Malik et al., 2020).The proposed scheme has also less embedding time and good embedding speed with respect to the current existing method (Malik et al., 2020). As a result, it is obvious that the suggested strategy outperforms all other current ones in terms of image quality and ability to conceal data.

In conclusion, when compared to pertinent interpolation-based strategies described in the literature, our RDH technique provides a better visual quality of the stego image and a higher data concealing capacity. The degree of trade-off between the stego image quality and data hiding capability can also be adjusted. This was accomplished without raising the computational complexity. No robustness testing against assaults were provided because the suggested technique is supposed to be fragile, as is typically the case with RDH strategies. The proposed method is typically used for medical image authentication, military satellite imaging, and other tasks requiring precise recovery of the cover image.

At last, even though we know that the distortion caused by the interpolation expansion step was minimised by our interpolation method, we still think that the distortions caused by this phase are the main weakness of interpolation-based data hiding strategies. Future research might therefore focus on creating interpolation algorithms that are even more effective in reducing distortions. The development of adaptive interpolation techniques and new RDH schemes, which embed the hidden data on both actual and interpolated picture cell to increase data concealing capacity without sacrificing reversibility, can be the objective of future study.

References

Allebach, J. and Wong, P. W. 1996. Edge-directed interpolation. In *Proceedings of 3rd IEEE International Conference on Image Processing*. Vol. 3. IEEE, 707–710.

Bai, X., Chen, Y., Duan, G., Feng, C., and Zhang, W. 2022. A data hiding scheme based on the difference of image interpolation algorithms. *Journal of Information Security and Applications 65*, 103068.

Benseddik, M. L., Zebbiche, K., Azzaz, M. S., and Sadoudi, S. 2022. Interpolation-based reversible data hiding in the transform domain for fingerprint images. *Multimedia Tools and Applications 81,* 14, 20329–20356.

Chang, Y.-T., Huang, C.-T., Lee, C.-F., and Wang, S.-J. 2013. Image interpolating based data hiding in conjunction with pixel-shifting of histogram. *The Journal of Supercomputing 66*, 1093–1110.

Coatrieux, G., Pan, W., Cuppens-Boulahia, N., Cuppens, F., and Roux, C. 2012. Reversible watermarking based on invariant image classification and dynamic histogram shifting. *IEEE Transactions on information forensics and security 8,* 1, 111–120.

Fan, M., Zhong, S., and Xiong, X. 2023. Reversible data hiding method for interpolated images based on modulo operation and prediction-error expansion. *IEEE Access 11*, 27290–27302.

Hong, W. and Chen, T.-S. 2011. Reversible data embedding for high quality images using interpolation and reference pixel distribution mechanism. *Journal of Visual Communication and Image Representation 22,* 2, 131–140.

Hu, J. and Li, T. 2015. Reversible steganography using extended image interpolation technique. *Computers & Electrical Engineering 46*, 447–455.

Huang, Z., Lin, Y., and Chen, X. 2023. A block-based adaptive high fidelity reversible data hiding scheme in interpolation domain. *Multimedia Tools and Applications*, 1–22.

Jana, S., Jana, B., Lu, T. C., and Vo, T. N. 2022. Reversible data hiding scheme exploiting center folding with fuzzy weight strategy. *Journal of Information Security and Applications 69*, 103276.

Jung, K.-H. 2018. A survey of interpolation-based reversible data hiding methods. *Multimedia Tools and Applications 77*, 7795–7810.

Jung, K.-H. and Yoo, K.-Y. 2015a. High-capacity index based data hiding method. *Multimedia Tools and Applications 74*, 2179–2193.

Jung, K.-H. and Yoo, K.-Y. 2015b. Steganographic method based on interpolation and lsb substitution of digital images. *Multimedia Tools and Applications 74*, 2143–2155.

Jung, K.-H. and Yoo, K.-Y. 2015c. Steganographic method based on interpolation and lsb substitution of digital images. *Multimedia Tools and Applications 74*, 2143–2155.

Jung, K.-H. and Yoo, K.-Y. 2015d. Steganographic method based on interpolation and lsb substitution of digital images. *Multimedia Tools and Applications 74*, 2143–2155.

Kim, H. J., Sachnev, V., Shi, Y. Q., Nam, J., and Choo, H.-G. 2008. A novel difference expansion transform for reversible data embedding. *IEEE Transactions on Information Forensics and Security 3,* 3, 456–465.

Kumar, R., Chand, S., and Singh, S. 2015. An efficient text steganography scheme using unicode space characters. *Int. J. Forensic Comput. Sci 10,* 1, 8–14.

Kumar, R., Chand, S., and Singh, S. 2018. A reversible high capacity data hiding scheme using combinatorial strategy. *International Journal of Multimedia Intelligence and Security 3,* 2, 146–161.

Lee, C.-F. and Huang, Y.-L. 2012. An efficient image interpolation increasing payload in reversible data hiding. *Expert systems with applications 39,* 8, 6712–6719.

Lin, C.-C., Tai, W.-L., and Chang, C.-C. 2008. Multilevel reversible data hiding based on histogram modification of difference images. *Pattern Recognition 41,* 12, 3582–3591.

Lu, T.-C. 2018. Interpolation-based hiding scheme using the modulus function and re-encoding strategy. *Signal Processing 142*, 244–259.

Lu, T.-C., Chang, C.-C., and Huang, Y.-H. 2014. High capacity reversible hiding scheme based on interpolation, difference expansion, and histogram shifting. *Multimedia tools and* *applications 72*, 417–435.

Malik, A., Sikka, G., and Verma, H. K. 2017a. Image interpolation based high capacity reversible data hiding scheme. *Multimedia Tools and Applications 76*, 24107–24123.

Malik, A., Sikka, G., and Verma, H. K. 2017b. An image interpolation based reversible data hiding scheme using pixel value adjusting feature. *Multimedia Tools and Applications 76*, 13025–13046.

Malik, A., Sikka, G., and Verma, H. K. 2020. A reversible data hiding scheme for interpolated images based on pixel intensity range. *Multimedia Tools and Applications 79*, 18005–18031.

Malik, A., Singh, S., and Kumar, R. 2018. Recovery based high capacity reversible data hiding scheme using even-odd embedding. *Multimedia Tools and Applications 77*, 15803–15827.

Meikap, S. and Jana, B. 2018. Directional pvo for reversible data hiding scheme with image interpolation. *Multimedia Tools and Applications 77,* 23, 31281–31311.

Mohammad, A. A., Al-Haj, A., and Farfoura, M. 2019a. An improved capacity data hiding technique based on image interpolation. *Multimedia Tools and Applications 78*, 7181–7205.

Mohammad, A. A., Al-Haj, A., and Farfoura, M. 2019b. An improved capacity data hiding technique based on image interpolation. *Multimedia Tools and Applications 78*, 7181–7205.

Qi, W., Zhang, T., Li, X., Ma, B., and Guo, Z. 2023. Reversible data hiding based on prediction-error value ordering and multiple-embedding. *Signal Processing 207*, 108956.

Ren, F., Liu, Y., Zhang, X., and Li, Q. 2023. Reversible information hiding scheme based on interpolation and histogram shift for medical images. *Multimedia Tools and Applications*, 1–27.

Shaik, A. and V, T. 2019. High capacity reversible data hiding using 2d parabolic interpolation. *Multimedia Tools and Applications 78*, 9717–9735.

Shi, Y.-Q., Li, X., Zhang, X., Wu, H.-T., and Ma, B. 2016. Reversible data hiding: advances in the past two decades. *IEEE access 4*, 3210–3237.

Tang, M., Hu, J., and Song, W. 2014. A high capacity image steganography using multi-layer embedding. *Optik 125,* 15, 3972–3976.

Wahed, M. A. and Nyeem, H. 2019. High capacity reversible data hiding with interpolation and adaptive embedding. *PloS one 14,* 3, e0212093.

Wang, X.-T., Chang, C.-C., Nguyen, T.-S., and Li, M.-C. 2013. Reversible data hiding for high quality images exploiting interpolation and direction order mechanism. *Digital Signal Processing 23,* 2, 569–577.

Xiong, X., Chen, Y., Fan, M., and Zhong, S. 2022. Adaptive reversible data hiding algorithm for interpolated images using sorting and coding. *Journal of Information Security and Applications 66*, 103137.

Xiong, X., Wang, L., Li, Z., Ye, C., Chen, Y., Fan, M., and Zhu, Y. 2022. An adaptive high capacity reversible data hiding algorithm in interpolation domain. *Signal Processing 194*, 108458.

Zhang, X., Sun, Z., Tang, Z., Yu, C., and Wang, X. 2017. High capacity data hiding based on interpolated image. *Multimedia Tools and Applications 76*, 9195–9218.

Abhinandan Tripathi is Ph.D. student in Department of Information Technology & Computer Application, Madan Mohan Malaviya University of Technology, Gorakhpur, India. He received B.Tech. & M.Tech. degree in Computer Science & Engineering in 2009 and 2012 respectively. He boasts a remarkable portfolio of more than 12 papers published in International Journals and Conferences. He has supervised 4 M.Tech. students as well. His expertise lies in Networks, Blockchain, Data Security and Image processing, which forms the core focus of his research pursuits.
Email: abhinandan2787@gmail.com

Jay Prakash is working as associate professor in the Department of Information Technology & Computer Application, Madan Mohan Malaviya University of Technology, Gorakhpur, India and has a total teaching experience of 23 years. He has published over 35 papers in National & International Journals & Conferences. His core teaching and research interests are in the domain of Networks, Parallel & Distributed Computing, Architecture, Video & Image processing. He conducts research in the design & analysis of various applications of networks and Distributed Environment. He also uses the techniques from Machine Learning, Soft Computing. His research focuses on Noise suppression in Video & Image in the transform domain, various protocols of networks, Antenna in Communication, and Gateway Discovery in Adhoc Networks for internet access.
Email: jpr_1998@yahoo.co.in