High-Capacity Reversible Data Hiding scheme using prediction tuning model

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ABSTRACT

With the growing importance of data security and information hiding, techniques of data hiding inimages have become widespread.Existing reversible data hiding techniques face the problem of errors due to inaccurate results of prediction models as well as the scope of improvement in terms of embedding capacity, which decreases the efficiency of security of sensitive data. Here, we propose a hyperparameter beta (β) for combining two regression models trained with different data.The first regression model is trained over the entire image and the second regression model with a limited block of surrounding pixels in neighboring regions of pixels in the image. For optimal results,parameters are tuned using Particle Swarm Optimization (PSO), and we have validated our results on standard test images. This technique outperforms the past techniques by improving data hiding in terms of parameters like embedding capacity (embedding rate), eliminating the errors from wrong predictions while keeping the visual quality of images preserved.

1. INTRODUCTION

Data hiding has been a broadly researched area of study for the security of data from unwanted access. Data hiding is a process in which the sender hides the critical data into a media preventingit from attackers. The key requirements of data hiding are the high capacity of hiding the secret data, reversibility of the media and multiple data insertions into an image. Image-based data hiding is mainly categorized into three parts: Digital watermarking, Steganography and Reversible data hiding (RDH). Digital Watermarking [1] places digital data into a digital cover file that accepts the file's copyright information. Steganography [2] changes the cover media in a way that only the sender and the receiver can detect the hidden sensitive data in an image. Digital Watermarking and steganography do not consider how to recover the original image after data extraction from the image. Importance of Reversible Data Hiding (RDH), also known as lossless data hiding in this field of hiding sensitive data in images, is imperative as it aims to achieve recovery of images withminimized errors. Various techniques have been utilized to develop efficient models for better outcomes in terms of embedding capacity and errors during recovery. In the process of reversible data hiding, the sender hides the critical information into an image such that the receiver can recover the original image after the data extraction. Recovery of the original image after data extraction is an important aspect because in many scenarios like medical image processing, remote sensing and military application where little changes in the original image can cause serious consequences. Therefore, it requires full recovery of the original image after data extraction. Through this paper, we have tried to explore the possibility of using a novel RDH technique which aims to improve the embedding rate, i.e. the maximum amount of data can be embedded in an image. Our technique also focusses on minimum degradation of quality after embedding the secretdata, i.e. maintaining the visual quality of an image. We have evaluated the performance of our study in terms of bits per pixel (bpp) which is a measure of Embedding capacity, prediction errorswhich is a count of errors in the prediction model and

Peak Signal to Noise Ratio (PSNR) value for measuring the visual

2. LITERATURE SURVREY

There are many conventional information hiding methods, including Least Significant Bit (LSB) insertion, Histogram Shifting (HS) and Difference Expansion (DE), to name a few. These techniques are studied extensively and many of their variants are proposed [1, 2, 3] to achieve a balance trade-off among embedding capacity, image quality, robustness against attacks, etc. However, these techniques are not widely adopted into the usual operations performed by the users, and often they are implemented as an additional step after the image is processed. In most cases, the user has to explicitly install or develop the data embedding algorithm to enable data embedding into the image of interest. Therefore, in this paper, we design an information hiding method as part of the image enhancement process. In other words, data can be inserted into the image while executing the image enhancement steps. As a proof of concept, the proposed method is demonstrated by using the Median Filter.Reversible data hiding (RDH) aims to embed secret message into a cover image by slightly modifying its pixels, and more importantly, the original image as well as the embedded message should be completely restored from the marked image. In the last decade, RDH has received much attention from the information hiding community and this technique has also been applied in some applications, such as image authentication, medical image processing multimedia archive management, image trans-coding, and data coloring in the cloud, etc. In general, RDH is a fragile technique and the marked image cannot undergo any degradation. In this light, a RDH method is usually evaluated by its capacity-distortion performance, i.e., for a given embedding capacity (EC), one expects to minimize the embedding distortion measured by PSNR of the marked image versus the original one. Early RDH methods are mainly based on lossless compression. The idea behind these methods is to lossless compress a feature set of cover image and utilize the saved space for reversible embedding. In Fridrich et al. proposed to compress a proper bit-plane with the minimum redundancy.In, Celik et al. proposed a generalized least significant bit (LSB) compression method to improve the compression efficiency by using unaltered bit-planes as side information. However, the lossless compression-based methods cannot yield satisfactory performance, since the correlation within a bit-plane is too weak to provide a high EC. As EC increases, one needs to compress more bit-planes, thus the distortion increases dramatically.Later on, more efficient RDH methods based on histogram modification and expansion technique have been devised. The histogram-modification-based method is firstly proposed by Ni et al. This method focuses on high visual quality with quite limited EC, in which the peak point of image histogram is utilized for data embedding. In this method, each pixel value is modified at most by 1, and thus the marked image quality is well guaranteed. Ni et al.'s method is improved by Lee et al. by using the histogram of difference image. The spatial correlation of natural images is exploited in by considering the difference of adjacent pixels. Thus, a regular-shaped histogram is utilized in Lee et al.'s method. This histogram is centered at origin and has rapid two-sided decay which is more suitable for RDH. The expansion technique is firstly proposed by Tian .This method is performed on pixel pairs, and one data bit is embedded into each selected pixel pair by expanding its difference. Compared with the lossless-compression based RDH, Tian's difference expansion (DE) based method can provide a higher EC with an improved PSNR.The DE approach has attracted considerable attention and it makes an important progress in RDH.Afterwards, the expansion technique has been widely investigated and developed, mainly in the aspects of integer-to-integer such as image authentication, medical image processing, multimedia archive management, image trans-coding [9], and data coloring in the cloud, etc. In general, RDHis a fragile technique and the marked image cannot undergo any degradation. In this light, a RDH method is usually evaluated by its capacity-distortion performance, i.e., for a given embedding capacity (EC), one expects to minimize the embedding distortion measured by PSNR of the marked image versus the original one.Early RDH methods are mainly based on lossless compression. 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Afterwards, the expansion technique has been widely investigated and developed, mainly in the aspects of integer-to-integertransformation, location map reduction, and prediction-error expansion (PEE). Besides the histogram modification and the expansion technique, the analysis about theoretical capacity limitsubjected to admissible distortion has also been studied in some recent works .Nowadays, the most effective and extensively exploited RDH technique is the PEE technique which is firstly proposed by Thodi and Rodriguez. Instead of the difference value in DE,the prediction-error is utilized in PEE for expansion embedding. Thus, unlike DE where only the correlation of two adjacent pixels is considered, the local correlation of a larger neighborhood is exploited in PEE. As a result, compared with DE, better performance can be derived by PEE.Following Thodi and Rodriguez's work, many RDH techniques related to PEE have beenproposed in recent years, for example, double-layered embedding adaptive embedding, context modification, optimal expansion bins selection and two-dimensional histogram modification etc.

3. PROPOSED METHOD

In this section, we discuss the details of the flow of our proposed RDH scheme. Initially, we introduce the tuned prediction model, which comprises of the predictions of two regression modelswith different training data to predict the original pixel values of the image. In the next part, we discuss the concept and significance of the error map for complete reversibility. We then describe the process of embedding of secret data in the image by the sender. Lastly, the secret data is extracted, and the image recovery can be achieved by the receiver.For recovery of the image, the receiver needs to predict the original value of pixels which contains the hidden data. This recovery would be possible due to the presence of regularities in images likespatially correlated neighbouring pixels. This property is used to predict the original value of the pixels. An example of a simple grayscale image of size H*W is illustrated to show how the sendercan hide secret data in an image. In the image, each pixel is made up of 8 bits either containing 0 or 1. An image is just a matrix of these pixels, and it is easy to imagine an image as a stack of eightsingle bit matrices or planes called bit planes, shown in Fig. 1. A single bit plane is just a matrix of 0 and 1. Sender then chooses a particular bit plane to hide the secret data, here hiding means simply overwriting the hidden data over the bit plane. There is a tradeoff between image distortionand pixel value prediction. Choosing a bit plane near Least significant bit (LSB) will provide the least distorted image, but the prediction would be difficult. Bit plane near Most significant bit (MSB) will provide accurate prediction, but its distortion is very high. For this reason, we have taken 3rd, 4th, 5th and 4th bit planes for validation of our results.

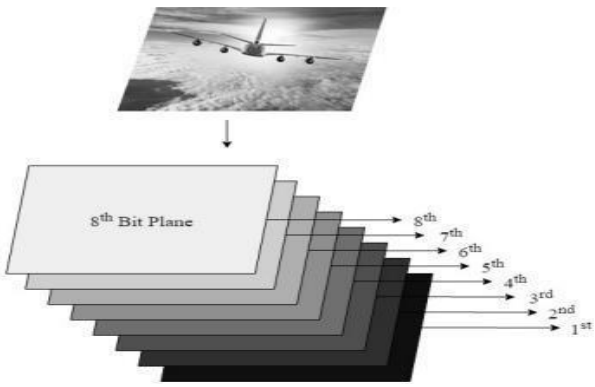


Fig : Bit Planes of an image

Sender trains a linear regression model over the image so that the value of the pixel can be predicted using neighbouring pixels, and this model can be called a Full image regression model.To predict the pixel, say yi, j value, model picks the three most neighbouring pixels one from top yi-1, j, one from left yi, j-1 and one from top left yi-1, j-1 and yi, j can be calculated as:

$$y_{i,j} = \alpha_0 + \alpha_1 * y_{i-1,j-1} + \alpha_2 * y_{i-1,j} + \alpha_3 * y_{i,j-1}$$

Where α0, α1, α2, and α3 are the training parameters for this regression model and these parameterscan be obtained as:

$$\alpha = (X^T X)^{-1} X^T Y$$

Where X represents the matrix of input pixels, Y represents the vector of output labels, and α represents the vector of training parameters, as shown below:

$$X = \begin{vmatrix} 1 & y_{1,1} & y_{1,2} & y_{2,1} \\ 1 & y_{1,2} & y_{1,3} & y_{2,2} \\ \dots & \dots & \dots & \dots \\ 1 & y_{H-1,W-1} & y_{H-1,W} & y_{H,W-1} \end{vmatrix}$$

This model does not include predicting the pixels present in the first row and the first column of the image as they do not have the neighbours specified above and therefore, these pixels are not considered for the data hiding. Naturally, an image is not regular entirely, there are many regions in the image where a drastic change in the pixel values can be seen, or the neighbouring pixels have quite different values, and these regions are named as complex regions. To improve this full image linear regression model's predictability, the sender selects pixels only from regular regions,since pixels in these regions are easy to predict. The pixels from the complex regions have quite different values and only contribute to error. To filter out the pixels from complex regions, the model calculates the regularity value Ri, j of a pixel yi, j as follows:

Ri, j = |yi, j - yi-1, j-1| + |yi, j - yi-1, j| + |yi, j - yi, j-1|

Only those pixels are included in training data for which regularity value is less than a threshold R_th (Ri, j ≤ R_th). Through this process, all complex pixels can be removed, and this full imageregression model can be trained over the regular regions, which will provide high accuracy. Alongwith the full image regression model, the sender trains a new Neighbour specific regression model. This new regression model is trained for every prediction over 8 neighbouring data points enclosedin 4*4 block

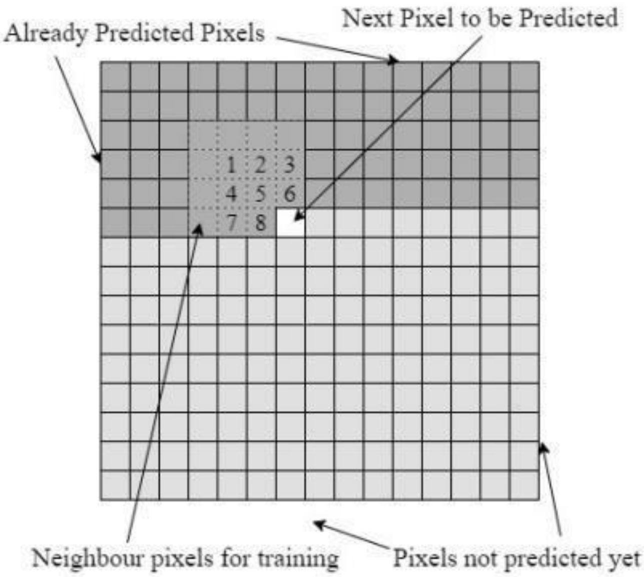


Fig: Process of prediction with neighbour specific model

Predicting the pixel value by using the neighbour specific regression model using surrounding pixels as its training data. The predicted value with this method can be called as Pf2. After getting two predicted values Pf1 and Pf2 for the pixel, the proposed scheme obtains final tuned prediction Pf from the full image as well as neighbour specific model using β (Beta) as shown in the equation:

Pf = β*Pf1 + (1-β)*Pf2

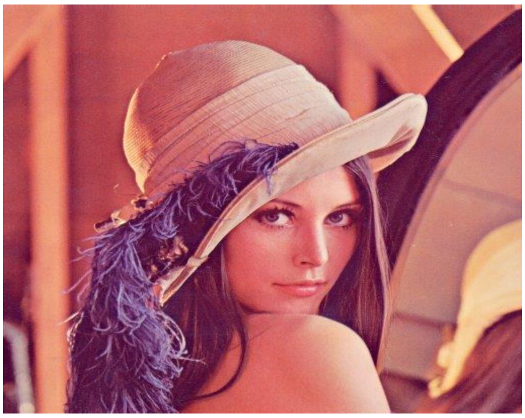
Here β is a hyperparameter such that 0 ≤ β ≤ 1. This parameter defines the proportions utilized ofthe predictions of the two different regression models in order to get optimized results as the final prediction of our combined model as:

If β = 1, then the prediction is only based on the full image regression model. No proportion the prediction of the neighbour specific model will be present.

If β = 0, then the prediction is only based on a neighbour specific regression model.

If 0 < β < 1, proportions of both the predictions are present. The proposed scheme uses an optimal value of β as well as regularity threshold (R_th) which is obtained using Particle Swarm Optimization (PSO) technique [9] such that the number of inaccurate predictions is as small as possible. Since evidently, the neighbour specific model does not include the predictions of first three rows and first three columns, the predictions of the pixels present in these rows and columns is taken from the full image regression model.

4. RESULTS



5. CONCLUSION

Through this study, we introduced an efficient lossless data hiding scheme which makes use of error map and tuned linear regression models to achieve reversibility and data hiding in images. We also addressed the problems with the existing techniques and provided the analysis and comparison of the proposed method with the previous methods in terms of embedding rate in table

V. The accuracy of the model for each of the bit planes for different images as well as the dataset has been depicted in table I-IV which shows the prediction errors and size of the error map has significantly reduced through our technique. It is observed that auxiliary information often decreases the embedding capacity in data hiding schemes. Therefore, we have used Huffman Coding, which is a lossless compression technique for compressing the size of error map so that the capacity increases for hiding secret data. For best results through our model, we have tuned the parameter β and regularity threshold using Particle Swarm Optimization (PSO) technique. Hence,we can conclude that this paper significantly increases the embedding capacity and provides more accurate results when compared to existing techniques maintaining the visual quality through keeping the low distortion of the images. In future, we will aim to work on better complexity of the algorithm and computational time of the process.

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