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A Novel Reversible Data Hiding Technique in Image Processing

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***Abstract*—Communication plays a major role in the technological field. Data hiding is one such application of communication where a secrecy or protection is maintained throughout a particular communication. The project introduces a new technology for data hiding in image processing, called rhombus prediction embedding algorithm with boundary expansion. The project also made an implementation of the lossless compression of a location map that plays a major role in increased embedding efficiency. Also the embedding capacity for different images with different pixel values was calculated and compared using VHDL language. Later the entire hidden data was retrieved with making no change in the original image thereby showing perfection in data retrieval from the image after use. The entire data hiding system for a particular image has been analysed and implemented in ModelSim software in VHDL language and MATLAB.**

***Index Terms*—VHDL, MATLAB, ModelSim, rhombus prediction**

1. INTRODUCTION

Data hiding comes from a very efficient ancient art of communication among people in a protected manner. There are various techniques for data hiding. Image processing plays an important role in data hiding, where the message to be transferred is embedded in form of a compressed data beyond an image. Even though many new emerging technologies have come in this field, the main aim of all of them remains the same- to maintain secrecy in communication purposes. The major reasons behind data hiding are to avoid misuse of data, prevent accessing data from unauthorized identities, etc. Data embedding in image processing is by means of software process. The data to be sent is embedded in an image and at the same time, one can analyse the embedding capacity of a particular image. Data hiding is a software development technique specifically used in Object-Oriented Programming (OOP) to hide internal object details (data members). Data hiding ensures exclusive data access to class members and protects object integrity by preventing unintended or intended changes.

In this paper, a new algorithm called rhombus prediction double-layered data embedding has been modified with boundary expansion to enhance the embedding capacity. The core concept of the project is Prediction Error Expansion (PEE) [1] calculation of the surrounding pixels of the reference pixel. Accordingly, data embedding is tried to achieve in an image for secret communication purposes. There have been many existing technologies for data hiding purposes in an image. This project analysed some of them and their disadvantages were taken into consideration to implement an efficient reversible data hiding technique in image processing.

Since Prediction Error Expansion (PEE) focuses on a reference pixel and its surrounding pixels arrangement and their related equations all of the above mentioned techniques concentrates around this criteria. In C-PEE [2]-[5], a reference pixel is taken along with its surrounding eight pixels (from a nine- squared pixel combination of an image) for data hiding using prediction error analysis. Here the difference between the reference pixel value and the average value of eight pixels calculated is considered as the prediction error. The major disadvantage of this technique is that the data embedding depends upon the closeness of values between the prediction error and the existing reference pixel value. Where the value is close to each other or almost equal there the maximum embedding take place or such a surface we call it as a smooth image. In addition, no embedding is possible for the large difference in values of reference pixel and prediction error. Hence embedding is limited to a smooth image are only or in other wordsThe proposed project combines both the technologies of Adaptive Optimized Prediction Error Expansion (AO-PEE) and rhombus algorithm together. Also the proposed project provides a modification or an extension to the conventional rhombus algorithm. This project gives an analysis of the embedding capacity of the conventional rhombus prediction algorithm and newly analysed one with boundary expansion as the core principle. The project also introduces a lossless compression of location map using new variable run length encoding scheme that is simple and easy to code and compress a particular set of run length composed of binary sequences. Later the entire hidden data is retrieved with making no change in the original image thereby showing perfection in data retrieval from the image after use. The project is analysed in ModelSim with the help of Very High Speed Integrated Circuit Hardware Description Language (VHDL) language and Matrix Laboratory (MATLAB), which used for conversion of an image to text for pixel value calculations.

2. PROPOSED SYSTEM

The Rhombus Algorithm

Previous RDH works have shown that the full-enclosing-based prediction is better in accuracy than half-enclosing-based prediction. Thus, it is adopt the rhombus prediction and double-layered embedding in the implementation. Specifically, the equilateral parallelogram pattern is employed in the method for prediction in which the cover image is divided into two sets denoted as "shadow" and "blank". One-half of the secret messages will be embedded into shadow pixels and the rest half will be embedded into blank pixels. In this case, twice-embedding need to be processed to cover the whole image and the prediction of blank pixels is processed only after the embedding of shadow pixels is completed.

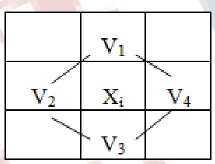

Figure.2.1.Rhombus formation of a selected pixel x_i

Prediction error calculation

In the project, cover image is divided into two sets denoted as "shadow" and "blank". One-half of the secret messages will be embedded into shadow pixels and the rest half will be embedded into blank pixels. In this case, twice-embedding need to be processed to cover the whole image and the prediction of blank pixels is processed only after the embedding of shadow pixels is completed.

Then the prediction error, e_i is computed. Here the figure.2.1 has been analysed by taking a sample of five pixels, four of them surrounding the selected pixel value in a rhombus shaped pattern in a nine- squared number system. Pixel number V1, V2, V3 and V4 are the surrounding pixels of selected pixel xi. On taking their average value, we get the $x_{i^\wedge}$. Here, m is the secret message to be hidden or retrieved from the image as per the conditions. As an example during project analysis, a_n is chosen as -2 and b_n as +2. So a_n and b_n can be considered as the two threshold values or limit up to which the embedding process is carried out. They can be taken any value under the condition that a_n must not be bigger than b_n.

Data Hiding

For project implementation, the following sample of figure 2.2 has been selected for the purpose of secret message embedding and retrieval. The entire image is divided into shadow and blank pixels. This is called shadow and blank pixels partitioning. Here, in order to accommodate the entire secret message beyond an image, first the secret bits in binary form are embedded inside shadow pixels. Then the remaining secret data, if available, are inserted in blank pixels. Blank pixel also accommodates location map and LSB replaced bits. Data hiding is from X_1 to X_9. Let x_i be the chosen pixel of an image fordata hiding. In the project LENA IMAGE has been selected.V_1, V_2, V_3 and V_4 are the neighbouring pixels that form a rhombus shape around x_i. The average values of surrounding pixels are calculated.

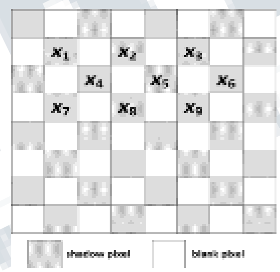

Figure 2.2 The pixels in rhombus prediction

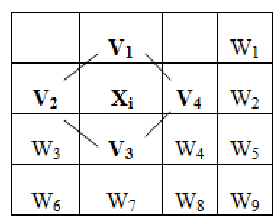

Figure 2.3 The four pixels in rhombus prediction

In figure 2.3, the four pixels {V_1, V_2, V_3, V_4} are used in rhombus prediction. The prediction value is calculated. Then it takes the average value of the pixels that surrounds the original pixel value.

3. SYSTEM IMPLEMENTATION

Reversible data hiding is performed by embedding a secret message of length 20 bits in a 512 by 512 LENA image (we can use different images as per our choice). Reversible means the data can be retrieved after the use without affecting the original image. For this rhombus, error prediction algorithm is used in a modified manner to increase the embedding capacity. In this project, first, the image is converted to textual file in MATLAB, and then with the obtained pixel values rhombus algorithm is performed. In that, a boundary expansion technique is performed in order to increase the embedding capacity from the previous one. After that, the compression of an already created location map is performed using variable run length coding scheme.

Image To Text

For converting text file into image, it needs to be converted from 1D matrix and then to image. The color image is converted to black and white that is RGB image to gray scale. Gray scale usually contains 512 lines with each 512 integer value.

Location Map

Within an image is the under flow or over flow condition of bits. This may lead to an insufficiency in secret data hiding. To avoid the over flow or underflow condition, 0 pixels is assumed to be 1 and 255 is assumed 254, respectively. Hence, a location map is needed to indicate this change made. Therefore, there comes a need to hide the location map along with the secret message inside an image. When the location map becomes very large it may consume the entire space for secret message embedding. Hence, the location map needs to be compressed. Location map is a binary sequence of 0's and 1's.In previous rhombus embedding techniques location map is compressed arithmetically. Results have shown that arithmetic compression is a complex process making compression of location map difficult. By focusing on simplicity, in the present project location map is compressed lossless using variable run length coding scheme. The total size of location map is assumed the exact size of image used. Initially, location map is set to zero. Later, a change of overflow or underflow condition produces a one in location map. During data retrieval, location map is expanded and cover image is obtained originally. Run-length encoding (RLE) is a very simple form of lossless data compression in which runs of data (that is, sequences in which the same data value occurs in many consecutive data elements) are stored as a single data value and count, rather than as the original run. Variable-length codes can allow sources to be compressed and decompressed with zero error (lossless data compression) and still be read back symbol by symbol.

Boundary Expansion

Boundary expansion is a modification to the figure 2.2 of the conventional rhombus prediction algorithm. One of the major disadvantage of the conventional rhombus prediction algorithm is the exclusion or elimination of pixels located around the edge of an image. These pixels are not used for embedding the secret message, since in the pixels the rhombus calculation cannot be performed due to the lack of adjacent neighbouring pixels that forms a rhombus structure. As a result, the data hiding is started from pixel number X_1 in figure 2.2. Therefore, this reduces the embedding capacity of secret message since the entire image is not utilized for this purpose. Here comes the need for boundary expansion where the entire image is included for data hiding. Hence, more embedding capacity is obtained. The extended rows and columns are created by replacing the second row and column respectively, in the pixel combination of the image. Now the expanded image have more chance of embedding efficiency in the first extended row and column of the image since due to replacement the adjacent pixels will have same values of that of the second row and column respectively. After complete embedding process the extended boundary is eliminated , once the cover image is completely utilised for data hiding.

Data Retreival

Data retrieval is efficiently implemented in this project without making any change in the original image. Once the error value is obtained, the secret bit is retrieved from the pixel values. This equation is the reverse of equation no.2.3.

LSB Replacement

LSB replacemnt is done during data hiding process for getting efficient data extraction from the image during data retreival process. Here an information called an auxillary information is first stored in a register.It contains the last LSB values of 8-bit

binary converted form of a_n and b_n ,32 bit secret message in binary form, 32 bit compressed code word for location map.This auxillary informations are hidden in blank pixels of the image in figure 2.2.

Data Encryption

In encryption, the message to be encrypted is known as plaintext. The plaintext is transformed by a function that is parameterized by a key. The output of the encryption process is known as the cipher text. Cipher text is then transmitted over the network. The process of converting the plaintext to cipher text is called as Encryption and process of converting the cipher text to plaintext is called as decryption. Data encryption is performed to give a protection or secrey of data to prevent its access from unauthorised personalities.For this an encryption key is used whose length is equal to the length of secret message.Same length key word is selected and direct bit by bit XOR operation is performed and only key word is

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retreived.Key word is known prior to the reciever and is send along with the reciever.

4. RESULTS AND DISCUSSIONS

The MATLAB software is used for conversion of image to pixel formats and a comparison on the conventional rhombus prediction algorithm and the boundary expanded system is carried out in and ModelSim 16 SE PLUS 6.3f with the help of VHDL language for different images with different pixel values.The following figures 4.1 and 4.2 show the proposed rhombus algorithm implemented in ModelSim software using VHDL language. Here the image is represented in matrix format where the pixel values forms the rows and columns of the matrix. LSB replacement is done in order to save the space during data hiding. Here, lsb_1 represents the secret message of 32 bits in binary form and lsb_2 represents the compressed code of location map.

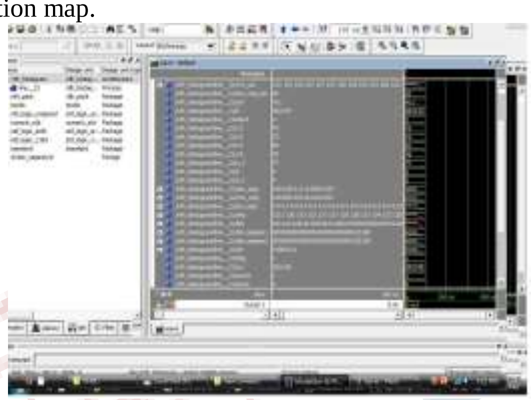

Figure.4.1 Rhombus algorithm proposed

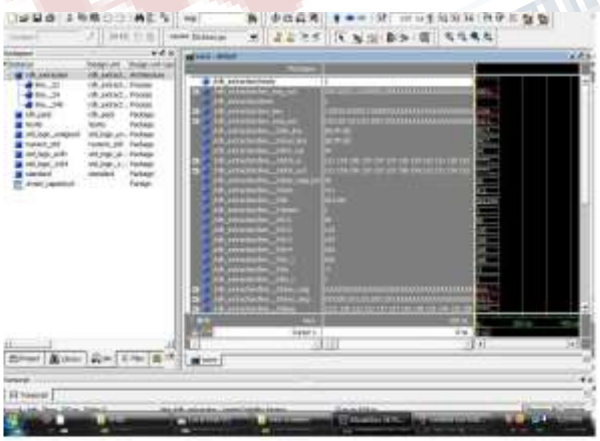

Figure 4.2 Data retrieval

Embedding Capacity

The following figures 4.3 shows the embedding capacity of the new proposed boundary expanded algorithm of Lena image. It has been an increase of bpp value in thousands on comparing with conventional one, means more embedding capacity for the secret data in the image.

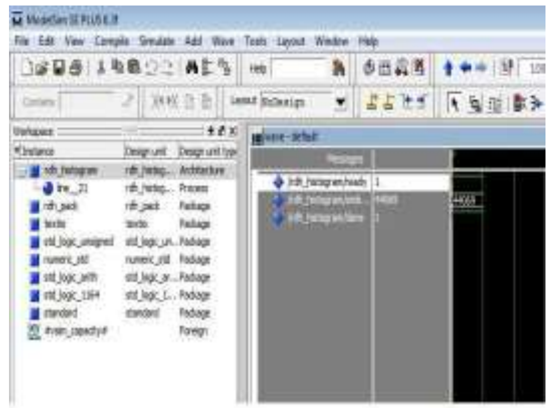

Figure.4.3 Rhombus algorithm extended boundary

Comparison of embedding capacity

The following section shows the ModelSim simulation results of embedding capacity

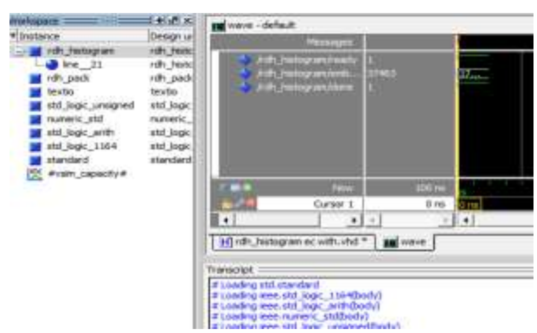

Figure.4.4 Peppers image conventional system

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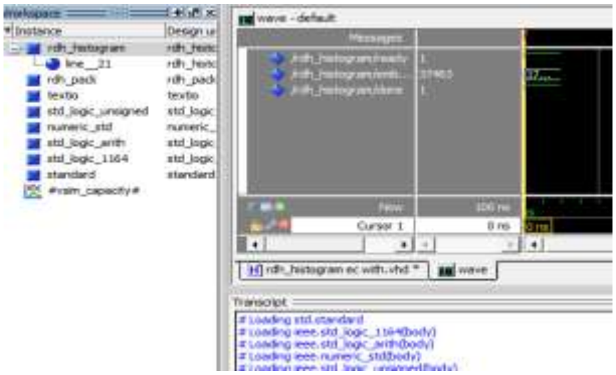

Figure.4.5 Peppers image proposed system

Table 4.1 Comparison between conventional and proposed system

Image type	Embedding capacity		Run length
	Conventional	Proposed	
Lena	43702	44069	0
Baboon	20461	20542	35
Peppers	37325	37463	3
Photographer	38191	38517	16

Table 4.2Embedding capacity comparison

Values		Lena		Baboon		Peppers		Photographer	
a_n	b_n	E	P	E	P	E	P	E	P
-2	2	43072	44069	20461	20542	37325	37463	21379	21534
-3	3	31841	32116	18859	18944	33636	33758	13756	13855
-4	4	22510	22706	17282	17374	28386	28501	9439	9531
-5	5	16002	16134	15282	15369	22570	22652	6778	6863
-6	7	9658	9713	12741	12818	15219	15302	4322	4365

From table 4.2 we get different embedding capacity efficiency for different image sizes done under both without boundary expansion (existing) and with boundary expansion (proposed).Here E stands for existing and P stands for proposed system. It is seen that maximum embedding efficiency is for Lena image for a_n and b_n values of -2 and 2 respectively. Minimum capacity is seen for Photographer image at values of -6 and 7 for a_n and b_n respectively.

CONCLUSION

A novel reversible data hiding technique in comparison to an existing technique is proposed and implemented in image processing. A new modification to the already existing secret message-embedding algorithm is implemented and achieved a considerable increase in data hiding efficiency and compared them for different image sizes and are analysed. The softwares used for implementing the proposed system are MATLAB and ModelSim 16 SE PLUS 6.3f with the help of VHDL language. The rhombus algorithm is chosen as the core of this project and it is modified to achieve further changes in data embedding in an image. Data retrieval is also achieved without any change in the original image. As a whole, the system finds its advantage in increased embedding capacity efficiency from the conventional system.

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