A Novel ColorImage Steganographic Method Based on Intra Predicted Bitstream Using DWT - SVD

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Abstract—Steganography is the art of hiding information and an effort to conceal the existence of the embedded information. Original message is being hidden within a carrier such that the changes so occurred in the carrier are not observable. In this paper we explain how digital images can be used as a carrier to hide secret images. Recent developments in Internet technology help the common users to store, send or receive large amount of information. Some information needs high security. In order to hide the secret data and reduce the amount of data for storing and transmission we proposed a novel method. This paper employs the technique of H.264/MPEG-4 Advanced Video Coding to improve still image compression. This paper utilizes the intra prediction approach of H.264/AVC and Huffman coding to improve the compression rate. Each 4×4 block is predicted by intra prediction. Then by applying the normal encoding we get the bitstream. This is the cover image for embedding. The combinations of Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) are used to embed the secret image. The singular values of different subband coefficients of bitstream are modified using different scaling factors to embed the singular values of three channels of the hiding image. At the receiver side the secret image is extracted and the cover image is reconstructed. The combinations of DWT and SVD increase the security, robustness and imperceptibility of the scheme and intra prediction reduces the amount of data for store and transmit. Experimental results show that the proposed algorithm can improve the compression efficiency of cover image and it extract the secret image correctly from the stego-image.

Keywords—Steganography; Intra Prediction; Huffman coding; Bitstream; Discrete Wavelet Transform (DWT); Singular Value Decomposition (SVD); Stego-images

I. INTRODUCTION

Information hiding is a technique in the field of information security presently. As defined by Cachin [1] steganography is the art and science of communicating in such a way that the presence of a secret information cannot be detected. It hides the existence of important information into cover-object to form stego-object.Steganography aims to hide the very existence of communication by embedding messages into other cover objects. However, watermarking aims to protect the copyrights of digital media owners. Therefore, the goal of steganograhy is the secret messages while the goal of watermarking is the cover object itself. Now, image steganography is focused on spatial and transform domain. Spatial domain algorithm directly embedded information in the cover image with no visual changes [7]. This kind of algorithms has the advantage in steganography capacity, but the disadvantage is weak robustness. Transform domain algorithm is embedding the secret information in the transform space. This kind of algorithms has the advantage of good stability, but the disadvantage of small capacity [12].

In recent years, compressed H.264/AVC images/videos become the most popular image on the Internet [12]. Therefore, steganographic techniques based on H.264/AVC are very important. This paper presents a steganography method based on compressed H.264/AVC images. This paper has two phases: H.264/AVC Compression and Secret Image Hiding. Nowadays, only few solutions are proposed for both access to the cover image and secret image with sufficient quality. In this paper we focused on both cover image and secret image.

The objective of image compression is to reduce irrelevance and redundancy of the image data in order to be able to store or transmit data in an efficient manner [9]. Image compression may be lossy or lossless. Lossless image compression techniques are error-free coding methodsand the size of the compressed results are not reduced so much. A lossless-compressed image can be decompressed to be one which is identical to the original image. Lossy image compression techniques instead produce results with smaller sizes and the image obtained from decompressing is not identical to the original one. The aim of a lossy compression technique is to getting higher similarity to the original image and maintaining higher compression rates. Lossy image compression is useful in applications such as broadcast television, video conferencing, and facsimile transmission, in which a certain amount of error is an acceptable trade-off for increased compression performance.

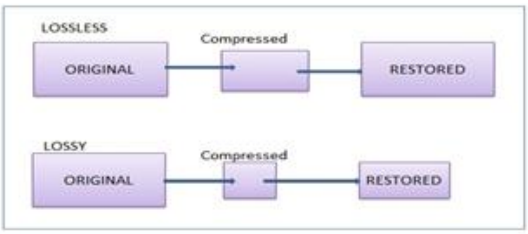


Fig 1: Lossless and Lossy Compression

The proposed method embeds the color secret image into bitstream. The bitstream is the compressed version of the color or gray scale input image. The color image is represented by Red (R), Green (G) and Blue (B) channels. Out of these three channels, change in intensity of Red channel is the most sensitive to human eyes whereas for Blue channel it is the least sensitive [1]. Hence, in the proposed method the blue channel is considered for compression. The wavelet transform of image gives four frequency subbands coefficients. In image processing each subband is resistant to different types of attacks or transformations. In the proposed method the secret image is embedded into high frequency subbands coefficients (HL, LH and HH), which is hard to destroy the secret image even after the different types of attacks on the stego-images. To improve the robustness of the method, the secret image is embedded into singular values of high frequency subband coefficients obtained from bitstream. The rigidity of the scheme is analyzed considering different types of image processing operations. Experimental results show that, the proposed method can improve the compression efficiency of images compared with other intra coding methods in literature. It also shows that this method has both larger steganography capacity and better stego-image quality than others.

The rest of this paper is organized as follows. In section II, explains the theory of Intra Prediction, Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD). In section III, the proposed color image steganographic method based on intra predicted bitstream will be described. Experimental results and performance evaluations are addressed in sections IV. Finally, conclusion and the future scope are discussed in section V.

II. BACKGROUND AND THEORY

A. *H.264/AVC*

H.264/AVC (Advanced Video coding) is an industrial standard for video coding [9]. H.264/AVC describes a set of tools or methods for video compression. H.264/AVC is a document co-published by the ITU-T (International Telecommunication Union) and the ISO/IEC (International Organization for Standardization / International Electrotechnical Commission). It defines a format or syntax for compressed video and a method for decoding this syntax to produce a displayable video sequence [8].

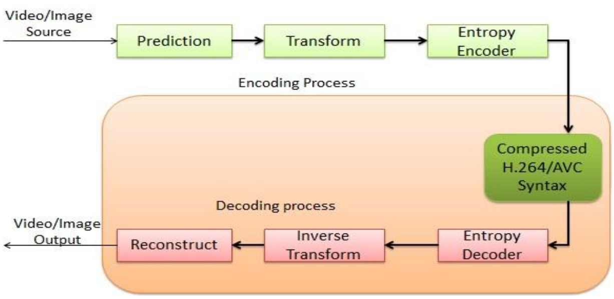


Fig 2: H.264/AVC Encoding and Decoding Process

B. *Intra Prediction of H.264/AVC*

Intra prediction is an effective method for reducing the coded information of an image or an intra frame within a video sequence. In H.264/AVC, intra coding process is performed by the prediction of the neighboring pixels of coded blocks [13]. The intra prediction process is used to remove the spatial redundancies of images or frames in video coding. H.264/AVC intra coding architecture includes Intra 4×4, Intra 16×16 and Intra8×8 prediction methods for luma and chroma components. For the luma signal, there are nine prediction modes labeled 0, 1, 2, 3, 4, 5, 6, 7, and 8. Mode 2 is ‘ DC prediction’. The other modes represent directions of predictions as indicated in Fig 3.

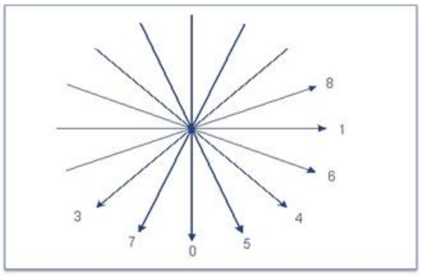


Fig 3: Intra Prediction Directions

In H.264/AVC, the intra prediction was adopted for reducing the redundancy within each intra frame. Intra prediction tries to predict the texture of the current block to be coded by the neighboring previously encoded/decoded blocks [13]. The residual of the prediction is the difference between the original and the intra predicted block.

C. *Discrete Wavelet Transform (DWT)*

Transform is basically a mathematical tool, which allows us to move from one domain to another domain (time domain to frequency domain) [22,23]. There are two reasons for transforming an image from one representation to another. (i) the transformation may isolate critical components of the image patterns so that they are directly accessible for analysis. (ii) The transformation may place the image data in a more compact form so that they can be stored and transmitted efficiently. Transform allows us to extract more relevant information. DWT captures both frequency and location information. It does not change the information content present in the signal.

The DWT is a system of filters. The DWT is obtained by filtering the signal through a series of digital filters at different scales. The scaling operation is done by changing the resolution of the signal by the process of subsampling. By applying DWT on an image, the image is decomposed into four subbands. They are I_{LL} - the wavelet approximation and low frequency part of the image, I_{LH}, I_{HL} and I_{HH} - the details of horizontal, vertical and diagonal directions and high frequency part of the image.

The magnitude of DWT coefficients is larger in the lowest bands (LL) at each level of decomposition and is smaller for other bands (LH, HL and HH). With multi-resolution analysis, image can be represented at more than one resolution level. High resolution subbands help to easily locate edges and textures patterns in an image.

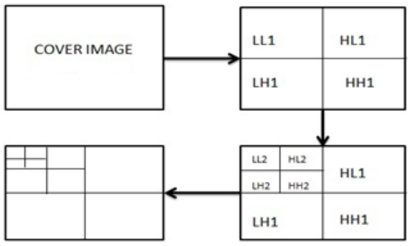


Fig 4: Workflow of third level of DWT

D. Singular Value Decomposition (SVD)

The Singular Value Decomposition of image I of size m×n, (m≥n) is a decomposition of the form of a product of three matrices

$$I = USV^T \qquad (1)$$

Where U and V are orthogonal matrices. S is a diagonal matrix comprised of singular values of I. The columns of U are the left singular vectors; S has singular values and is diagonal; and V^T has rows that are the right singular vectors. Each singular value represents the luminance of image layer while the corresponding pair of singular vectors represents the geometry of the image layer [22,23]. The singular values $\sigma_1 \geq \sigma_2 \geq \ldots\ldots\ldots. \geq \sigma_n \geq 0$ appear in descending order along the main diagonal of S.

III. PROPOSED STEGANOGRAPHIC METHOD BASED ON BITSTREAM USING DWT-SVD

The proposed system contains two phases (i) H.264/AVC Image Compression and (ii) Secret Color Image Embedding. The general block diagram of the proposed system is shown in Fig 5.

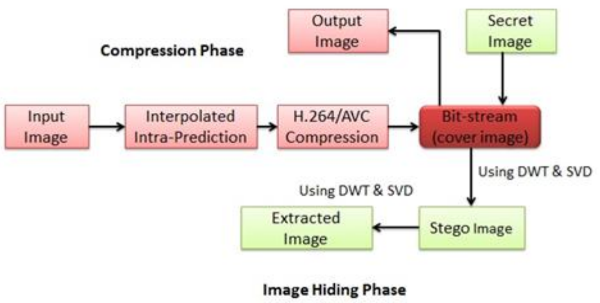


Fig 5: Block diagram of the proposed method

In this paper H.264/AVC, utilize the intra prediction approach use in still image coding, and it improve the coding efficiency. For this a fast and efficient intra-prediction mode decision algorithm is used. In the intra predicted residue apply the normal H.264 encoding process we get the bitstream.

In the H.264/AVC based compression phase – a color or gray scale image is compressed using intra prediction method. In the secret image hiding phase - in the bitstream (cover image) a color image is embedded. In the receiver side, from the stego image, the secret image is extracted and from the bitstream the original image is reconstructed.

A. H.264/AVC Image Compression

In H.264/AVC, intra coding process is performed by the prediction of the neighboring pixels of coded blocks. The intra prediction process is used to remove the spatial redundancies of frames in video coding. H.264/AVC intra coding architecture includes Intra 4×4, Intra 16×16 and Intra 8×8 prediction methods for luma and chroma components. The samples of a 4×4 block containing samples a to p are predicted using samples A to Q from neighboring blocks. Samples A to Q may already be decoded and may be used for prediction. Any sample A-Q shall be considered not available under the following circumstances: (1) if they are outside the picture or outside the current slice, (2) if they belong to a macro block that is subsequent to the current macro block in raster scan order, or (3) if they are in a non-intra macro block and constrained intra prediction is 1.

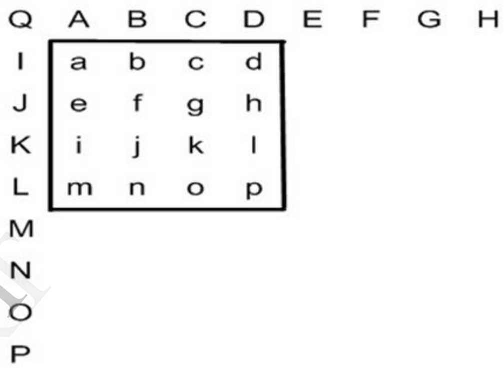


Fig 6: Identification of samples used for Intra Prediction

When samples E-H are not available, the sample value of D is substituted for samples E-H. When samples M-P are not available, the sample value of L is substituted for samples M-P.

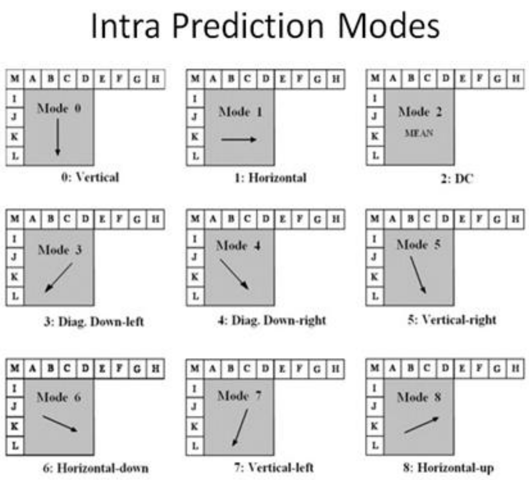


Fig 7: Block based intra prediction for Luma 4×4 blocks

The 9 prediction modes (0-8) are calculated for the 4×4 block [9]. The Sum of Absolute Errors (SAE) for each prediction indicates the magnitude of the prediction error. The best match to the actual current block is detected according to the smallest SAE. In the residue apply the DCT and it is quantized with appropriate scaling factor. This coefficient values are arranged in zigzag sequence. Then Huffman encoder is used for ENCODING we get the bitstream.

B. Secret Color Image Hiding

The cover image is the compressed image (bitstream) I of size m×n and the color image W of size m/ 2×n/ 2 as the secret image. On the bitstream one-level DWT is applied to generate subband coefficients LL, HL, LH and HH. The color image is transformed into R, G and B channels. The SVD decomposition is applied on all high frequency subband coefficients of bitstream and all channels of secret image. The singular vales of secret image (λ_w) are added to the singular values (λ_l for l ϵ LL, LH, HL, HH) of the DWT transformed bitstream using scaling feator α.

$$\lambda_l^- = \lambda_l + \alpha\lambda_w \quad (2)$$

On the modified subband coefficients the inverse DWT is applied to achieve the stego image.

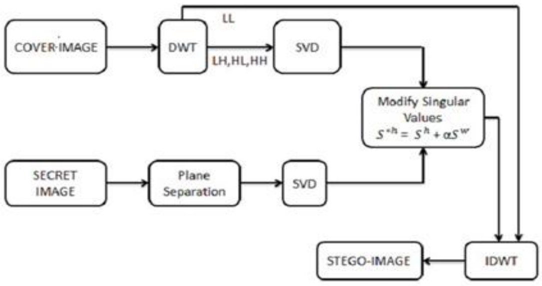


Fig 8: Block diagram of Image Embedding

The extraction algorithm uses stegoimage I'. The one-level DWT is applied to generate subband coefficients LL, HL, LH and HH. The SVD decomposition is applied on all subband coefficients of both stego-image ans secret image. The singular values of secret image λ_w are extracted from the singular values (λ_l for l ϵ LL, LH, HL, HH) and (λ_l^- for l ϵ LL', LH', HL', HH' of the DWT transformed of secret image anestego-image using scaling factor α.

$$\lambda_w = \frac{\lambda_l^- - \lambda_l}{\alpha} \quad (3)$$

The extracted singular values of secret image are combined with other matrices of secret image, to generate the secret image.

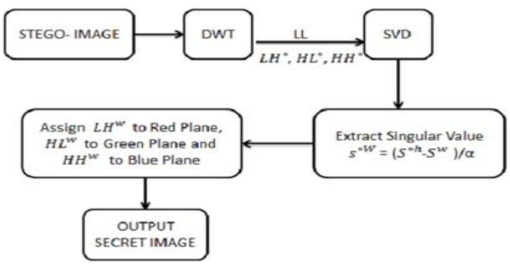


Fig 9: Block diagram of image extraction

IV. RESULTS AND PERFORMANCE EVALUATION

A set of experiments are conducted to analyze the effect of compression and embedding – extraction algorithms on the color image. In these experiments a color or gray scale image of size 256×256 and color secret image of size 128×128 are considered. Change in the intensity of Blue channel is the least sensitive to human eyes. Blue plane compression gives better quality reconstructed image and compression ratio. So in the paper we consider Blue plane of the color image for compression.

Input Image	Plane Separated Image	Compressed Image	Decoded Image	Compression Ratio
RED				
				31.289877
GREEN				
				28.100551
BLUE				
				35.791228

Fig 19: Plane separated compression and decompression of Lena image

Intra prediction is an effective method to reduce the redundancy of an image. In this paper we use modified diagonal down-left and diagonal down-right prediction directions to improve the coding efficiency.

In this paper color secret image is embedded in the bitstream. The bitstream cover image is decomposed into four frequency subbands by applying first level DWT. Take the SVD of high frequency subbands. The secret image is plane separated as Red plane, Green plane and Blue plane. The Red plane image is embedded in the LH subband, Green plane image is embedded in the HL subband and Blue plane image is embedded in the HH subband of cover image bitstream. Take the SVD of secret image. The singular values of bitstream and secret image is combined and it is multiplied with a scaling factor α. The modified high frequency subbands are obtained and take the IDWT of low frequency subband (LL) and modified high frequency subbands we get the stego image. In Fig 11 shows the stego image of secret image Vegetables embedded in the bitstreamof Lena.

Fig 11: Secret image embedding

The stego image is decomposed into four frequency subbands. Take the SVD of high frequency subbands. Extract the singular values by subtracting the singular value of secret image from the singular value of stego image and it is divided by the scaling factor α. Obtain the output secret image by combine the extracted singular value and the other SVD values of secret image. Fig 12 shows the extracted secret image.

Fig 12: Extracted secret image

Some examples of Input Images and Secret Images are shown in Fig 13 and Fig 14.

Fig 13: Examples for input images

Fig 14: Examples for secret images

Performance Evaluation
The parameters considered for evaluation are:

A. Compression Ratio

The objective of image compression is to reduce irrelevance and redundancy of the image data in order to be able to storeor transmit data in an efficient form. Image compression is measured by

$$\text{Compression Ratio} = \frac{Uncompressed\ \ Image\ \ Size}{Compressed\ \ Image\ \ Size} \quad (4)$$

Where uncompressed image size is the number of bits in the original input image and compressed image size is the number of bits obtained after the compression. Lossy compression provides high level of data reduction, where loss can be tolerated. The comparison is shown in Table below.

Table: Comparison of compression ratio

I/P Image	H.264/AVC Standard	Comp. Ratio	Proposed Method	Comp.Ratio
	1631	12.5082 77	1453	14.0406
	1591	54.0572	1239	69.4149
	1783	2.82333	1411	3.5677
	2208	5.28895	1525	7.6577
	1452	27.8898	1161	34.8803
	2672	116.808	2668	116.9831
	1891	4.71126	1218	7.3144

B. PSNR – Peak Signal-to-Noise Ratio

PSNR is an engineering term for the ratio between the maximum possible power of a signal and the power of computing noise that affects the fidelity of its representation. PSNR is the most commonly used to measure the quality of reconstruction of lossy compression codecs. The signal in this case og image compression is the original image and the noise is the error introduced in compression. PSNR is an approximation to human perception of reconstruction quality. The PSNR is defined as

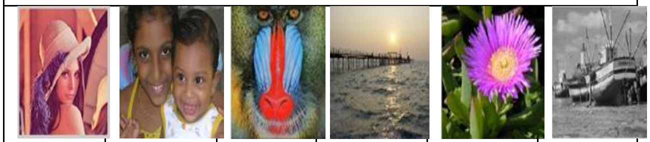
$$\text{PSNR} = 10.log_{10}\frac{MAX_I^2}{MSE}\text{dB} \quad (5)$$

Where MAX_I is the maximum possible pixel value of the image. The MSE is the measurement of average of square of errors and the cumulative squared error between noisy and original image. A higher PSNR generally indicates that the reconstruction is of higher quality. MSE is calculated as

$$\text{MSE} = \frac{1^2}{N}\sum_{i=1}^{M}\sum_{i=1}^{N}(X_{ij}-X'_{ij})^{\ 2} \quad (6)$$

Examples for input images with corresponding PSNR values are shown in Table 2.

Table 2: Examples for input images with corresponding PSNR values

Input Images					
					
Reconstructed Images					
					
PSNR Values					
63.5777	**61.9905**	**60.1322**	**64.8526**	**55.1464**	**66.0728**

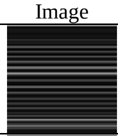
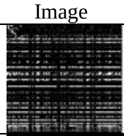
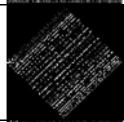
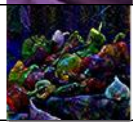
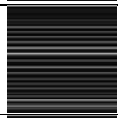
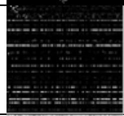
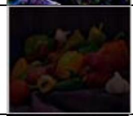
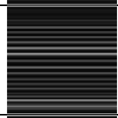
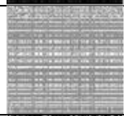
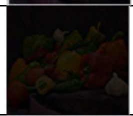
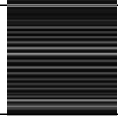
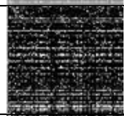
In the case of steganography, robustness is the measure of the intentional and unintentional attacks. It is evaluated using PSNR value. The PSNR is employed to evaluate the difference between original cover image and the stego image. For the robust capability, mean absolute error (MSE) measures the mean of the square of the original secret image and the extracted secret image from the attacked image. Examples for embedded secret images and extracted secret images with corresponding PSNR values shown in Table 3.

Table 3: Examples for secret imaged with corresponding PSNR values

Embedded Secret Images				
				
Extracted Secret Images				
				
PSNR Values				
58.3278	57.8470	57.4256	57.1747	63.7104

The proposed steganography method was tested using ordinary image processing: Rotation, Scaling, Histogram Equalization, Median Filter, Salt & Pepper noise and Gaussian noise. Consider an example with Lena as input image and Vegetables as secret image. Various attacks, bitsream as cover image, stego images, extracted secret images and PSNR values are shown in the Table 4.

Table 4: Image processing attacks on stego images

Attack	Cover Image	Stego Image	Extracted Image	PSNR
General				58.3278
Rotation (45°)				58.3040
Median Filter				58.3262
Histogram Equilization				58.3270
Salt & Pepper Noise(0.1)				58.3218
Gaussian Noise(0,0.1)				58.3204

V. CONCLUSION

This paper emphasizes a novel color image steganographic method based on intra predicted bitstream using DWT-SVD. An overall improvement in lossy coding compression capability achieved without a substantial increase in the complexity of the encoding or decoding processes. For the image hiding, the cover image is the bitstream. In the bitstream the color image is embedded. We use DWT and IDWT transformation to obtain the high frequency image. In each high frequency subbands (HL, LH and HH) of bitstream embeds the red plane, green plane and blue plane of the secret images respectively. SVD is an efficient tool for embedding in the DWT domain. To embed the secret image into the cover image the scaling factor is chosen from a wide range of values for all subbands. The image is embedded into high frequency subbands which is very difficult to remove or destroy. With the experiment results, the proposed intra prediction H.264/AVC system achieves better compression ratio. The rigidity of the proposed system of steganography is analyzed by various types of image processing attacks. The system was found robust to various image processing attacks.

In future, there can be many possible improvements that will broaden the scope of this work. The presented 'Color Image Steganography' methodology can be extended for videos. For increasing the compression rate, as a future work we can consider interpolation on intra prediction and instead of 'Lossy Compression' we can try for 'Lossless Image Compression' to form the cover image for embedding.

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