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Image Hiding Using Lifting Wavelet Transform

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Abstract-High security technique and high embedding capacity speech steganography system based on integer-to-Integer Lifting Wavelet Transform (Int2Int LWT) is proposed. Two levels of Int2Int LWT are performed and least significant bits (LSB) used to replace bits of color image in the coefficient of detail sub-band1 and detail sub-band2. Image data is encrypted by using chaotic key generation (CKG) to rearrange pixels positions. Also two chaotic keys are used as secret keys in embedding stage. The proposed method offers lossless and unnoticeable changes in the contents of the speech file and imperceptible by human auditory system (HAS). It is possible to use speech signal as channel to send any secret message between two persons for the purpose of secret communication with good security.

Index Terms — Speech steganography, color image hiding, (LSB) technique, Int2Int LWT.

1Introduction

Each steganography algorithm demands some characteristic that rely on the applications and transmission environment. An effective sound steganography algorithm should have the following characteristics for successful embedding and extracting data [1, 2]:

- Perceptual transparency: The Carrier sound file and the original sound file must be imperceptible.
- High capacity: The data hiding rate is large amount as much as possible.
- High robustness: Secret data should be resistant to any change from any attempt by attacker.

Many sound steganography techniques have been introduced. The LSB method has been utilized within signal in time domain or transform domain such as Fast Fourier Transform (FFT) and Discrete Wavelet domains (DWT) [3]. But both of these methods have a problem in data conversion (from integer-to-floating and vice versa). Both of them needed to scaling and rounding operations before data hiding and decaling, rounding after the data hiding. As a result, part of the hidden data may be lost. In this research the proposed developed algorithm is reduce possible errors that may be occurred during conversion processes.

2 Lifting wavelet transform

The lifting scheme of DWT is an algorithm to implement wavelet transforms in an efficient way. It is also a wonderful method to create so-called second-generation wavelets. The lifting wavelet transform is a multi-resolution representation that means the signal divided to two parts the first called approximation sub-band and second part named detail sub-band these parts are obtained by applying corresponding wavelet filters (high-pass filter, low-pass filter). Generally lifting scheme consists of three steps, Splitting, production, and update [4, 5]:

2.1 Splitting (Lazy wavelet transform)

This stage splits entire set of signal to two frames. One frame consists of even index samples such as ($\lambda_{0,0}$,$\lambda_{0,2}$, $\lambda_{0,4}$, ...$\lambda_{0,2k}$) we will call this frame as smoother resolution signal or approximation other frame consists of odd samples or call as detail such as ($\lambda_{0,1}$, $\lambda_{0,3}$,$\lambda_{0,5}$ ... . $\lambda_{0,2k+1}$).

New sequence can be given as: $\lambda_{-1,k} = \lambda_{0,2k}$ where $k \in Z$.

The sequence $\gamma_{-1,k}$ can be given as: $\gamma_{-1,k} = \lambda_{0,2k+1}$, Where $k \in Z$.

Minus sign indicates that new data set is smaller compare to the original data set.

2.2 Prediction (Dual lifting)

Predict the odd samples by using linear interpolation predict the odd coefficient based on a linear combination of even samples and odd samples (replace ($\boldsymbol{\lambda_{0,2k+1}}$) with $\gamma_{-1,k}$) as follow:

$$\gamma_{-1,k} = \lambda_{0,2k+1} - \mathrm{P}(\lambda_{-1,k}) \ldots\ldots\ldots (1)$$

Odd value Predicted value

$$\mathrm{P}(\lambda_{-1,k}) = \frac{1}{2}\ (\lambda_{-1,k} + \lambda_{-1.k+1}\ ) \ \ldots\ldots (2)$$

Substitute's equation (2) in (1) getting equation (3):

$$\gamma_{-1,k} = \lambda_{0,2k+1} - \frac{1}{2}\ (\lambda_{-1,k} + \lambda_{-1.k+1} \ \ldots.. (3)$$

2.3 Update (Primal lifting)

Update the even samples based on a linear combination of difference samples obtained from the predict step [4, 5]. We require constructing update operator U for this lifting process.

$$\lambda_{-1,k} = \lambda_{0,2k} + U(\gamma_{-1,k}) \dots\dots\dots\dots\dots \quad (4)$$
$$\mathrm{U}(\gamma_{-1}) = \frac{1}{4}(\gamma_{-1,k-1} + \gamma_{-1,k}) \dots\dots\dots \quad (5)$$
$$\lambda_{-1,k} = \lambda_{0,2k} + \frac{1}{4}(\gamma_{-1,k-1} + \gamma_{-1,k}) \dots . (6)$$

Figure (1) represents forward transform scheme of three stages for multi levels of LWT.

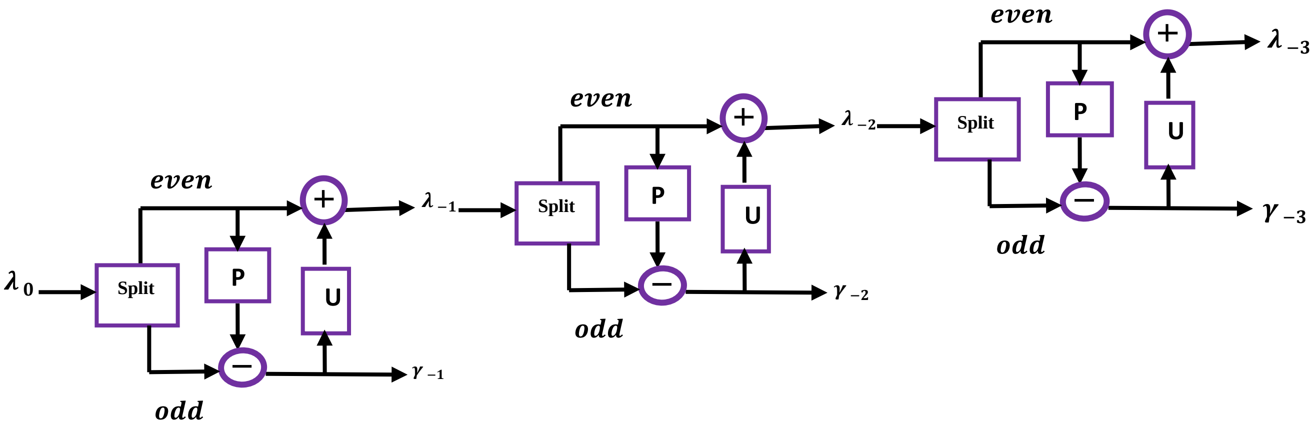


Figure 1 multilevel wavelet transform with lifting scheme

To finding level 2 equation (3) and equation (7) become as follows:

$$\gamma_{-2,k} = \lambda_{-1,2k+1} - \frac{1}{2}\ (\lambda_{-2,k} + \lambda_{-2.k+1} \quad \dots . (11)$$

$$\lambda_{-2,k} = \lambda_{-1,2k} + \frac{1}{4}(\gamma_{-2,k-1} + \gamma_{-2,k}) \dots\dots (12)$$

3 Inverse wavelet transform

Inverse wavelet transform is exactly reverse process of forward wavelet transform in lifting scheme it is very easy to find out inverse wavelet transform because it can be obtained by just changing sign. Inverse lifting wavelet transform consists of following steps [6]:

- **Undo Update (Inverse Primal Lifting):** Original even samples are recovered by simply subtracting the update information. The Equation (8) represents undo update, which is obtained by changing sign in Equation (7).

$$\lambda_{-1,k} = \lambda_{0,2k} - \frac{1}{4}(\gamma_{-1,k-1} + \gamma_{-1,k}) \dots (8)$$

- **Undo Predict (Inverse Dual Lifting):** Odd samples can be recovered by adding prediction data to loss of data that can be given by Equation (9) by changing sign in equation **(**3)

$$\gamma_{-1,k} = \lambda_{0,2k+1} + \frac{1}{2}\ (\lambda_{-1,k} + \lambda_{-1.k+1} \quad \dots . (9)$$

- **Merge:** After recovering odd and even samples, final job is to merge them together to get original signal.

$$\lambda_{0,\mathrm{k}} = \mathrm{Merge}(\lambda_{-1}, \gamma_{-1}) \dots . (10)$$

Figure (2) is a scheme to multilevel Inverse LWT with three-steps for any filter user [5, 6].

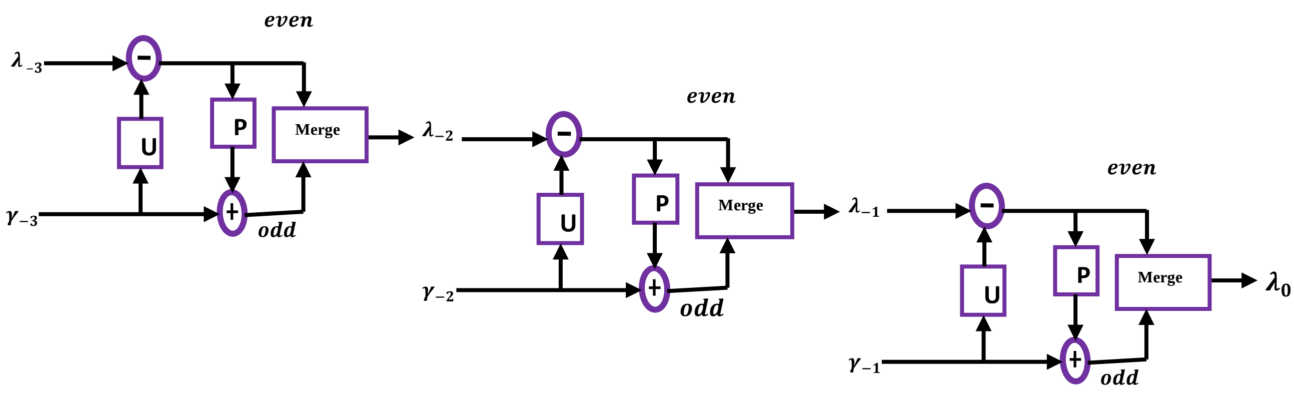


Figure 2 Multilevel Inverse Wavelet transform with lifting scheme

4 Integer Lifting Wavelet Transform

In many multimedia applications the input data consist of integer samples. In other applications like speech compression, demined that the data will be storage in a few space of memory [4]. If we store wavelet coefficients as a floating point values, it requires 32 bits per coefficients, in addition the wavelet coefficient is rounded to transform it into integer number for efficient encoding and storage. Because of this rounding process, the original data cannot be reconstructed from its transform without causing an error.
So that, there is a certain need for the reversible transformation convert signals to the frequency domain and produced an integer numbers which are store in a few amount of memory.
Fortunately the Int2Int LWT scheme can be modified easily to a reversible transform to integer numbers.
It is an importance great practical that represented the wavelet transform by a set of integer numbers. For example let us consider sequence of samples [6]: {1, 2, 3, 4, 6, 7, 8, 10, 11 }

Split: λ_{2k} = {1, 3, 6, 8, 11} , λ_{2k+1} = {2, 4, 7, 10}
Predict: P(λ_{2k})= { 2, 4.5, 7, 9.5}
| P(λ_{2k})| = {2, 4, 7, 9} {Rounding predicted value to integer}
$\gamma_{-1,k} = \lambda_{2k+1}$ - | P(λ_{2k})| = {0, 0, 0, 1}

During inverse transform:

Undo Predict: $\lambda_{2k+1} = \lambda_{2k+1} + \gamma_{-1,k}$ = {2, 4, 7, 10}
Merge: {1, 2, 3, 4, 6, 7, 8, 10, 1}

Although, wavelet coefficients have been rounded, the original values back will be obtained because of reversible operation. Using Int2IntLWT, rounding error is cancelled during the inverse transform. So that it is possible to achieve perfect reconstruction. During forward transform the error that added is subtracted in inverse transform so that, net error is zero. This is the reason for not losing speech data reconstruction in filter bank implementation. So that it is possible to achieve perfect reconstruction [6].

5 Chaotic System

A noticeable characteristic of chaotic systems is its ability to produce very complicated Styles of behavior. This quality has made it them especially advantageous for the application in a broad variety of disciplines, such as biology, economics, engineering, and compress the information and data encryption. In those applications, and systems chaos, simulate, or to control the different processes and to improve its performance or provide output more suitable [7].

$$\boldsymbol{y_{n+1} = r.y_n.(1 - x_n) \ldots..(11)}$$

Where y_n have values in rang [0, 1], and the parameter (r) is a positive real number takes values (3.6 to 4). The chaotic system has different Characteristics with parameter (r, x) and length of key which is named bifurcation parameter, it's decides and explores the attributes of the logistic map. One of the numbers in the rage can be changed to get a new key. The main feature of CKG is its higher sensitization to change one or both of the initial conditions (r, x) [8].

6 The Proposed System Design

The general proposed system is depicted in Figure (3). The figure illustrates that there are three stages:

1. Preprocessing
2. Embedding
3. Extraction

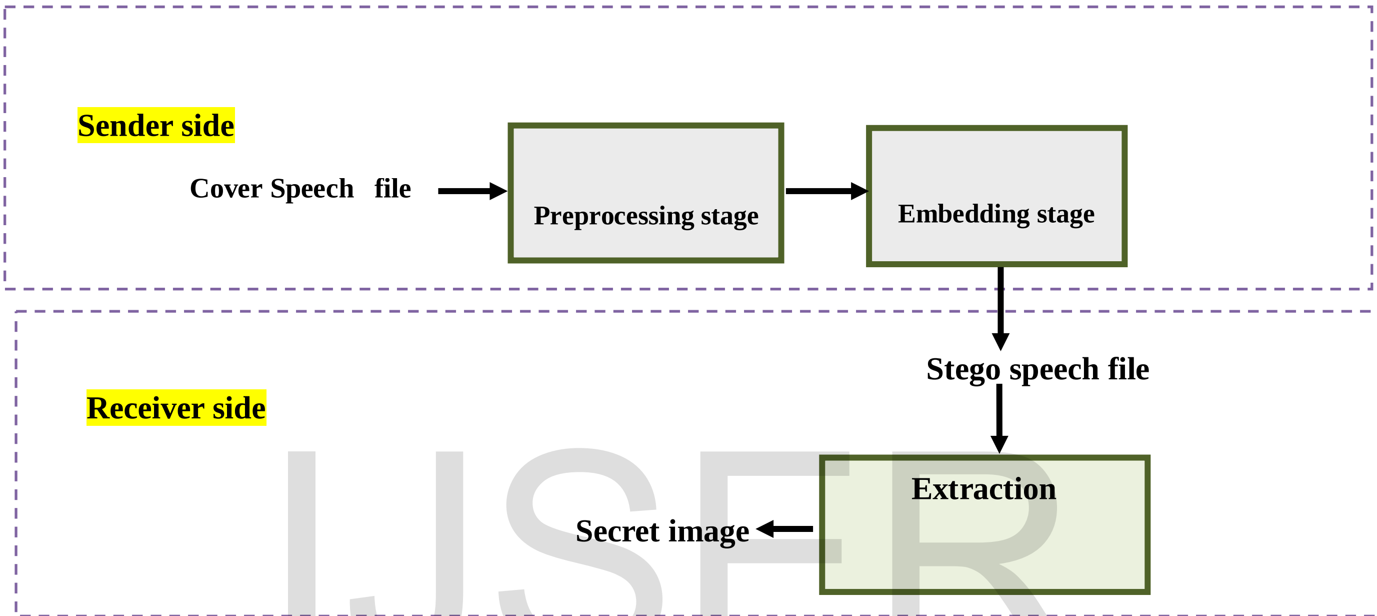


Figure (3) Block diagram of the proposed system

6.1 Preprocessing

The preprocessing stage is depicted in Figure (4). The figure illustrates the steps of preprocessing stages. The secret image as input is scrambled using first key generator (CKG1) by changing the positions of pixels or samples values to get new image completely different from the original one.

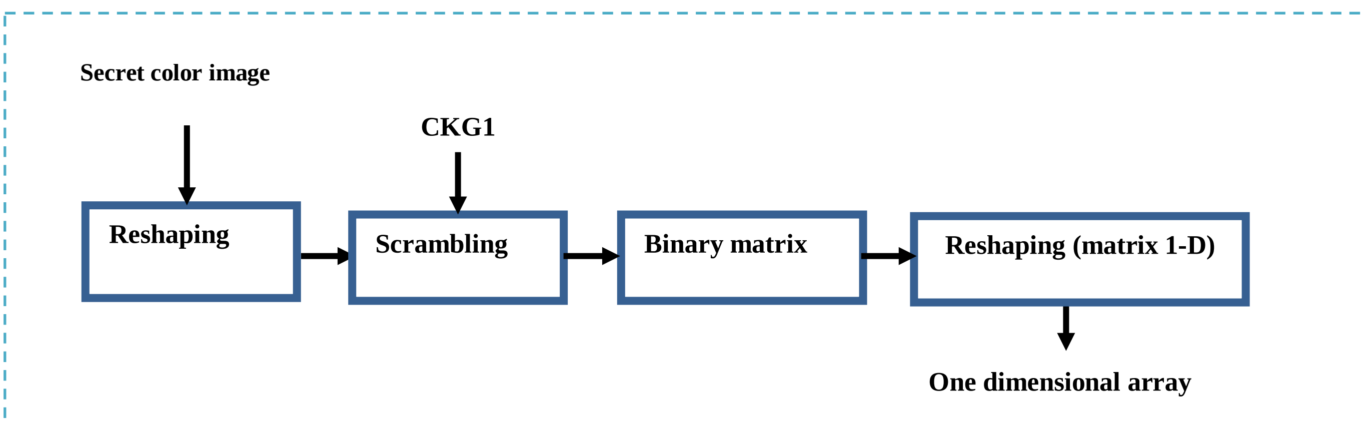


Figure (4) Block diagram for preprocessing stage

The resulting image is with no similarity with original one. Finally the resulting image is converted to binary ad then converted to one dimensional array. The algorithm of this stage is listed in Algorithm *(1):*

Algorithm (1): Preprocessing stage
Input: Image // Secret message (color image)
CKG 1 // Chaotic Key Generation
B // Length of frame
Output: Scrambled image
Began
Step1: Reade secret image and calculate its size
msg ← imread (Image)
[c1 c2 c3] ← size(msg)
Step2: Reshaping secret image from matrix in 3-D to matrix in 1-D and scrambled result matrix by using CKG1
msg1 ← reshape(msg ,1, c1 ∗ c2 ∗ c3)
msg2 ← msg1(CKG1)
msg22 ← reshape(msg2, c1, c2, c3) // the result matrix in 3-D is the scramble image
desiply ← show(msg22) // Show Scrambled image on screen computer
Step3: Converted msg2 from decimal to binary with 8 bites for each pixel
msg3 ← dec2bin(msg2,8)
Step4: reshaping msg3 from matrix 8 column to matrix 1 column and calculate length matrix
msg4 ← reshape(msg3,1, size(msg3))
Len ← length(msg4)
End

6.2 Embedding stage

The aim of this stage is producing the stego speech file. As depicted in figure 5, two important steps are implemented

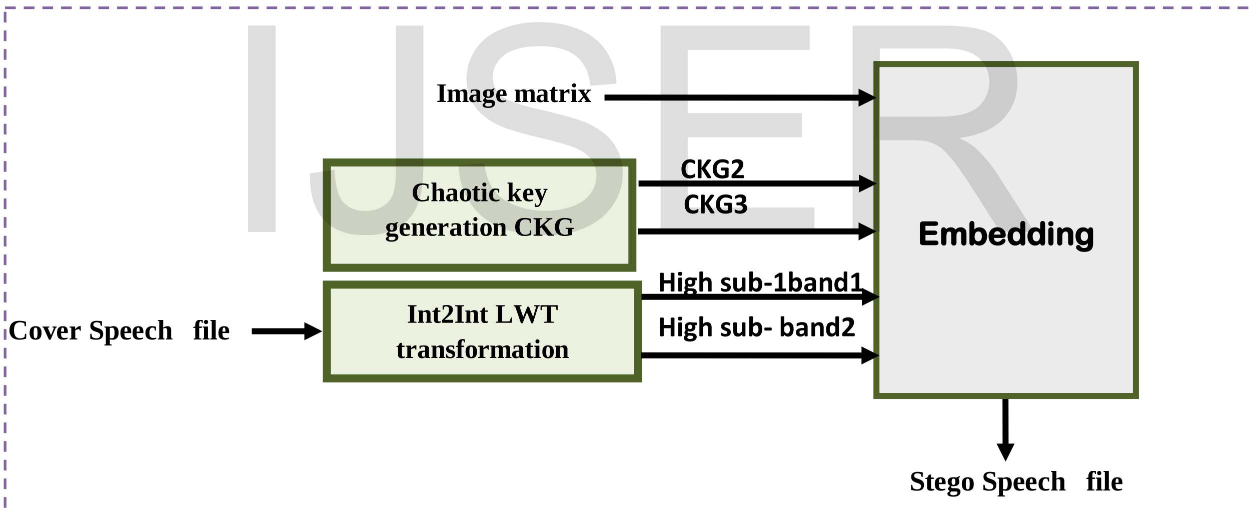


Figure (5) Block diagram for preprocessing stage

Int2IntLWT and embedding are implemented. At first step two levels Int2IntLWT is performs on host signal (speech) . The output coefficients representing high frequency sub-band (detail) and low frequency sub-band (approximation). The detail coefficient is chosen to be the host for embedding secret message. The approximation coefficients or low frequency sub-band leaving without any changing. The first level is performs on Frame contain 512 samples and the result is two matrixes with 256 coefficients each. The detail sub-band1 contains 256 coefficients is used for hiding process. Second level is implemented on approximation sub-band1. The result is another two matrixes of 128 coefficients each. In the second level detail sub-band2 is used for hiding process. The total coefficients that are using for hiding process in both levels are 384 coefficients. At embedding step the LSB is used for replacement and two chaotic keys CKG2and CKG3 are used to generate random values with length 256 and 128 respectively. Segmentation the digital matrix of message in to blocks, each block consists of set of bits. Each one of set bits was being hidden in one frame of cover. The embedding stage algorithm is listed in algorithm (2):

Algorithm (3): Embedding secret message

Input: Cover // Cover speech file
Msg4 // Binary matrix of secret message
X // Number LSB replaced for each coefficient of Int2IntLWT
B // Length each frame
CKG2, CKG3 // chaotic keys using in selection hiding positions
Output: Stego // Stego file that contains embedded secret image
Begin:
Step1: Reade speech file and calculating its length and size
$Y \leftarrow$ wavered (Cover) // Store speech file in matrix Y
$L \leftarrow \text{length}(Y)$
$Z \leftarrow \text{size}(Y)$
Step2: Calculate total number of frames in speech file and that will be needed to hide message
$Frm_{cov} \leftarrow \frac{L}{B}$
$$Frm_{msg} \leftarrow \frac{Len}{X * (\frac{B}{2} + \frac{B}{4})}$$
Step3: Test if the size of speech file is enough to hide secret message
If $Frm_{msg} > Frm_{Cov}$
Error $\leftarrow$ Message Box (Cover is small to hide this message)
End if
Step4: Beginning hiding process for all frames of speech file that needed to embedded message
Begin
For $i \leftarrow 1$ to Frm_{msg}
$F1 \leftarrow 0$
$\mathbf{F2 \leftarrow 1}$
$Frm \leftarrow Y(F1 * B + 1 : F2 * B)$
[low1 $(1 : \frac{B}{2})$, high1 $(1 : \frac{B}{2})$]←Int2Int LWT (Frm) // Implemented 2 levels of Int2Int LWT on frame
[low2 $(1 : \frac{B}{4})$, high2 $(1 : \frac{B}{4})$]←Int2Int LWT (low1)
Replacing LSB of matrixes coefficients high1 and high2with block bits message
For $j \leftarrow 1$ to X
$$high11\left(1 : \frac{B}{2}\right) \leftarrow \text{replace }(high1(CKG2\left(1 : \frac{B}{2}\right)), j, msg4\left(1 : \left(\frac{B}{2}\right)\right))$$
End if // j
For $k \leftarrow 1$ to X
$$high22\left(1 : \frac{B}{2}\right) \leftarrow \text{replace }(high2(CKG2\left(1 : \frac{B}{4}\right)), j, msg4\left(1 : \left(\frac{B}{4}\right)\right))$$
End if // k
$hig1 \leftarrow \text{InversInt2It LWT}[low2, hig22]$ // Implemented invers Int2IntLWT for two levels
$D1 \leftarrow \text{InversInt2It LWT}[low1, hig1]$
$YY(F1 * B + 1 : F2 * B) \leftarrow D1$ // Store output frame in stego speech file
$F1 \leftarrow F1 + 1$
$F2 \leftarrow F2 + 1$
End For // i
End
Step5: Putting the rest samples that did not used for hiding in stego file and read sound
$YY(F2 * B : (siz(Y)) \leftarrow Y(F2 * B : end)$
Stego $\leftarrow$ wavread(YY)

6.3 Extraction stage

Figure (6) shows the steps of extraction stage. It is implemented as the same way of embedding stage but in reverse form.

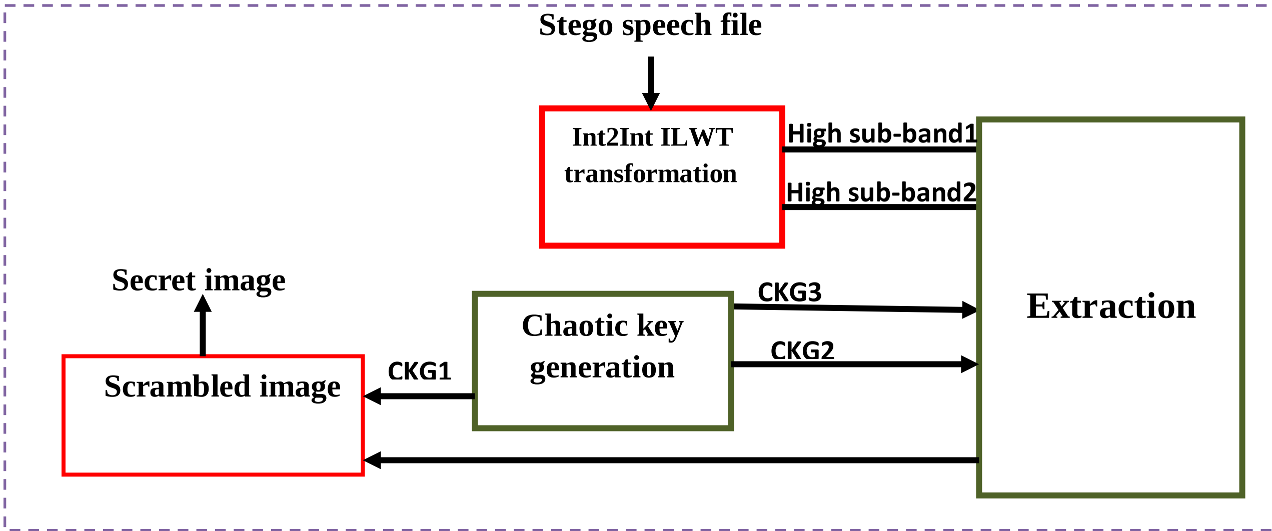
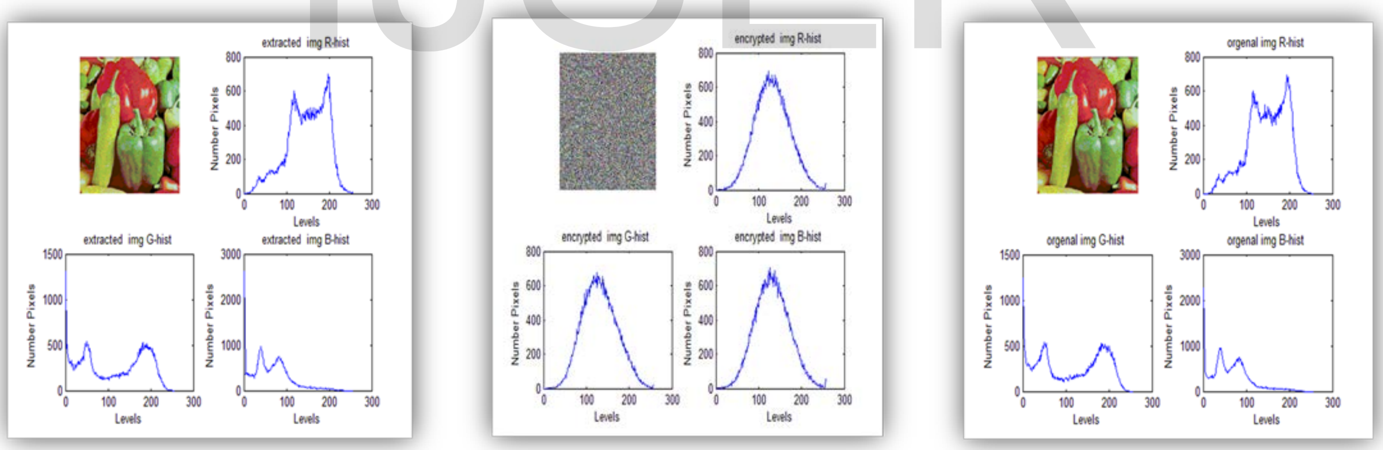


Figure (6) Block diagram for extraction stage

7 Experimental results

Several experimental results have been conducted using four speakers (two females and two males). Time of each speech files is 2 minutes with 16 bits resolution and 8 KHZ. The two colored standard images that have been used in algorithm testing are Pepper and Lena with size (256 * 256).



(A) (B) (C)

Figure (7) Histogram for components (RGB) for (A) original image, (B) scrambled image,

(C) Extracted image for Pepper image

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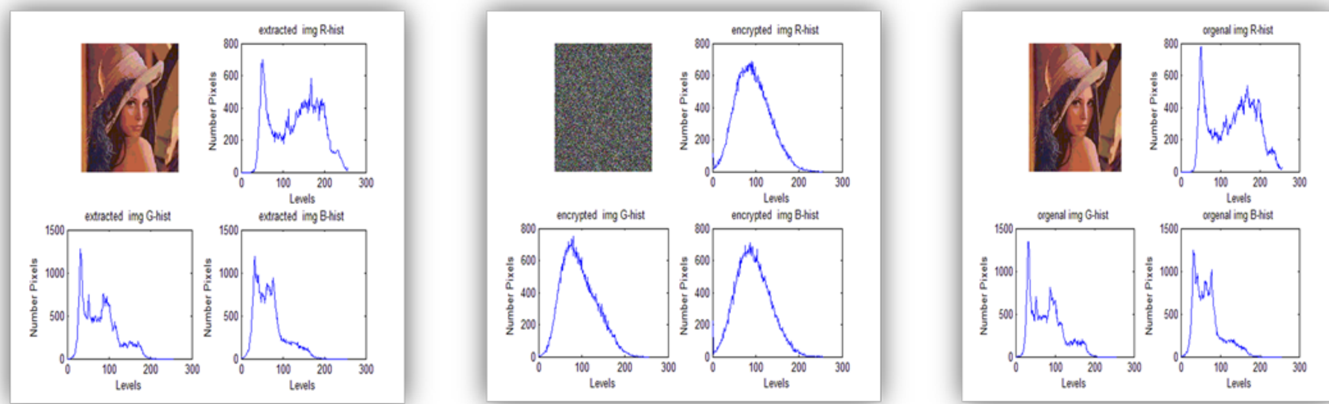

(A) (B) (C)

Figure (8) Histogram for components (RGB) (A) original image, (B) scrambled image

(C) Extracted image for Lena image

Histogram of original, scrambled and extracted images are shown in figures (7, 8). It is noted that the scrambled images give normal distribution. Table (1) declares five of objective measurements that are implemented resulted for Pepper and Lena images. It is noted that correlation test (R_{xy}), signal to noise ratio (SNR), signal to noise ratio segmental (SNR_{seg}), signal to noise ratio spectral (SNR_{spec}) are decreases as the number of replaced bits increased. But mean square error (MSE) is increases with the increasing of number of replacement. Also the experimental result points to that the stego file is undetectable and imperceptible by the HAS. Figure (6) shows waveform of stego speech file and it's original.

Table (1) the result of calculated measurements to hide image in speech file.

cover name	secret image	number replaced bits	SNR	SNRseg	SNRspc	MSE	R_{xy}
female1	Pepper	4	52.4468	50.2477	53.2681	4.3762e-08	0.9854
		6	42.1722	38.0988	41.0951	4.6618e-07	0.9755
		8	31.3158	26.2601	29.3729	5.6781e-06	0.9353
		10	19.4631	14.2476	17.0105	8.6990e-05	0.7882
female1	Lena	4	52.3938	50.2299	53.2266	4.4299e-08	0.9854
		6	42.0760	38.0860	41.0918	4.7662e-07	0.9756
		8	31.2259	26.2905	29.3475	5.7967e-06	0.9355
		10	19.3661	14.2380	17.0638	8.8953e-05	0.7880
female2	Pepper	4	56.4028	53.0303	56.0170	4.3669e-08	0.9856
		6	46.0994	40.9097	43.9818	4.6829e-07	0.9781
		8	35.1653	28.5016	31.5818	5.8066e-06	0.9645
		10	23.6948	16.4334	19.0272	8.1465e-05	0.9158
female2	Lena	4	56.3469	53.0565	56.0810	4.4235e-08	0.9856
		6	46.0150	40.9217	43.9731	4.7748e-07	0.9781
		8	35.1087	28.5603	31.6789	5.8828e-06	0.9646
		10	23.6294	16.5040	19.1119	8.2701e-05	0.9158
male1	Pepper	4	60.2116	57.4941	60.5331	4.3134e-08	0.9856
		6	36.1498	31.9724	35.0476	4.9664e-07	0.9027
		8	24.6153	20.0194	23.0437	7.0712e-06	0.8045
		10	12.8523	7.7007	10.0552	1.0612e-04	0.6676

cover name	secret image	number replaced bits	SNR	SNR_{seg}	SNR_{spc}	MSE	R_{xy}
male1	Lena	4	60.1274	57.5172	60.5557	4.3978e-08	0.9856
		6	36.0699	31.9715	35.0522	5.0587e-07	0.9026
		8	24.5295	20.0244	23.0797	7.2123e-06	0.8052
		10	12.7899	7.6776	10.0726	1.0765e-04	0.6658
male2	Pepper	4	50.4507	47.3696	50.3927	4.3538e-08	0.9784
		6	49.9092	45.6618	48.6851	4.6244e-07	0.9771
		8	39.0497	33.4135	36.4446	5.6365e-06	0.9538
		10	27.3755	21.2573	24.2856	8.2876e-05	0.8557
male2	Lena	4	50.3905	47.4081	50.4120	4.4145e-08	0.9785
		6	49.8308	45.6683	48.6905	4.7087e-07	0.9771
		8	38.9626	33.4616	36.5583	5.7507e-06	0.9536
		10	27.2959	21.2632	24.3421	8.4408e-05	0.8550

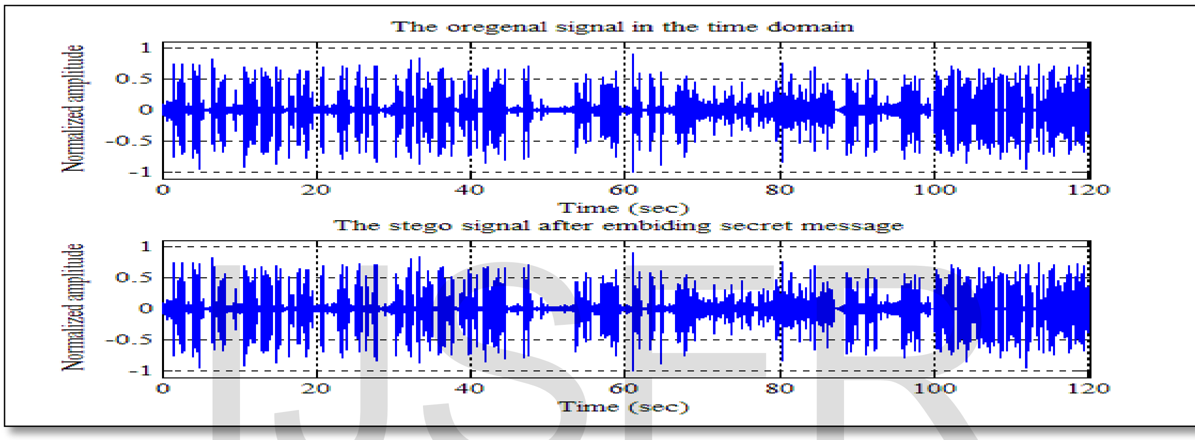

Figure (9) Waveform for the original and stego speech signal

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