

Hiding medical image in an audio signal Using (Curvelet / IWT) transforms And modified LBS method

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Abstract

In this paper we enhance an algorithm to hide a medical image in an audio signals (speech or musical signal) uses the frequency domain to increase its robustness and security.

The proposed algorithm consists of two major parts, the first; the cover audio signal (of type WAV) divided into many blocks then transferred each block to a frequency domain (low and high frequencies) using (Curvelet or Integer Wavelet Transform). Takes the medical image information to be hidden that represented in binary form, then this binary values hides in the low frequency coefficients of the input audio signal blocks by replacing image information with low frequency coefficients digits using a modified LSB method, and the second, is procedure to get a hidden medical image from it, further than this algorithm consists of many parts or procedures to enhance this algorithm to complete this process. This method is done without making noise in sound file. A number of parameters are also used to evaluate the proposed framework such as Mean Square Error (MSE), peak signal to noise ratio (PSNR), Normalized Cross-Correlation (NK), Average Difference (AD), Structural Content (SC) and maximum difference (MD) between the cover and stego audio signal.

Based on the metric parameters value of each audio signal, the stego audio signal uses Curvelet transform has high PSNR value and low MSE value. Hence this uses of Curvelet transform in this new steganography algorithm is very efficient to hide the medical image data inside the audio signal. We implement our proposed system using MATLAB 2011b.

Keyword: steganography, curvelet transform, LSB, IWT.

I. Introduction

Security of information becomes one of the most important factors of information technology and communication because of the huge rise of the World Wide Web and the copyrights laws. Cryptography was originated as a technique for securing the confidentiality of information. Unfortunately, it is sometimes not enough to keep the contents of a message secret, it may also be necessary to keep the existence of the message secret and the concept responsible for this is called steganography. Steganography is the practice of hiding secret message within any media. Most data hiding systems take advantage of human perceptual weaknesses ⁽¹⁾. The Steganography word is come from the Greek words “stegos” meaning “cover” and the name “grafia” as “writing” defining it as “covered writing” ⁽²⁾.

There are a lot of data to be embedded such as text, image, audio, and video. Hiding of secret message using steganography can be done in different forms like text steganography, image steganography, audio steganography and video steganography⁽³⁾. In audio Stenography the weakness of the Human auditory system is used to hide message in the audio. However embedding secret information in digital audio is usually a high difficult process then encodes data in other media and can hide data into a host signal is perceptually transparent. Embedding message into audio Stenography seems more secure due to less steganalysis techniques for

attacking to audio. Furthermore, natural sensitivity and difficulty of working on audio and improvement in related techniques is needed ⁽²⁾.

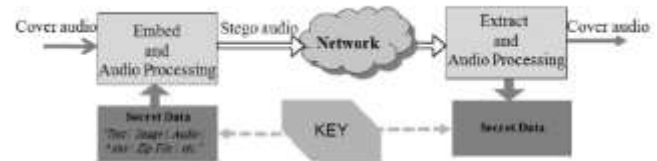


Fig. (1): Blocks diagram for audio steganography.

The digital sound is obtained from the analog sound by converting it to digital domain. This process implies two sub processes: Sampling and Quantization. Sampling is the process in which the analogue values are only captured at regular time intervals. Quantization converts each input value into one of the discrete values. The most popular file formats for sounds are the Windows Audio-Visual (WAV) and the Audio Interchange File Format (AIFF). The most popular format for representing samples of high- quality digital audio is a 16-bit linear quantization e.g., Windows Audio-Visual (WAV) and Audio Interchange File Format (AIFF). Another popular format for lower quality audio is the logarithmically scaled 8-bit m-law. These quantization methods introduce some signal distortion, somewhat more evident in the case of 8-bit m-law. Popular temporal sampling rates for audio include 8 kHz (kilohertz), 10 kHz, 12 kHz, 16 kHz, 22.05 kHz, and 44.1 kHz⁽⁴⁾. The three important parameters in designing steganography method are perceptual transparency, hiding capacity and robustness. The hidden information is imperceptible if a listener is unable to single out between the cover- and the stego-audio

signal. Hiding capacity refers to the amount of obscured data (in bits) within a cover audio signal. The robustness criteria are assessed through the survival of concealed data against noise and manipulations of the audio signal⁽⁵⁾.

II. Materials and Methods

1. Curvelet Transform

Curvelet transform is multiscale and multidirectional transform. It exhibit highly anisotropic shape obeying parabolic scaling relationship. Curvelets are elongated needle shaped structures. It can efficiently represent edge discontinuities in images. The coefficients of curvelet are more sensitive to orientation, which is a useful property for detecting curves in images. The curvelet transform produces smooth image except for discontinuity along a general curve. Generally, in order to extract curvelet features, the images are decomposed into its approximate and detailed components for various levels. These sub images greatly reduce the dimensionality of the original image⁽⁶⁾. The idea of curvelets is to compute the inner product between the signal or function and the curvelet function to realize the sparse representation of the signal or function. So the curvelet transform can be expressed as⁽⁷⁾:

$$c(j, l, k) = \langle f, \varphi_{j,l,k} \rangle \quad \dots (1)$$

Here, $j = 0, 1, 2, \dots$ is a scale parameter; $l = 0, 1, \dots$ is an orientation parameter; and $k = (k_1, k_2) \in \mathbb{Z}^2$ is a translation parameter. The waveform $\varphi_j(x)$ is defined by means of its Fourier transform $\varphi_j(x) = U_j(\omega)$, where U_j is frequency window defined

in the polar coordinate system such as (see fig.(2))⁽⁸⁾:

$$U_j(r, \theta) = 2^{-\frac{3j}{4}} W(2^{-j} r) V\left(\frac{2|j/2|\theta}{2\pi}\right) \quad \dots (2)$$

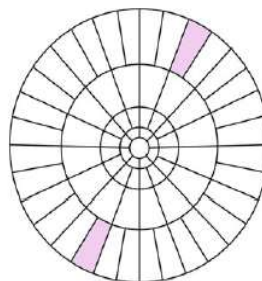


Fig.(2): Continuous Curvelet Tiling of frequency.

W and V are radial and angular windows respectively and will always obey certain admissibility conditions. Curvelets at scale 2^{-j} , orientation θ_l and position $x_k^{j,l} = R_{\theta_l}^{-1}(k_1, 2^{-j}, k_2, 2^{-\frac{j}{2}})$ can be expressed as⁽⁷⁾:

$$\varphi_{j,l,k}(x) = \varphi\left(R_{\theta_l}\left(x - x_k^{(j,l)}\right)\right) \quad \dots (3)$$

Where $\theta_l = 2\pi \cdot 2^{-|j/2|} \cdot l, l = 0, 1, \dots, 0 \leq \theta_l < 2\pi$, R_θ is the rotation by θ radians. A curvelet coefficient is then the inner product between an element $f \in L^2(\mathbb{R}^2)$ and curvelet $\varphi_{j,l,k}$ as⁽⁸⁾:

$$\begin{aligned} c(j, l, k) &= \langle f, \varphi_{j,l,k} \rangle = \\ &= \int f(x) \overline{\varphi_{j,l,k}(x)} dx = \\ &= \frac{1}{(2\pi)^2} \int \hat{f}(\omega) U_j(R_{\theta_l} \omega) e^{i\langle x_k^{(j,l)}, \omega \rangle} d\omega \quad \dots (4) \end{aligned}$$

Fig.(3) shows the digital frequency tiling of the Curvelet transform.

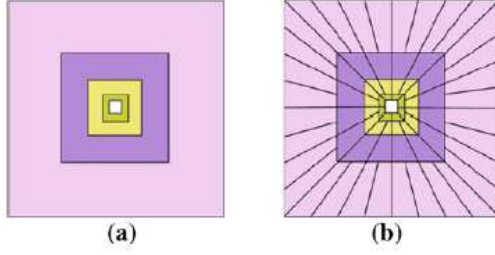


Fig.(3): The basic digital curvelet tiling using, (a) W segmentation and (b) V Direction segmentation.

Digital Curvelet transform is linear and take as input Cartesian arrays of the form $f[t_1, t_2]$, $0 \leq t_1, t_2 < n$, which allow the output as a collection of coefficients ⁽⁷⁾:

$$C^D(j, l, k) = \sum_{0 \leq t_1, t_2 < n} f[t_1, t_2] \overline{\varphi_{j,l,k}^D[t_1, t_2]} \dots (5)$$

The implementation referring to as the FDCT (Fast Discrete Curvelet Transforms) via USFFT. They (1) take the 2D FFT of f' and obtain Fourier samples f' , (2) resample (or interpolate) f' for each scale/angle pair (j, l) to obtain sample values for sheared f' , (3) multiply the sheared object f' with the parabolic window U_j and (4) apply the inverse 2D FFT to collect the discrete coefficients $C^D(j, l, k)$ ⁽⁷⁾. It is provable that curvelets provide an essentially optimal representation of edges. Such representations turn out to be far more sparse than the wavelet decomposition of the object. Roughly speaking, to represent an edge to squared error $1/N$ requires $1/N$ wavelets and only about $1/N$ curvelets ^(7,8).

2. Integer Wavelet Transform

By using Wavelet Transform, the significant parts of the spatial domain signal exist in the approximation band

that consists of low frequency bands and the edge and texture details usually exist in high frequency sub bands ⁽⁹⁾. Integer Wavelet Transform is much faster than the floating point arithmetic in almost all general purpose computers because the floating point wavelet transform demands for longer data length than the integer wavelet transform does. The input data consist of integer samples. The lifting scheme is modified to a transform that maps integers to integers and that is still reversible. The lifting scheme is a simple method for designing customized biorthogonal wavelets and offers several advantages , Allows a faster implementation of the wavelet transform, Saves storage by providing an in- place calculation of the wavelet transform, Simplifies determining the inverse wavelet transform, Provides a natural way to introduce and think about wavelets. The Forward lifting scheme wavelet transform divides the data set being processed into an even half and odd half. Lifting scheme algorithms have the advantage that they do not require temporary arrays in the calculation steps ⁽¹⁰⁾. The Haar wavelet transform can be written as simple pair wise averages and differences ⁽¹¹⁾:

$$S_{1,n} = \frac{(S_{0,2n} + S_{0,2})}{2} \dots (6)$$

$$d_{1,n} = S_{0,2n} - S_{0,2n} \dots (7)$$

Where $S_{i,1}$, $d_{i,1}$ are the n th low frequency and high frequency wavelet coefficients at the i th level respectively.

It is obvious that the output is not integer. The Haar wavelet transform in (6) and (7) can be rewritten using

lifting in two steps to be executed sequentially⁽¹¹⁾:

$$d_{1,n} = S_{0,2n+1} - S_{0,2n} \quad \dots (8)$$

$$S_{1,n} = S_{0,2n} + d_{1,\frac{n}{2}} \quad \dots (9)$$

Then the inverse transform can be calculated by⁽¹¹⁾:

$$S_{0,2n} = S_{1,n} - \left(d_{1,\frac{n}{2}} \right) \quad \dots (10)$$

$$S_{0,2n+1} = d_{1,n} + S_{0,2n} \quad \dots (11)$$

3. Least Significant Bit (LSB)

It is one of the earliest methods used for information hiding. It consists in embedding each bit from the message in the least significant bit of the cover audio in a deterministic way (fig. (4)). Thus, for a 16 kHz sampled audio, 16 kbps of data is embedded. The LSB method allows high embedding capacity for data and is relatively easy to implement or to combine with other hiding techniques. However, this technique is characterized by low robustness to noise addition and thus by low security as well since it is very vulnerable even to simple attacks⁽¹²⁾.

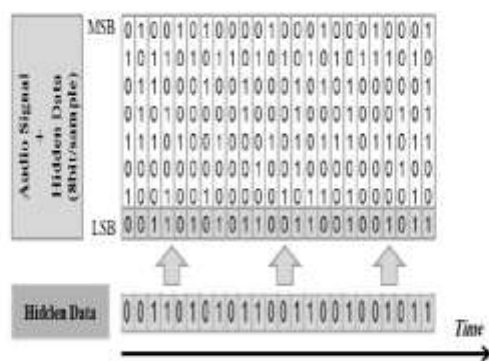


Fig. (4): LSB in 8b/sample signal is overwrote by one bit of the embedded data

In secret message extraction from an LSB encoded audio file, the recipient needs access to the sequence of sample

indices used in the embedding process. The length of the secret message to be encoded is smaller than the total number of section in audio file. We also know about how to choose the subset of samples which contain the secret message or information and communicate that decision to the recipient. One trivial it is to start at the beginning of the audio file and perform LSB coding unto message completely embedded, leaving the remaining sections unchanged. But it creates a problem like in the first part of the audio file will have different statistical properties than the second part of the audio file which was not modified. Solution to this problem is to pad the secret message with random bits so that the length of the message is equal to the total number of samples^(13, 14).

4. Modified LSB

In the modified LSB algorithm here, instead of stuffing bit of the secret medical image only in the least significant bit in the consecutive bytes of WAV file, a random bit selected between (b2 and b3) of the cover audio signal to stuff bits. The chosen bit will be saved in the LSB (b1). The secret medical image can be encrypted before embedding it inside the LSB (b2 or b3) of the audio signal byte by chosen a random binary value (0 or 1). If the random value equal one, we convert the LSB1 (b1) value to '1' then evaluate an encrypted image value by using xored operation between the image value bit and LSB4 (b4) and LSB5 (b5). After that we saved the encrypted value in the LSB2 (b2) of the audio signal byte. If the random bit

equal zero we also extract LSB1 (b1) from audio signal byte and save '0' in it. Then xored operation computed between the LSB6 (b6), LSB7 (b7) and the image value bit. This encrypted value saved after that in the LSB3 (b3) of the audio signal byte. We will Repeated all the above technique until hidden all the image bits in the audio signal bytes. Fig.(5) describe an examples of the Modified LSB.

5. Proposed Algorithm

This paper proposes a technique to hide medical images in an audio signal like speech or music signals. In this paper curvelet, Integer wavelet transforms and modified LSB method of hiding data are used together to obtain a new methodology for hiding a medical image in an audio signal. The methodology is divided in two parts: embedding medical image and extracting medical image.

a. Embedding Algorithm

Embedding algorithm hides the medical image in an audio signal using modified LSB technique. The process of embedding involved the conversion of block values of audio signal and secret medical image into binary sequence and then embedding the binary sequence of medical image in 8th plane of the cover audio signal as following:

- Select medical image (128*128 pixels).
- Obtain the gray scale of medical image (which used for hiding)
- Covert it from decimal to binary system.

- Save all the image binary bits (HiddenBit) in a vector.
- Read the cover audio signal. Leave the header of the audio file untouched. Divide data samples of the audio file to sub blocks with size 256 values.
- For each sub block do the following steps :
 1. Separate each sub block into low frequency and high frequency (CA and CD) Using (Integer Wavelet transform or Curvelet Transform).
 2. Convert each low frequency (CA) into 8 bit sequence.
 3. Do the following:
 - a- Chosen a random binary bit (R= 0 or 1).
 - b- if (R=1) do the following :
 - Extract LSB1 (b1) from low frequency bit sequence's (CA) and save '1' in it (b1=1).
 - Extract LSB4 (b4) and LSB5 (b5) from low frequency bit sequence's (CA).
 - evaluate an encrypted hidden bit for each value in a vector bits (HBits) as following :

$$EHBit = b4 \oplus b5 \oplus HBit$$
 - Extract LSB2 (b2) from low frequency bit sequence's (CA) and save the encrypted image bit in it (b2= EHBit).
 - c- if (R=0) do the following :
 - Extract LSB1 (b1) from low frequency bit sequence's (CA) and save '0' in it (b1=0).

- Extract LSB6 (b6) and LSB7 (b7) from low frequency bit sequence's (CA).
 - evaluate an encrypted hidden bit for each value in a vector bits (HBits) as following :

$$EHBit = b6 \oplus b7 \oplus HBit$$
 - Extract LSB3 (b3) from low frequency bit sequence's (CA) and save the encrypted image bit in it (b3= EHBit).
4. Repeat steps 1-3 until all the vector bits are successfully hidden into CA coefficients of the audio signal blocks.
- Applying Inverse transform that uses above (Integer Wavelet transform or Curvelet Transform) on the modified low frequency coefficients (CA) and high frequency coefficients (CD).
 - The Stego audio signal is generated from the sub blocks that contain the medical image.

b. Extraction Algorithm

The extraction process is reverse of embedding procedure. For this process stego audio signal is considered and the algorithm was applied on it. The steps for the extraction algorithm are:

- Read the stego audio signal then divided it to sub blocks of size 256 values.
- For each sub block do the following steps :
 1. Covert each block to frequency domain (using Integer Wavelet Transform or Curvelet

Transform) to obtain (CA and CD) coefficients.

2. Select (CA) coefficients to convert it into 8 bit sequence.
3. Do the following:
 - a- If LSB1 (b1) equal 1, do the following :
 - Extract LSB2 (b2), LSB4 (b4) and LSB5 (b5) from low frequency bit sequence's (CA).
 - Extract the medical image bit as following :

$$mImageBit = b4 \oplus b5 \oplus b2$$
 - b- If LSB1(b1) equal 0, do the following:
 - Extract LSB3 (b3), LSB4 (b6) and LSB5 (b7) from low frequency bit sequence's (CA).
 - Extract the medical image bit as following :

$$mImageBit = b6 \oplus b7 \oplus b3$$
4. Repeat steps 1-3 until extracting all the medical image values.
- Convert extracting image values from binary to decimal system before saving it in a 2D array of 128*128 values which represent the reconstructed medical image.

III. Results and Discussion

Results were calculated by embedding ten medical images in four audio signals (two speech signals and two musical signals).

To maintain the audio signal quality and provide a stronger robustness and security of a proposed steganography scheme, the statistical parameters are further considered. The value of statistical parameters reduces the audio signal perceptibility and also enhances the robustness to resist attacks. We used Peak Signal-to-Noise Ratio

(PSNR), Mean Square Error (MSE), normalized cross correlation (NK), average difference(AD), structural content(SC) and maximum difference (MD) are used to measure the audio signal quality after embedding the secret medical image.

Suppose that $x = \{x_i | i = 1, 2, \dots, N\}$ and $y = \{y_i | i = 1, 2, \dots, N\}$ are two finite-length, discrete signals like audio signal, where N is the number of signal samples and x_i and y_i are the values of the i^{th} samples in x and y, respectively. The MSE between the signals is given as ⁽¹⁵⁾:

$$MSE(x, y) = \frac{1}{N} \sum_{i=1}^N (x_i - y_i)^2 \dots (12)$$

For this steganography paper purpose, x is cover audio signal and y is medical image to be hidden. Hence it will be referred to as error signal, a difference between original audio signal and its stego signal version.

The PSNR can be calculated by using the following formula ⁽¹⁵⁾,

$$PSNR = 20 \times \log_{10} \left(\frac{255}{\sqrt{MSE}} \right) \text{dB} \dots (13)$$

For computing The AD, SC, MK and MD values, we used the following equations⁽¹⁵⁾:

$$AD = \frac{1}{MN} \sum_{i=1}^M \sum_{j=1}^N ([S(i, j)] - [C(i, j)]) \dots (14)$$

$$SC = \frac{\sum_{i=1}^M \sum_{j=1}^N ([C(i, j)])^2}{\sum_{i=1}^M \sum_{j=1}^N ([S(i, j)])^2} \dots (15)$$

$$NK = \frac{\sum_{i=1}^M \sum_{j=1}^N ([C(i, j)] \cdot [S(i, j)])}{\sum_{i=1}^M \sum_{j=1}^N ([S(i, j)])^2} \dots (16)$$

$$MD = \max(\max([S(i, j)] - [C(i, j)])) \dots (17)$$

Where S (i,j) is pixel value of Cover audio signal and C(i,j) is pixel values of Stego audio signal at location (i,j).

A number of experiments which are used to investigate the effectiveness of our proposed hiding algorithm will be performed. The algorithm was written in MATLAB 2011.a using ten medical images of size (128×128 pixels). A total number of the four audio pieces were used as cover audio signals. Clips were 44.1 kHz sampled audio files, represented by 16 bits per sample. Duration of each sample was 8 seconds. The audio files are categorized as sound of speech and music.

IV. Conclusions

From the information that has been presented in this paper, the steganography technique is a very good method to secrete medical image by sending it through audio signal, and when we applied this method to four audio signals (two speech and two musical signals), we get the same result to hide and retrieval a medical image. It means that this method works in a good way.

Time domain to frequency domain conversion with the assistance of Curvelet transform and IWT is employed. The stego audio signal uses Curvelet transform has high PSNR value and low MSE value (see Table (1) and Table (2)). Hence this uses of Curvelet transform in this steganography algorithm is very efficient to hide the medical image information inside the audio signal.

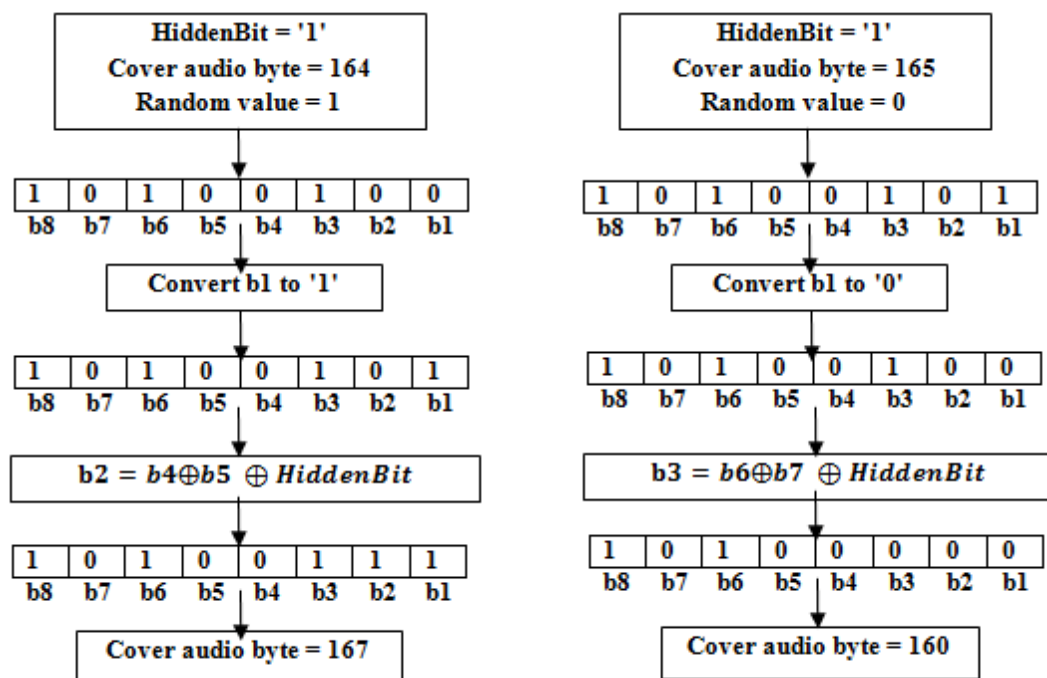


Fig.(5): modified LSB examples.

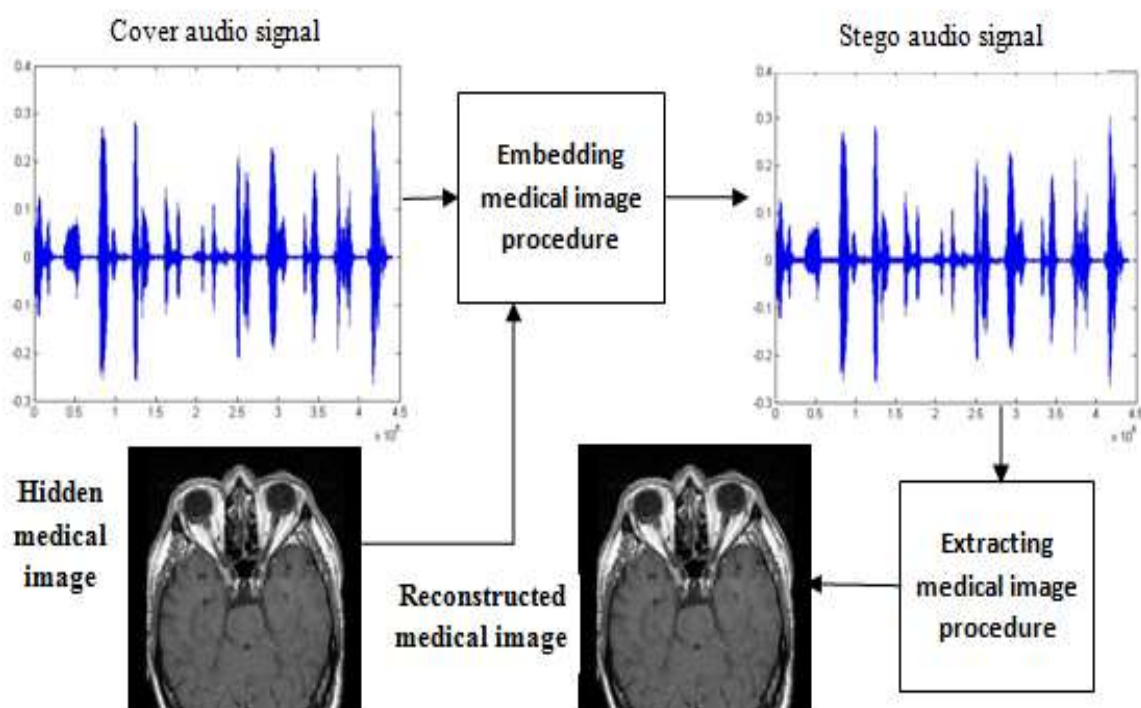


Fig. (6): methodology of the proposed hiding algorithm.

Table (1): Experiment results using Curvelet transform and modified LSB

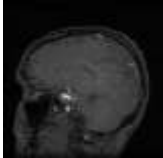
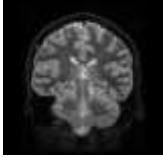
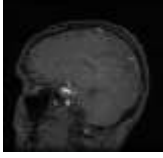
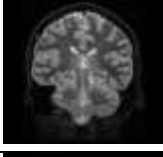
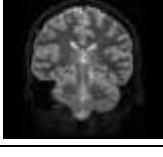
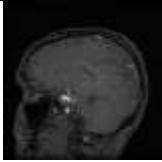
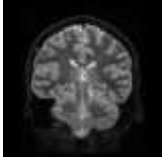
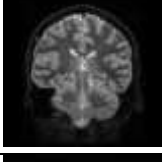
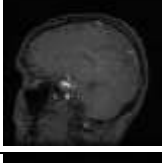
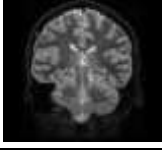
Cover audio signal(8sec.)	Hidden image (128× 128 pixels)	MSE	PSNR	AD	SC	NK	MD
Speech signal1		0.0001	87.6718	0.0036	1.2259	0.8461	0.0308
Speech signal1		0.0001	87.6458	0.0037	1.2268	0.8454	0.0309
Speech signal2		0.0228	64.5486	0.0462	1.4062	0.7574	0.9134
Speech signal2		0.0228	64.5445	0.0462	1.4064	0.7573	0.9131
Musical signal1		0.0152	66.3039	0.0427	2.3940	0.5064	0.8371
Musical signal1		0.0152	66.2991	0.0427	2.3948	0.5061	0.8379
Musical signal2		0.0015	76.2647	0.0192	1.6701	0.6280	0.1568
Musical signal2		0.0015	76.2528	0.0192	1.6704	0.6274	0.1572

Table (2): Experiment results using IWT and modified LSB.

Cover audio signal	Hidden medical image	MSE	PSNR	AD	SC	NK	MD
Speech signal1		0.0001	86.0688	0.0024	1.2243	0.8191	0.0314
Speech signal1		0.0001	86.0495	0.0024	1.2246	0.8186	0.0314
Speech signal2		0.0272	63.7900	0.0269	1.4668	0.7240	0.7490
Speech signal2		0.0272	63.7869	0.0269	1.4669	0.7239	0.7490
Musical signal1		0.0099	68.1676	0.0253	1.4899	0.7038	0.7450
Musical signal1		0.0099	68.1624	0.0254	1.4901	0.7036	0.7450
Musical signal2		0.0008	78.8837	0.0097	1.2430	0.8085	0.1189
Musical signal2		0.0008	78.8683	0.0098	1.2430	0.8081	0.1189

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اخفاء صور طبية في اشارة صوتية باستخدام تحويلي (curvelet/ IWT) وطريقة LBS المحورة

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المستخلص

في هذا البحث تم تصميم خوارزمية لأخفاء بيانات الصور الطبية في ملفات صوتية (اصوات بشرية او موسيقية) باستخدام المجال الترددي Frequency Domain لتوفير كفاءة عالية وامنية شديدة في اخفاء البيانات المرسله. تتكون الخوارزمية المقترحة من قسمين رئيسيين : الاول يبدأ بتقسيم اشارة الصوت (الغطاء) من النوع WAV الى عدة كتل ثم تحويل بيانات كل كتلة الى مجال التردد (الترددات الواطنة والعالية) باستخدام احدى التحويلين (تحويل Curvelet او التحويل المويجي الصحيح Integer Wavelet Transform) وبعد ذلك نقوم باخفاء بيانات الصور الطبية بشكلها الثنائي في الترددات الواطنة من كل كتلة من كتل الاشارة الصوتية (الغطاء) باستخدام طريقة LSB المحورة التي تم اقتراحها في هذا البحث. اما القسم الثاني فيشتمل على اليه استرجاع الصور الطبية المخبئة من الاشارة الصوتية stego audio signal. تتكون هذه الخوارزمية من العديد من الأجزاء أو الإجراءات لإتمام عملية الاخفاء. تقوم هذه الطريقة باخفاء الصور الطبية من دون اضافة ضجيج ملحوظ الى الملف الصوتي.

استخدمنا عدد من المقاييس لتقييم عمل النظام المقترح مثل (MSE) و (PSNR) و (NK) و (AD) و (SC) و (MD) من خلال قياس الفرق بين الاشارة الصوتية قبل وبعد الاخفاء. واستنادا إلى قيمة المعلمات وجدنا ان استخدام تحويل Curvelet ادى الى الحصول على قيمة عالية لمعامل PSNR مقارنة بانخفاض قيمة معامل MSE. مما بين كفاءة هذا التحويل في اخفاء بيانات الصور الطبية داخل الإشارات الصوتية. صمم النظام المقترح باستخدام بيئة العمل MATLAB 2011b.

الكلمات المفتاحية : الاخفاء، تحويل Curvelet، تقنية LSB، التحويل المويجي الصحيح IWT.