Mesopotamian journal of Cybersecurity
Vol.2021, **pp**. 22–32
DOI: https://doi.org/10.58496/MJCS/2021/005; ISSN: 2958-6542
https://mesopotamian.press/journals/index.php/CyberSecurity

Review Article

Theoretical Background of steganography

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ARTICLE INFO

Article History

Received 10 Dec 2020
Accepted 9 Jan 2021
Published 10 Jan 2021

Keywords

Steganography

Hiding Data

Information Security

ABSTRACT

Steganography is a form of encryption which has been used since the days of ancient Greece. It is a method of hiding information within other data. For instance, you may have a company logo in your email, and if someone intercepted the emails being sent, they would see only the innocuous image data. But if they could get access to the same file on your hard drive, they would realise that it contains a message. Steganography deals with hiding the secret information in the cover medium with as minimum distortion as possible. Three types of hiding; text hiding, speech hiding, and encrypted text hiding in coded images are presented in this paper. Also, the challenges and future directions are presented

1. INTRODUCTION

This paper illustrates some concepts about the theoretical background related to hiding secret information in the cover media. All devices and infrastructure required to apply this proposal are also explained in this paper. The cover medium in this thesis is a colour image, and the secret information is text or speech will be hidden inside it in different ways using multiple methods. All the integral equations for implementing are explained.

2. IMAGE PROCESSING AND COMPUTER VISION

Imaging in computer may be separated into two primary categories firstly, the Computer Vision which prepared the images to be used by the computer (PC), secondly, the image processing which yields the images for human utilization as in the following [1]:

2.1 Computer Vision

One of the significant points in this field of computer vision is the analysis of image. The use of computer vision may be in manufacturing systems, medical community and field of security in a functioning region of computer vision framework. Finally, the application goes from programmed distinguishing proof of fingerprints to DNA examination, Satellites Orbiting and infrared imaging [2].

2.2 Image Processing

The term “Image processing” refers to a digital image that is processed by a digital computer that uses pixel to denote the elements of a digital image. It incorporates a wide and different field of applications. In general, it refers to the computer imaging for applications interacting with a human in the visual loop. The main topics of image processing contains Image restoration, Image enhancement, and image compression [3].

3. IMAGE FILE FORMAT

There are several formats to store images, as follows [4]:

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3.1 Bitmap File format (BMP)

Bitmap File format are files of the image inside the Microsoft Windows operating system. BMP files are additionally called paint or raster images and made of a large number of dots called 'pixels,' with various colors and arrangements to construct an image or pattern. It may be an 8-bit (256 color), 16-bit (65536 color) or 24-bit image (16,777,216 color).

3.2 Tagged Image File Format (TIFF)

Tagged Image File Format is used for huge file sizes. TIFF images are uncompressed and contain a lot of points by point which is the reason of the records that suffering enormous. TIFF is most widely in recognized record type utilized in photograph programming, (for example, Photoshop) [5].

3.3 Joint Photographic Experts Group (JPEG)

Joint Photographic Experts Group is a packed image file format used to store a great deal of data in a little size file. Most digital camera card can have different configurations. A JPEG packed losses some of the images details to make small file (and therefore called "lossy" compression). JPEG files are generally utilized for photographs on the web since they make a small file that is effectively stacked on a site page and looks well.

3.4 Graphic Interchange Format (GIF)

This images file format is compressed form of lossless compression (no detail is lost in the compression). GIFs additionally have an amazingly restricted color range reasonable for the web. This configuration is never utilized for photography, due to the predetermined number of colors. GIFs can likewise be utilized for activities.

3.5 Portable Network Graphics (PNG)

It takes into consideration a full scope of color and good compression. It is utilized only for web images, never for the print of images. For photographs, PNG is not better than JPEG, in light of the fact that it makes a bigger file. The colour represented

4. DISCRETE TRANSFORMATIONS

Discrete transforms have mathematical transfers, often linear, for signals between separate domains, for example, between separate discrete frequency and time [6]. Most of discrete transform used in the compression of Image that is used to reduce the expense of capacity or transport. Calculations may profit by visual observation and measurable qualities of image information to give better outcomes thought general compression techniques used in advanced digital information [31].

4.1 Discrete Cosine Transform

Discrete Cosine Transform as in equation (1) is utilized in the video and image compression. DCT isolates images into parts of various frequencies where less imperative frequencies are disposed of through quantization and essential frequencies are utilized to recover the image decompression [32].

$$F(u,v) = \frac{2}{N} C(u)C(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y)\ cos\ \left[\frac{\pi(2x+1)u}{2N}\right]\ cos\ \left[\frac{\pi(2y+1)v}{2N}\right] \dots (1)$$

for u=0…, N-1 (row index in frequency domain), v= 0, …, N-1(column index in frequency domain), x is row index in spatial domain, and y is column index in spatial domain,

Where N=8 and C(k) = {1/√2 for k=0 otherwise it is equal 1}

The inverse of discrete cosine transforms (IDCT) as in equation (2):

$$f(x,y) = \frac{2}{N} \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} C(u)C(v)F(u,v)\ cos\ \left[\frac{\pi(2x+1)u}{2N}\right]\ cos\ \left[\frac{\pi(2y+1)v}{2N}\right] \dots (2)$$

for u=0, …, N-1, v= 0, …, N-1

2.4.2 Discrete Wavelet Transform

DWT changes a discrete time samples to a discrete wavelet representation. It changes series of an input x0, x1…xn, into one low-pass wavelet coefficient arrangement and one high-pass wavelet coefficient arrangement (of length n/2 each) given by equation (3) and equation (4) respectively [7]:

$$H_i = \sum_{n=0}^{k-1} X_{2i-n} \,.\, S_n \quad \ldots (3)$$

$$L_i = \sum_{n=0}^{k-1} X_{2i-n} \,.\, t_n \quad \ldots (4)$$

Where sn and tn are called wavelet filters, K is the length of the filter, and i=0, ..., [n/2]-1. Wavelet filters have been intended for a wide scope of uses and a wide range of sets of wavelet have been proposed for various applications [34].

Haar Wavelet is the most straightforward kind of wavelet. The Haar transforms a separate signal into two sub-signals of a large portion of its length. Haar wavelet is applied for a one- dimensional (1D) low pass and high pass filtering on each of the columns and rows in the input image [8]. Each step of filtering is followed by a sub-sampling, resulting in a change in size. The 2D conversion is distinguishable and can be calculated by applying the comparing one dimensional change on the first column, then on the rows. At every level there are four distinctive images as shown in figure (1), an estimate (LL) of the input image and three detailed images (LH, HL, HH), contained in the yield sub-groups of the DWT [9]:

LL coefficients that relate a low pass channel to rows, trailed by low pass channel to columns.

LH coefficients which relate a low pass channel to rows, trailed by high pass channel to columns.

HL coefficients that relate a high pass channel to rows, trailed by low pass channel to columns.

HH coefficients which relate a high pass channel to rows, trailed by high pass channel to columns.

The linear equations (5) and (6) can be utilized to calculate a mean (a_i) and a difference (d_i) from odd and even component from the input information collection:

$a_i = (S_i + S_{i+1})/2$ … (5)

$d_i = (S_i - S_{i+1})/2$ … (6)

Where S represent samples of input signal.

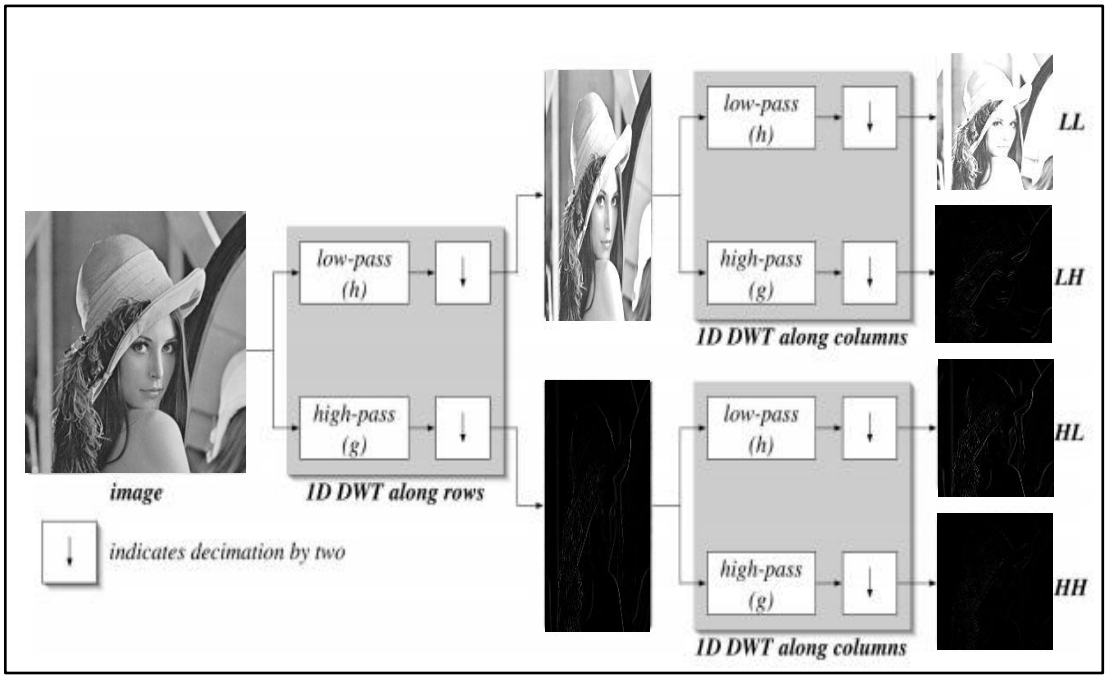

Fig.1. The LL, LH, HL and HH images by Haar wavelet transform (Implemented in MATLAB).

5. STEGANOGRAPHY COMPONENT

Generally, the components of steganography that used for hiding information are as follows [10]:

Cover medium

It is the host medium in which the secret information will be hidden. It may be an innocent looking as part of information or some essential media which must be ensured against copyright or respectability infringement. Covers should contain information which will not probably be recognized to any kind of extraction methods.

Embedded message

The secret message must be placed in the cover medium. Some data may be instruction about the hidden information, copyright information, or some extra contents to a digital watermark.

Stego-key

It is performed by some confidential information, which is necessary in arrangement to extract the embedded message of the stego-object. The stego-key is a little additional information that the recipient ought to know in order to retrieve the message of the container.

Stego-object

It is the output part produced from steganography engine. Steganography could be expressed as in equation (7):

Stego-Object = (Cover medium + Embedded message) + Key … (7)

When the stego-object is produced, the sender can transmit it over an insecure channel to partner (receiver), that is the only person can reconstruct secret message from stego-object because of the knowledge of embedding method and stego-key that is used in the embedding process. In a perfect steganography system, the cover should not be recognizable from a stego-object, neither by human nor through a computer (PC) searching for measurable pattern. Figure (2) describes a steganography components and examples.

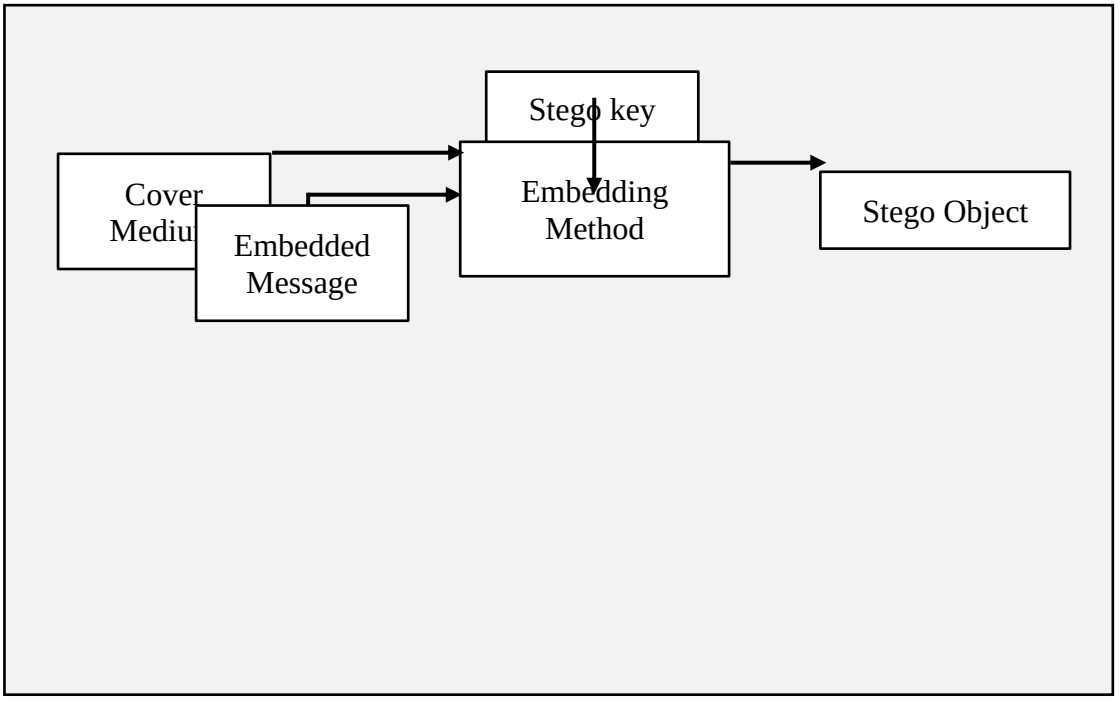

Fig.2. Steganography components block diagram [11].

Digital Speech Representation

A speech represented in digital form is a procedure of converting the analog wave to a number of samples in fixed quantize level. The number of bits required for digitization depends on sample rate, number of quantization level, and the method of representing these bits [12].

Speech coding is a system that utilizes a few bits of the digital speech signal as possible with speech quality consideration. Because of the expanding interest for speech communication, speech encryption innovation has got increasing dimensions of enthusiasm from the examination, institutionalization, and business networks.

Pulse Code Modulation (PCM) is a way to represent speech within a digital domain. PCM is that the most direct mechanism for speech storage with figure (3) shows PCM of analog signal. The file of WAVE is the most popular format to store PCM information. The file of WAVE format backups a different rates of samples, bit resolution, and audio channels. The WAVE file with PCM has uncompressed data, and it could be used in different applications; coding, feature extraction, transformation or others. Therefore, the cover speech, and secret speech chosen as WAVE file format.

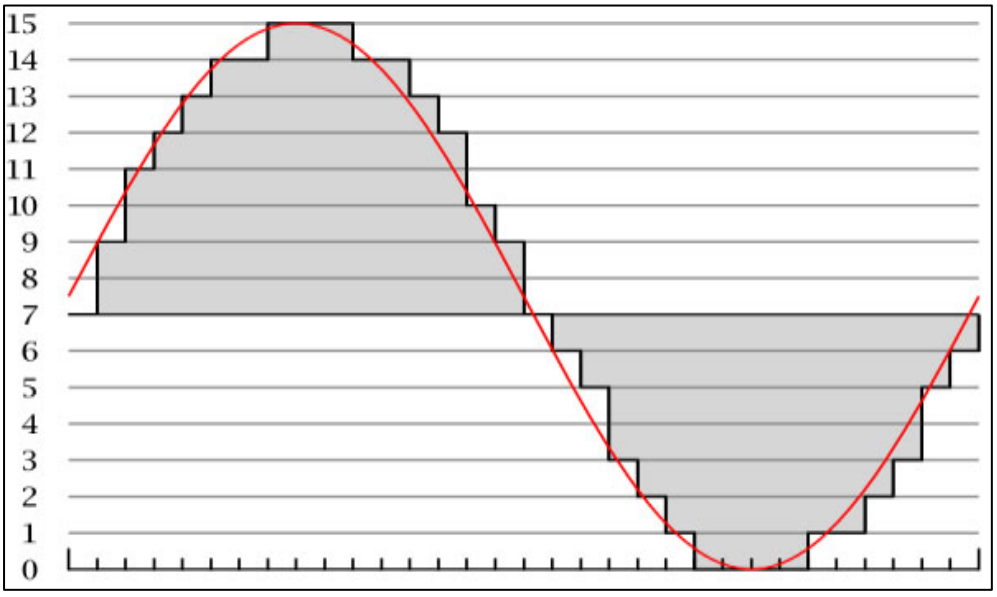

Fig.3. Pulse code modulation (PCM) of an analog signal [13].

6. SPEECH SIGNALS CLASSIFICATION

The speech signal is categorized as unaffected or vocal. Sound are produced when the vocal cords are vibrated so that the airway from the lungs is interrupted intermittently making a set of heartbeat to activate the acoustic channel. Through fixed vocal cords, the fluctuations of the air current passing through the throttle of the acoustic device produce inactive sounds [40]. In the domain of time, voiced sound was portrayed by solid periodicity present in the flag, with the essential recurrence alluded to as the pitch recurrence, or basically pitch. For men, pitch ranges from 50 to 250 Hz, while for ladies the range, as a rule, falls someplace in the interim of 120 to 500 Hz. Unvoiced sounds do not show any sort of periodicity and are basically irregular in nature. In the spectrum, there was a lot of high-frequency parts, comparing to quickly evolving signals. Figure (4) shows the classification of the speech signal into the voiced and unvoiced frame. The length of the edge is chosen so that the measurements of the signal remain practically consistent inside the interim.

6.1 Pre-processing of Speech

The pre-processing of secret speech is partitioned into fixed frame lengths, overlapping and windowing to be transformed later after passing through filters to remove noise.

6.2 Speech Framing

The speech framing partitions the speech signal into frames with a limited number of samples. The first step fixes the desired time of frame like (10, 20, 30 ms … etc.), and the sampling frequency (sample rate) of the selected file. Thus, the number of samples (Seg) in each frame is calculated by applying equation (8) and the number of frame (NoS) is calculated by equation (9).

$$Seg = t_f . F_{rq} \quad \text{... (8)}$$

Where t_f is the frame length in msec, and F_{rq} is the frequency of the selected file.

$$NoS = Floor\left(\frac{Len}{Seg}\right) \quad \text{... (9)}$$ Where Len is the length of file.

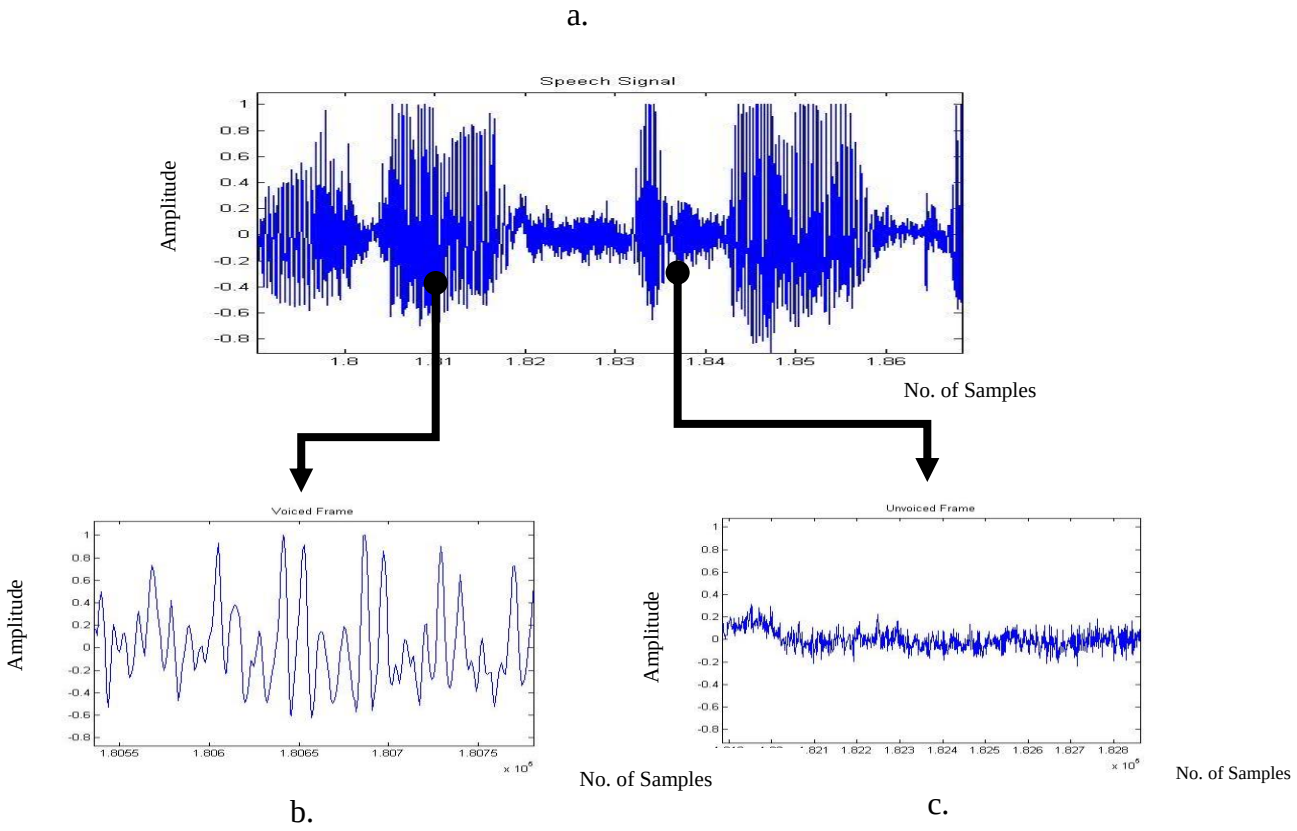

Fig.4. The classification of speech signal [14]

Frame sample of The original signal, b. Voiced frame, and

c. Unvoiced.

Chaotic Map

To some extent, the mathematics behind a chaotic map (evolution function) can be described as chaotic. Depending on the type, it can be used for either continuous or discrete time. It is common practice for individual maps to adopt this strategy for iterating functions via a parameter. In the study of dynamic systems, chaotic maps are frequently employed.. There are some characteristics recognized a chaotic system such as nonlinear, deterministic and dynamical behavior that also produced pseudorandom attribute. In general, all chaotic system is sensitive to initial conditions. A little Difference in parameters values leads to completely difference states of result. These facilities of Chaotic system let it used in cryptographic that satisfied a disorder, a diffusion, and a confusion [12]. In this thesis two type of chaotic map are used and the mathematical definition are explained as follow:

7. LOGISTIC MAP

An often-cited prototypical example of how complex, chaotic behavior can arise from very simple non-linear dynamical equations [19] is the logistic map, a polynomial mapping. Logistic maps can be expressed mathematically using equation (10):

$$X_{n+1} = X_n . R . (1 - X_n) \dots (10)$$

Where xn is a real number between 0 and 1, representing the current population's fraction of the maximum population, and R (sometimes also denoted) is a control parameter with an interest in the range [0,4].

Because of its accessibility, the logistic map is often employed as a first step toward understanding chaos [41]. Chaotic systems are highly sensitive to their initial conditions, and this is a good shorthand for describing their behavior. Maps are often sensitive to initial conditions because they represent a repeated folding and stretching of the space in which they are defined.

8. HENON MAP

Michel Henon introduced the Map of Henon, which is essentially a reorganized version of the Poincare region of the Lorenz display. One of the plane's underlying purposes, as shown by the established map, is to head toward a collection of foci collectively referred to as the Henon strange attractor. Smooth in one direction and a Cantor set in the other, the Henon Attractor is a fractal. According to numerical evaluations, the attractor of the classic map has a correlation dimension of 1.25 0.02 [15] and a Hausdorff measurement of 1.261 0.003. Applying equations (11) and (12), which are iterated several times to generate the necessary elements, can produce chaotic values..

$$x(n+1) = 1 - a . x(n)^2 + y(n) \quad \dots (11)$$

$$y(n+1) = b . x(n) \quad \dots (12)$$

To generate a random number sequence, the iterative sequence of output values is the constants 'a=1.76', 'b=0.1,' x, and y. Keys with an initial value that yields real numbers in period are generated using the Henon Map (0, 1).

9. IMAGE SCRAMBLING

Scrambling of image is considered as a level of security that made image visually unreadable and also difficult to decrypt it for unauthorized users. In general scrambling used in preliminary stages of encryption or coding algorithm of image. There are multiples method of scrambling that may be depend on block based, pixel based, byte based or bit based [16, 20]. The term scrambling, it is expending the attribute of the digital image (array of pixels), to confuse the location of image pixels or intensity of color. The scrambling technique is mainly concerned about the strength of the encryption or decryption [21].

10. IMAGE QUALITY MEASUREMENT

In order to measure the deterioration of the available quality of an image distorted with signal into the original image, a category of fineness assessment measures called the Full Reference (FR) is required. Full benchmarks perform distortion actions that have entire access of the original image. Quality assessment measures are evaluated as following [22]:

Peak signal-to-noise ratio (PSNR)

PSNR are most broadly utilized to measure the quality of rebuilding decompression image. For this situation, the signal is the original information, noise is the error presented by the compression. When comparing compression codes, PSNR is almost for human visualization of reconstruction quality. Typical PSNR values in the video compression and lossy image range from 30 dB to 50 dB, provided that the depth of bit is 8 bits, where the height is good. For typical 16-bit data values of PSNR range between 60 and 80 dB. Accepted values for loss of quality wireless transmission are about 20 dB to 25 dB (13) and (14) which are equations of (mean Square Error) MSE and PSNR respectively.

$$MSE = \frac{1}{m\,n} \sum_{i=0}^{m-1} \sum_{j=0}^{m-1} [I(i,j) - K(i,j)]^2 \quad \dots \quad (13)$$

$$PSNR = 10 Log_{10} \left(\frac{MAX_I^2}{MSE} \right) \quad \dots (14)$$

Where, I is original image, K is distorted image, and (m and n) is image dimensions

The Structural similarity (SSIM)

High natural image signals organized as the pixel display powerful dependency, particularly while they are almost spatially close, their dependency carries information that is very important on the structure about the objects at the scene of visual [46]. Suggested system for designing quality image standards based on assuming that the human visual system (HVS) is very equipped to reproduce structural data from the display area. It follows measuring the change of structural data which may provide almost good distortion of the perceived image. The aims of the Structural Similarity Scale (SSIM) is to measure the quality by taking the images similarity. Three parts of luminance are similarity, structure, and contrast that are determined by equation (2.15).

$$SSIM(x,y) = \frac{(2m_x m_y + c_1)(2\sigma_{xy} + c_2)}{(2m_x^2 + m_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad \dots (15)$$

Where, m_x, and m_y are mean of orignal image and distorted image, σ_x,and $\sigma_x$are standard deviation of orignal image and distorted image, σ_{xy}coverance of two images, and c_1, c_2 a free constant.

Speech Recognition

To recognize speech needs feature extraction of speaker and apply classification algorithm for recognition. Mel Frequency Cepstral Coefficients (MFCC) are features widely used in automatic speech and speaker recognition. Total main steps of MFCCs that considered as a feature type for automatic speech recognition (ASR) as follow: [22, 25]

Frame the signal into short frames.

For each frame calculate the periodic estimate of the power spectrum.

Apply the Mel filter bank to the power spectra.

Sum the energy in each filter.

Take the logarithm of all filter bank energies.

Take the DCT of the log filter bank energies.

Keep DCT coefficients 2-14, discard the rest.

11. DATA CLASSIFICATION (KNN)

Data classification is the process of reordering and labeling data into groups, formulae or distinct class. According to data set requirements, data classification enables the separation and classification of data. In general, it is a data management process. K-Nearest Neighbor (KNN) algorithm K nearest neighbors is a simple algorithm that stores all available cases and classifies new cases based on a similarity measure that used distance to find it. These distances have more than one method such as: Euclidian Distance (Ed), Manhattan distance (Md), or Minkowski distance (Mkd) as explained in equations (16-18)[26]:

$$Ed = \sqrt[2]{\sum_{i=1}^{k}(x_i - y_i)^2} \dots (16)$$

$$Md = \sum_{i=1}^{k}|x_i - y_i| \dots (17)$$

$$MKd = \left(\sum_{i=1}^{k}(|x_i - y_i|)^q\right)^{1/q} \dots (18)$$

Where x_i, y_i are two individuals vectors, K is number samples, and q is problem dimensions

Choosing the optimal value of K is best done by first inspecting the data. In general, a large K value is more precise as it reduces the overall noise but there is no guarantee. Cross-validation is another way to retrospectively determine a good K value by using an independent dataset to validate the K value. Historically, the optimal K for most datasets has been between 3-9.

12. ARDUINO AND SPEECH RECOGNITION

The Arduino board which shown in figure (5) is an open-source device and programming organization by venture and client network that plans and makes single-board microcontrollers and microcontroller units for advanced structure and intelligent systems that can be detected and controlled physically. The design of Arduino has been used by a diversity of

controllers and microprocessors [27]. The boards are outfitted with sets of analog and digital input/output (I/O) pins that might be interfaced to different development boards or breadboards (shields) and different circuits. The feature of boards serial communications interfaces, including Universal Serial Bus (USB) on certain models, which are additionally utilized for stacking programs from personal computers (PCs). The microcontrollers are regularly customized by utilizing the C programming dialects and C++ language. Utilizing conventional compiler toolchains, the Arduino venture gives a coordinated improvement condition (IDE) in light of the processing language venture.

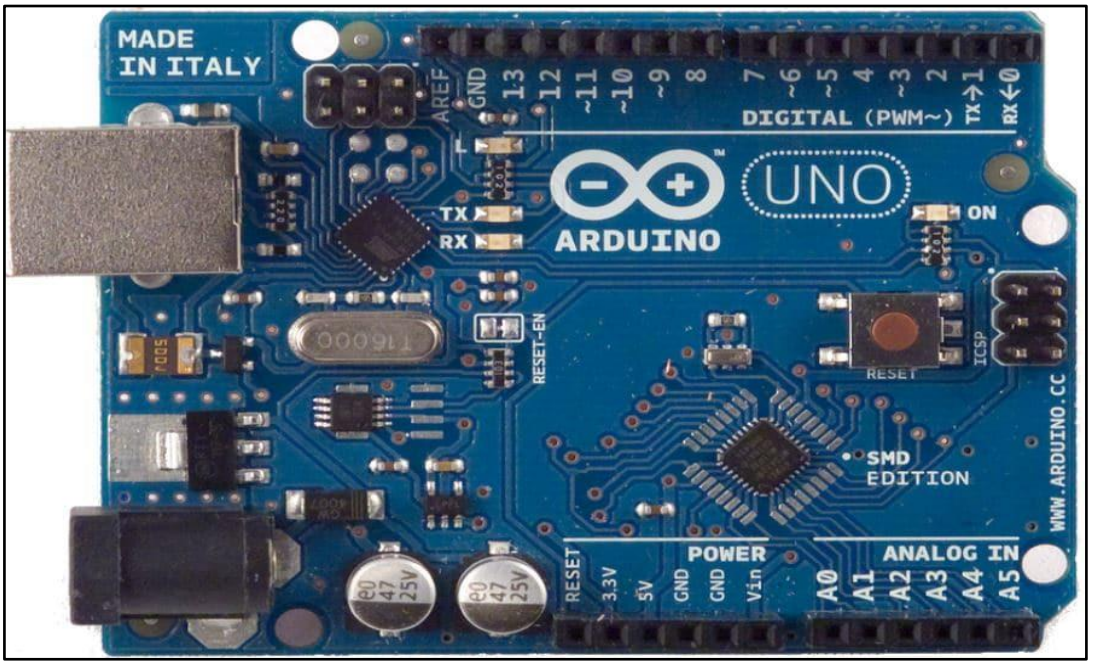

Figure (5): Arduino electronic board [28].

The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. The Arduino programming is distributed as open source apparatuses, accessible for augmentation by experienced developers and the language can be extended through C++ libraries. The speech recognition board as shown in figure (6) is used in two ways for using this module either by using the serial port or through the built-in GPIO pins. The V3 board has the capacity to store up to 80 voice commands each with a duration of 1500 milliseconds. This one will not just convert the commands to text but will compare it with an already recorded set of voices. Therefore, technically there are no language barriers to use this product. It is possible to record command in any language or literally any sound can be recorded and used as a command. Therefore, it needs to train it first before the recognition of any voice commands [29].

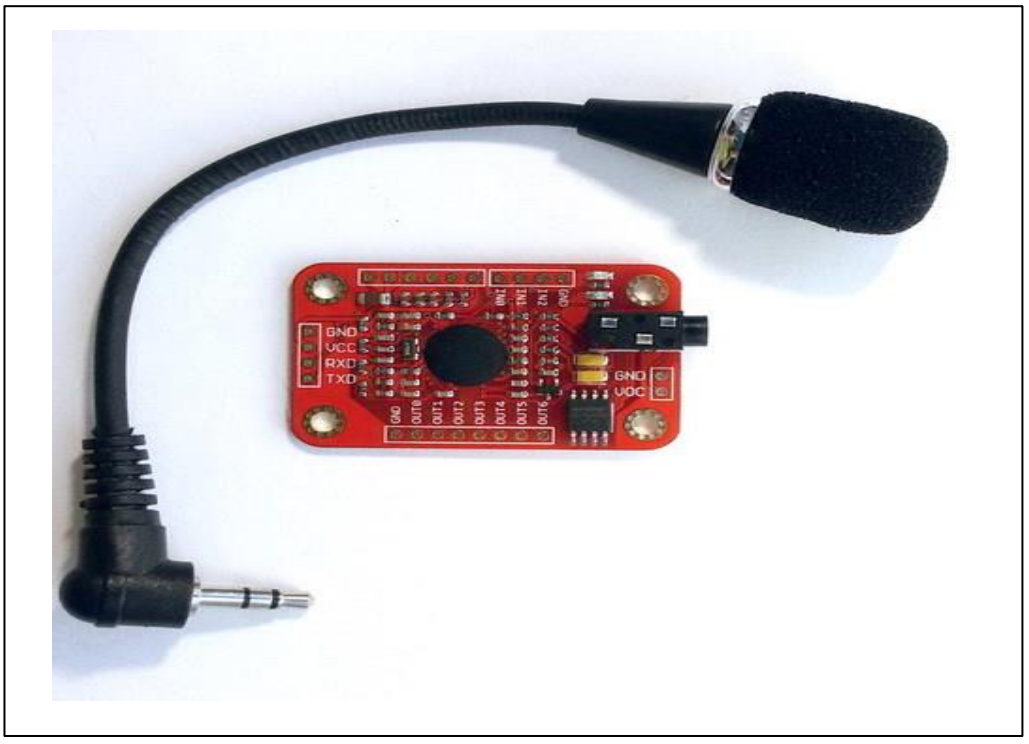

Fig.6. Speech recognition part [30].

Funding

None

Conflicts Of Interest

The authors declare no conflicts of interest.

Acknowledgment

Authors would like to thank Alsalam University college for their support

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