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A Robust Audio Watermarking Scheme based on Quantization Method for Convert Communication

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Abstract:
In this modern era, the importance of multimedia information security cannot be denied. This research paper presents an efficient, secure and reliable audio watermarking scheme based on quantization method for covert communication of digital audio files. The proposed Audio Watermarking Scheme is robust to noise attacks, thus providing safe and secure communication between the transmitter and the receiver. The proposed scheme is implemented in MATLAB. The simulations are carried out and the results are explained with the help of graphs. The audio watermarking is done by quantizing an audio sound and converting it into bits. These bits are then watermarked behind another audio sound having the same number of quantized samples as the number of bits so that each bit is exactly watermarked behind each sample. The audio watermarked sound is then transmitted and the two different sounds i.e. the watermarked sound and the carrier sound are separated at the receiver side.

Keywords: *Audio Watermarking, Concatenation, Covert Communication, Quantization Method.*

I. INTRODUCTION

In recent times, progressions in advanced multimedia technology has enabled us to store, transfer, broadcast and reproduce the digital audio files in a quite efficient way [1]. This expansion in digital multimedia technology has brought us to the world of new challenges. The challenges we are facing today in the field of digital media are copyright protection, security and privacy for our digital audio files [2]. It turns out to be quite imperative to protect and secure the copyright of the digital audio data [3]. Digital Audio watermarking technique is one of the best approaches to protect our digital audio data from theft of a copyright intellectual property [4].

Digital watermarking is the way towards embedding a particular electronic identifier in an audio sound signal to demonstrate its proprietorship or copyright [5][6]. The special audio watermarked signals are embedded into digital audio. The way to extract these signals are detection mechanisms before they are decoded. The three most important requirements of an effective audio watermarking are imperceptibility, robustness and capacity payload [7]. Furthermore, an audio watermarked signal must be inaudible, be statistically invisible, have similar compression properties as the original audio signal, self-clocking and should be embedded directly in the data rather than being in a header [8].

A digital audio watermarking technique is proposed in this paper that is based on the ‘Quantization’ in the time domain. The time domain methodology incorporates techniques in which embedding is implemented without transformation. The original samples of the audio signals are used in the implementation of audio watermarking [9]. The sample values are quantized to generate valid and

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invalid sample values in this proposed quantization based watermarking. This method is proposed because it is robust with a good level of fault tolerance.

The sequence of remainder of the paper is as follows: Section 2 describes the mathematical modelling and working principle of a quantization method. Section 3 illustrates the proposed quantization based audio watermarking scheme with the elaborated implementation steps of proposed quantization method. Section 4 explains the simulation results and discusses the proposed audio watermarking technique. Finally, Section 5 completes the paper with a conclusion and discusses prospective future work.

II. QUANTIZATION METHOD

Quantization, in arithmetic and digital signal processing, is the way towards scaling a large set of input values to a smaller set, for example, adjusting quantities to some unit of accuracy [10]. The sample values are quantized to make valid and invalid sample values in quantization based watermarking. Quantization also forms the core of many audio watermarking schemes.

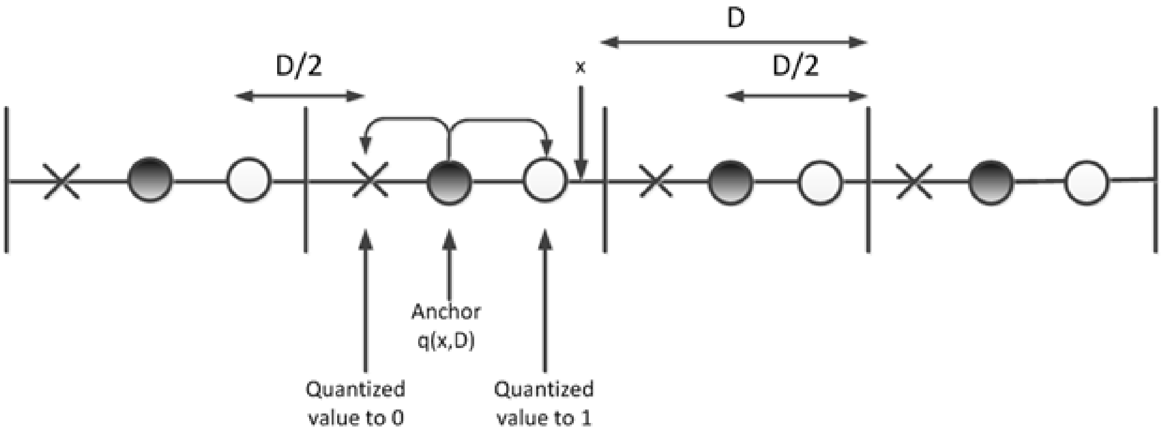

Fig. 1. Numerical representation of working principle of a simple quantization method

A. Working Principle of Quantization Methodology

In a scalar quantization technique, a sample value x is quantized and new value is allocated to sample x depending on the quantized sample value. Consequently, the watermarked sample value denoted by w can be represented as [11]:

$$w = \begin{cases} q(x,D) + D/4 & if \;\; a = 1 \\ q(x,D) - D/4 & if \;\; a \neq 1 \end{cases} \qquad (1)$$

where D is a quantization step. The quantization function denoted by *q* (x) is represented as [12]:

$$q\,(x, D) = [x/D].D \qquad (2)$$

where [*x*] in the above equation denotes the rounded value to the nearest integer of *x*. The demonstration of a simple quantization technique depicted in (1) is illustrated in Fig. 1. *q* (*x*, *D*) represents the quantized value of sample value x. It is represented by a black circle as shown in Fig. 1. If the watermarking bit *a* is 1, then the anchor *q* (*x*, *D*) moves to white circle as shown in the above Fig. Else, a cross shows the watermarking bit as 0 [13]. For instance, let *x* be 81 and *D* be 8. It results in *q* (*81*, *8*) as 80. If *a* = 1, then *w* = 82. Else w = 78. The distance separating the two anchors is denoted by *D*.

The inverse process of embedding is known as detection. The process of detection is summarised in (3) below:

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$$a = \begin{cases} 1 & if \quad 0 < w - q(x, D) < D/4 \\ 0 & if \ -D/4 < w - q(x, D) < 0 \end{cases} \quad (3)$$

It is relatively simple to implement this scheme. If the noise margin remains below *D*/4, this scheme is robust against distortion or noise. If the quantum of additive noise is greater than *D*/4, the detector misunderstands the watermarking bit as the quantized value is perturbed to a significant amount.

III. PROPOSED QUANTIZATION BASED AUDIO WATERMARKING SCHEME

A. Proposed Methodology

A perceptual and robust audio watermarking based on quantization method for covert communication is presented in this section. The audio watermarking is performed by quantizing an audio sound signal and converting it into bits. These bits are then watermarked behind another audio sound having the same number of samples as the number of bits so that each bit is exactly watermarked behind each sample. The audio watermarked sound is then transmitted and the two different sounds i.e. the watermarked sound and the carrier sound are separated on the receiver side.

B. Implementation of Proposed Quantization Method

This section explains how the quantization based proposed audio watermarking scheme is implemented in different steps.

Step 1:

Record an audio sound of 1 second (s) of sampling frequency of 8000 Hz. The objective should be to record the sound clearly without any distortions so that noise will not affect the results. Quantize this audio sound into 32 Levels (n=5). Quantization of 1 s audio sound of sampling frequency 8000 into 32 Levels (n=5) will produce 8000 samples. The quantized sound has more clarity as compared to the original sound. This step is described in (1).

Step 2:

In step 2, convert the samples into bits. For 8000 samples, if each sample is represented by 5 bits, then 40000 bits of 1 s audio sound (8000*5=40000) is obtained. The purpose of representing each sample by 5 bits is that the audio sound is sampled into 32 Levels (n=5). The quantized samples of Step 1 are now obtained in the form of bits. Since this sound is to be watermarked, so its conversion into bits makes it possible to be hidden behind an audio carrier sound.

Step 3:

In step 3, the same procedure is repeated as in step 1 but this time the sound is recorded for 5 s with the same frequency and quantized into 256 Levels (n=8). Quantization of 5 s audio sound of sampling frequency 8000 into 256 Levels (n=8) will produce 40000 samples (5*8000). Hence 40000 quantized samples are obtained. This sound is used as a carrier sound since watermarking will be added to this sound file. The watermarked message in the form of bits will be hidden behind this message. The purpose of recording it for 5 s and converting it into 40000 samples is because the number of bits is equal to 40000 and for unmitigated watermarking to take place the number of samples should also be equal to 40000 so that each bit is exactly watermarked behind each sample.

Step 4:

The step 4 is a further modification of step 2. In step 2, quantized samples are converted into bits. In step 4, first step 2 is repeated and then inverse process of step 2 is carried out as described in (3), i.e. to produce quantize samples from bits. By using the same bit sequence that was used in step 2, the quantized sampled values are recovered. This is to ensure that transmitted data is correct and can be detected. To be able to recover the original quantized samples is very important to ensure that conversion of samples into bits is a reversible process since at

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the receiver side the inverse process of it is carried out to recover the original sound. This is to validate that conversion of bits back to samples gives the same sound that was recorded originally.

Step 5:

In step 5, steps 2 and 3 are combined to transmit the watermarked audio sound. Step 2 produces 40000 bits and step 3 produces 40000 samples. Therefore, each bit of 1 s audio sound which is the hidden message is watermarked behind each sample of 5 s audio sound and is transmitted. Hence eavesdroppers can only hear 5 s audio sound with a beep behind it. The actual message is hidden in that beep. This protects the real message from behind heard and provides a reliable and safe communication of secret messages. The real aim is to provide undetectable and untraceable communication between the transmitter and receiver so that even the message is traced or tapped, still the listener will not be able to hear the actual message. To make the transmission more secure and reliable, the amplitude of 5 s audio sound can be increased to 10 times so that 1 s hidden sound is almost suppressed and even the beep will not be heard.

Step 6:

Separation of audio sounds at receiving end is done in step 6. At the receiving end, the transmitted watermarked audio sound which is actually a combination of 1 s and 5 s audio sounds is separated so that the listener at the receiving end separately receives the hidden message and a 5 s audio sound which was actually used as a carrier. The successful and clear receiving of 2 different audio sounds that were recorded earlier ensures that audio watermarking is successfully done.

IV. SIMULATION RESULTS AND DISCUSSION

This section describes the simulation results and provides the analysis of the presented quantization based audio watermarking technique. The proposed algorithm is implemented in MATLAB. As described above in Steps (1-6), the two audio sound signals are recorded of same sampling frequency of 8000 Hz. One is used as a watermarked signal and the other one as a carrier signal. The objective is to record the sound clearly so that noise will not affect the results.

A. Quantization of audio sound (1 s) into 32 levels

As illustrated above in Step 1, the audio sound of 1 s is quantized into 32 Levels (n=5) to produce 8000 samples. The quantized sound has more clarity as compared to the original sound. Quantization is the discretion of amplitude. The process of quantization is to round up the amplitude values according to the number of levels defined.

B. Conversion of samples into bits

The quantized samples are converted into bits as explained in Step 2. For 8000 samples, if each sample is represented by 5 bits and is then concatenated with each quantized sample, then 40000 bits of 1 s audio sound (8000*5=40000) are obtained. Since this sound is to be watermarked, so its conversion into bits makes it possible to be hidden behind an audio carrier sound. They original sound of 1 s recorded is represented as 'Time Domain Plot of Input Sound' in Fig. 2 and the quantized sound into 32 Levels is represented as 'Quantized Input Sound Using 32 Level uniform Quantizer' in Fig. 3 below:

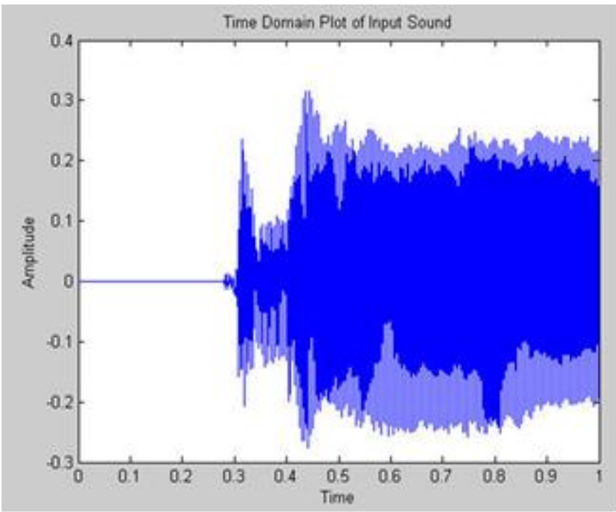

Fig. 2. Watermarked Audio Sound (1s)

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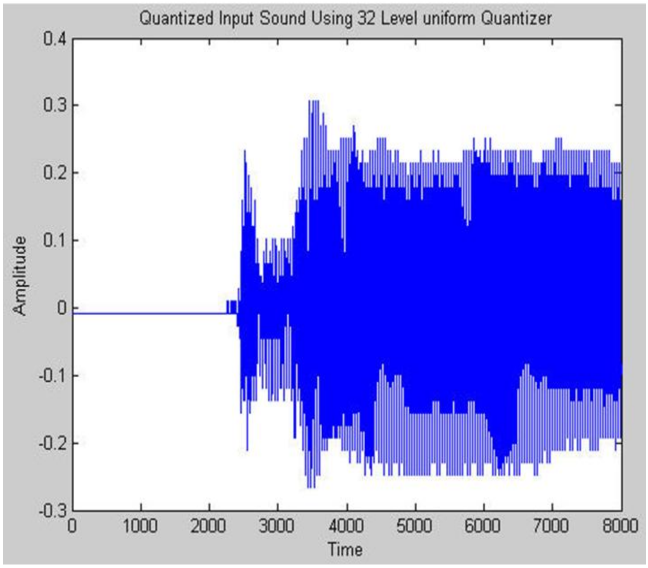

Fig. 3. Quantized Watermarked Audio Sound (n=5)

C. Quantization of audio sound (5 s) into 256 levels

As stated in Step 3, an audio signal of 5 s is recorded which is a carrier signal and is quantized into 256 Levels (n=8) to produce 40000 samples (5*8000). This sound is used as a carrier sound since watermarking will be done on this sound. The watermarked message in the form of bits will be hidden behind this message. The recorded sound of 5 s is represented as 'Time Domain Plot of Input Sound' in Fig. 4 and the quantized sound into 256 Levels is represented as 'Quantized Input Sound Using 256 Level uniform Quantizer' in Fig. 5 below:

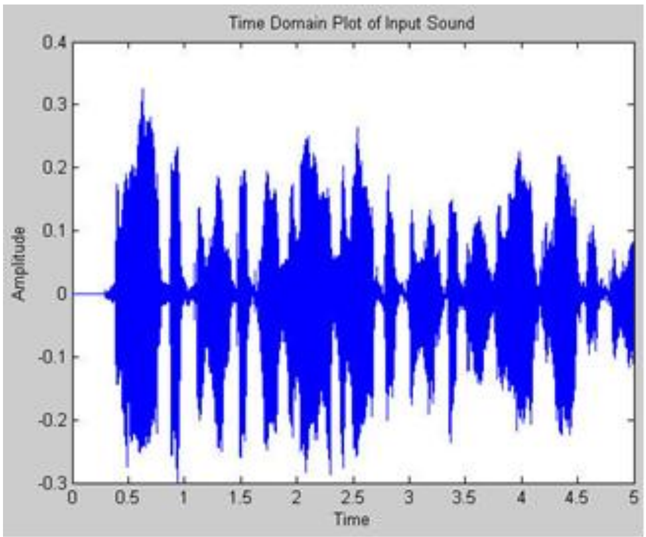

Fig. 4. Carrier Audio Sound (5s)

D. Producing samples from bits

As described in Step 4, the quantized sampled values are retrieved from bits. Successful detection after embedding is very important to ensure the successful recovery of watermarked sound at the receiver end. This also validates that conversion of quantized samples into bits is a reversible process. This step has a significant importance to ensure that intended listener will be able to hear the original sound without any distortion or any loss of bits in data during transmission. Fig. 6 shows the recovered quantized bits represented as 'Quantized Input Sound Using 32 Level. uniform Quantizer' showing identical result as shown in Fig. 3.

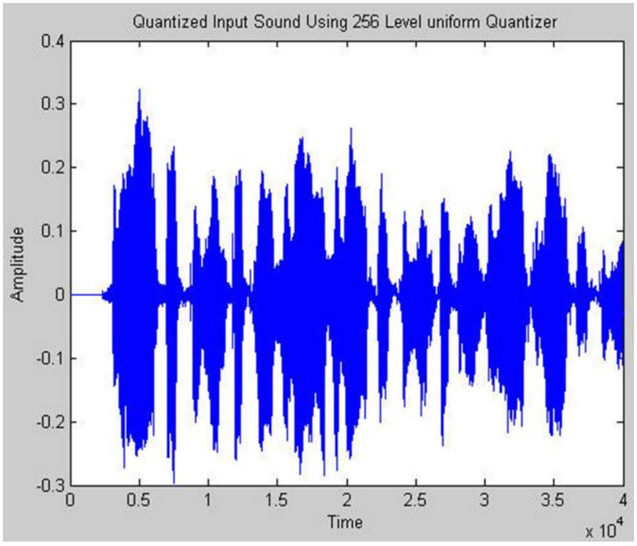

Fig. 5. Quantized Carrier Sound (n=8)

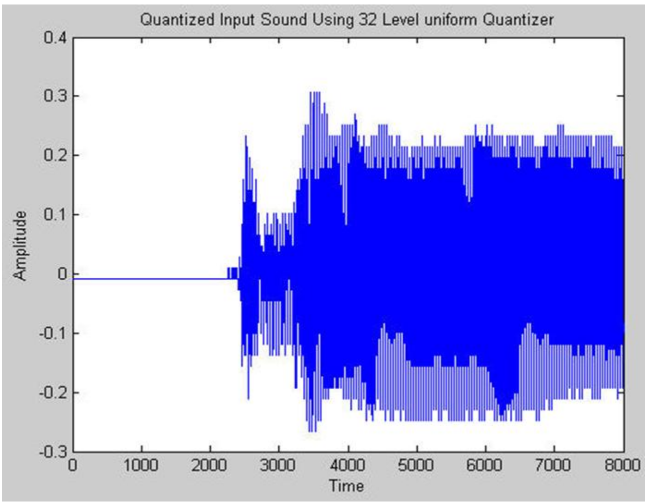

Fig. 6. Recovered quantized samples from bits

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E. Transmission of watermarked audio sound

Transmission of watermarked audio sound is done according to the procedure elaborated in Step 5. As mentioned earlier, Step 2 produces 40000 bits and step 3 produces 40000 samples. Therefore, each bit of 1 s audio sound which acts as a hidden message is watermarked behind each quantized sample of 5 s audio sound and is transmitted. Hence eavesdroppers can only hear 5 s audio sound with a beep behind it. The actual message is hidden in that beep. The amplitude of 5 s audio sound is increased to 10 times to make the process more compact and reliable thus ensuring covert communication. It is represented as 'Audio Watermarked Transmitted sound' as shown in Fig. 7.

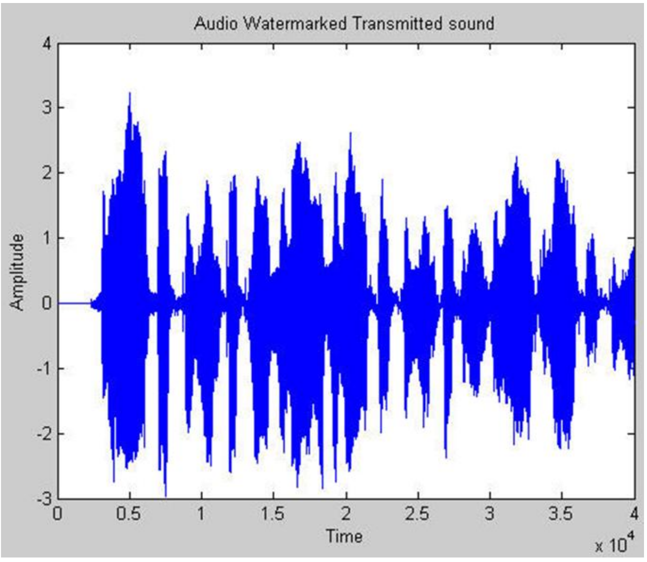

Fig. 7. Transmitted Audio Watermarked Sound

F. Separation of audio sounds at receiving end

Separation of audio sounds at the receiving end is achieved according to the step 6. The listener at the receiving end can hear both sounds separately. The watermarked message hidden in the beep which was almost suppressed by the higher amplitude of the carrier sound can be heard clearly and separately at the receiver end. Thus, the objective to successfully transmit watermarked audio sound is achieved. This whole process can be repeated for any duration of sounds but the care should be taken that quantized samples of one sound should be equal to the bits of other sound to ensure covert watermarking and successful retrieval of the two sounds separately at the receiver.

V. CONCLUSION AND FUTUTRE WORK

This paper has proposed a new, simple and more reliable audio watermarking technique based on Quantization. The technique is easy to implement and provides secure and covert communication. This proposed audio watermarking technique can be emerged as an alternative method that compels and imposes intellectual property rights. It can help to prevent digital audio sounds from theft and tempering. The proposed digital audio watermarking has a significant level of robustness against noise attacks. This audio watermarking is performed by quantizing an audio sound signal and then converting it into bits. These bits are then watermarked behind another audio sound that has the same number of samples as the number of bits so that each bit is exactly watermarked behind each sample. The audio watermarked sound is then transmitted as a combination of two sounds i.e. watermarked sound and carrier sound and both sounds can be retrieved separately at the receiving end. If any eavesdropper tries to pilfer the audio information, this audio watermarking scheme provides undetectable and untraceable communication between the transmitter and receiver so that even if the message is traced or tapped, still the listener will not be able to hear the actual message. This synthesis of a secure and robust audio watermarking scheme can provide a new direction in the field of digital watermarking and copyright prevention. The composition of recent research findings, numerical framework and practical applications of this proposed technique can benefit researchers in engineering and information technology and professionals working in the field of digital audio.

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