An Ownership Verification System using DWT-Arnold Transform with M-Sequence Key for Audio Systems

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***Abstract*— Audio watermarking has been proved as a powerful tool to solve or mitigate the new challenges of audio ownership verification. These challenges arose because of the easiness of copying and distributing audio systems. So audio watermarking is always used as a multimedia copyright protection tool. In this paper we propose an audio ownership verification system based upon utilizing a combination of DWT, Arnold Transform and M-sequence key technique. In order to provide authentication, the input audio signal is framed, DWT matrix formation and embedding methods are proposed and successfully implemented. Arnold transform is performed on the watermark image and a scrambled output is produced. Then M-sequence algorithm is used to encrypt the 2-D images in a single step, thereby providing double security and is embedded into DWT coefficients of the original audio signal. Performance of this technique is evaluated in terms of Signal to Noise Ratio (SNR), Mean Square Error (MSE), Normalized Coefficient (NC) and Accuracy Rate (AR). Objective evaluations unveil that the proposed watermarking scheme preserves high quality and robustness. Also a higher Accuracy Rate verifies the ownership of original audio signal.**

Keywords — Audio watermarking, DWT, Arnold Transform, M- Sequence algorithm, Signal to Noise Ratio (SNR), Mean Square Error (MSE), Normalized Coefficient (NC), Accuracy Rate (AR)

I. INTRODUCTION

With the rapid advancement of the information technology, the use of multimedia such as digital audio, image and video are extensively increased. Although digital signals can offer much better quality and flexibility than analog ones, but it may lead to some illegal copying, production, tampering of digital data, so to counter these problems, a copyright protection system is required. For authentication an audio ownership verification system is also required. One solution for copyright protection mechanism is Watermarking.

Watermarking is the process of embedding an information into a signal in such a way that it should not be removed. Digital watermarking is the method of hiding information into a digital media such as image, audio etc. It is essential that the watermarking system should meet a set of requirements such as Imperceptibility, Robustness, Capacity and Security.

Audio watermarking algorithms should meet certain requirements according to International Federation of the Phonographic Industry (IFPI). The embedded watermark should not be effected by any signal processing effects and unauthorized attacks [1]. Many effective watermarking algorithms have been proposed and implemented for images and videos. Existing audio watermarking system exploit the irrelevant properties of the human auditory system (HAS). Particularly, HAS is insensitive to small changes in the time and frequency domains, allowing the addition of weak noise signals to the host signal such that the changes are inaudible [3]. However, due to the complex and sensitive nature of HAS, only a few algorithms have been proposed for audio watermarking.

Audio Watermarking can be grouped into time-domain and frequency domain. These two domains have different characteristics, and thus its performance may vary with respect to the robustness and imperceptibility requirements of audio watermarking. Inaudibility refers to the condition that the embedded watermark should not produce audible distortion to the sound quality of the original audio, in such a way that the watermarked version of the file is indistinguishable from the original one. Robustness determines the resistance of the watermark against removal or degradation [2].

In time domain, the watermark is embedded directly into a digital media and then the signal values are modified. P. Bassia et al. [4] came up with a method that does not require the use of the original signal for watermark detection. Here, the watermark is generated using a key and watermark embedding depends on the audio signal amplitude and frequency in a way that minimizes the audibility of the watermark signal. J. Huang et al. [5] proposed an algorithm which embeds synchronization signals in time domain to resist the attacks such as cropping while keeping the computation for resynchronization lower. A. N. Lemma et al. [6] formulated a system known as modified audio signal keying. Here the short–time envelope of the audio signal is modified in such a way that the change is imperceptible to the human listener.

In frequency domain, the digital media is transferred to frequency domain where the embedding process takes place. Frequency domain techniques have been more effective than time-domain techniques, since watermarks are added to selected regions in the transformed domain of the host audio signal, such that inaudibility and robustness are maintained. Boney L. et al. [7] framed a method in which watermark is generated by filtering a PN-sequence with a filter that approximates the frequency masking characteristics of the human auditory system and then weighted in time domain to account for temporal masking.

In 2005, an algorithm was developed in which SVD of the spectrogram is modified adaptively according to the information to be watermarked [8]. Raj Kiran et al. [9] suggested a technique based on the quantization in DWT and DCT domains, while considering the more active components of the signal. Copyright protection using DWT-DCT based blind watermarking [10] was another successful method. Here the watermark is scrambled and embedded in a spread spectrum pattern which improved the security and robustness. N. Lalitha, G. Suresh, V. Sailaja proposed an efficient audio watermarking procedure in the frequency domain [11] by embedding an inaudible audio watermark. A DCT- Arnold transform based audio watermarking system [12] evolved recently in which the watermark image is scrambled using Arnold transformation and then embedded into the Discrete Cosine Transformed original audio signal.

This paper proposes an effective audio watermarking technique by suitably exploiting the attractive properties of three powerful mathematical tools: Discrete Wavelet Transform, M-sequence algorithm and Arnold Transform.

The rest of the paper is organized as follows: Section II deals with the mathematical tools such as DWT, M-sequence algorithm and Arnold transform. Section III deals with the proposed method. Section IV deals with the results and performance evaluation. Section V deals with the concluding remarks and future scope.

II. MATHEMATICAL TOOLS

A. *Discrete Wavelet Transform*

The discrete wavelets transform (DWT) is a method capable of giving a time-frequency representation of a signal. DWT produces two sets of coefficients: approximation coefficients A and detail coefficients D. Based on the application and the length of the signal, the approximation coefficients might be further decomposed. Also the original signal S can be reconstructed using the inverse DWT process.

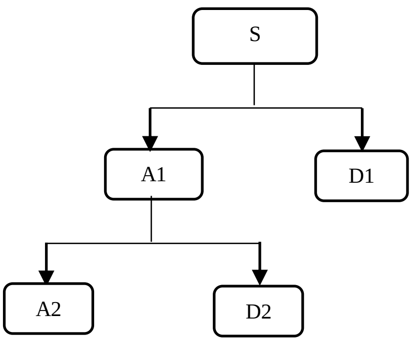

Fig. 1. *2-level DWT decomposition*

B. *Arnold Transform*

Arnold transform changes the position of pixels. After several transformations in the image, disordered image is produced which is very difficult for an intruder to find out the original image. Arnold Transformation algorithm is simple and periodic method.

The K×K binary watermark image W is transformed into W' by Arnold transformation and is given by

$$\begin{bmatrix} a' \\ b' \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} [mod\ k] \quad (1)$$

where k represents the height or width of the original image; $(a,b)^T$ is the original image's pixel coordinate; $(a',b')^T$ represents the scrambled image's pixel coordinate.

Because of its periodicity, the original image can be recovered. Inverse Arnold transform is obtained by using the equation (2). Here $(a1,b1)^T$ is the coordinate of the Arnold transformed image pixel coordinates and $(a1',b1')^T$ is the original pixel coordinates. Mathematically,

$$\begin{bmatrix} a1' \\ b1' \end{bmatrix} = \begin{bmatrix} 2 & -1 \\ -1 & 1 \end{bmatrix} \begin{bmatrix} a1 \\ b1 \end{bmatrix} [mod\ k] \quad (2)$$

C. *M-sequence algorithm*

M–sequence algorithm is basically a scrambling tool that converts an original image into a form that is not easily identified by an unauthorized party. It can encrypt the 2-D images in a single step. M-Sequence is a sequence of random numbers which acts as a key, and is represented in the form of a matrix on the basis of image size. Using this random matrix, the position of pixels are shuffled and a scrambled image is produced which cannot be predicted by any normal person [14]. This image can also be descrambled by a reverse process.

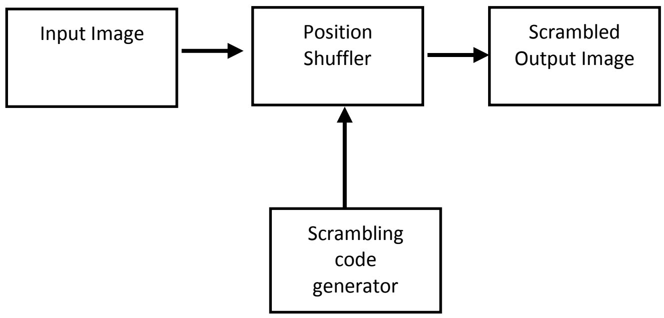

Fig. 2. *Overall process of srambling an image using M-sequence algorithm*

III. PROPOSED METHOD.

Here we propose a DWT- Arnold transform with M-sequence algorithm based audio ownership verification system. Here the watermark image or logo that refers to the owner is embedded into the audio file in a way that it should not affect quality of the original audio. This is achieved by using DWT, Arnold Transform and M-sequence algorithm. The watermark is scrambled using M-sequence algorithm and Arnold Transform and is then embedded into DWT coefficients of the original audio signal. Thus the proposed system is broadly classified into 3 sections:

A. Embedding section
B. Extracting section
C. Verification section

A. Embedding Section

The embedding process is implemented in the following steps.

Step 1: Original audio signal is sampled at a sampling frequency (fs) and partition the sampled signal into frames each having certain samples.

Step 2: Perform DWT on the audio signal. This operation produces two sub bands: approximation sub band (A) and detail sub band (D)

Step 3: Read the watermark image or logo.

Step 4: Apply Arnold transform to the input watermark image.

Step 5: Apply M- sequence algorithm and DWT to the image obtained in step 4.

Step 6: Embed the transformed watermark coefficients into the DWT transformed original audio signal. This can be achieved by the following equation:

$$A_W = A + (\alpha * W) \quad (3)$$

where

α is a scaling factor and it is chosen such that audio quality is not degraded.

A is the original audio signal

W is the watermark image

A_W is the watermarked audio signal

Step 6: Apply the inverse DWT operation to obtain each watermarked audio frame.

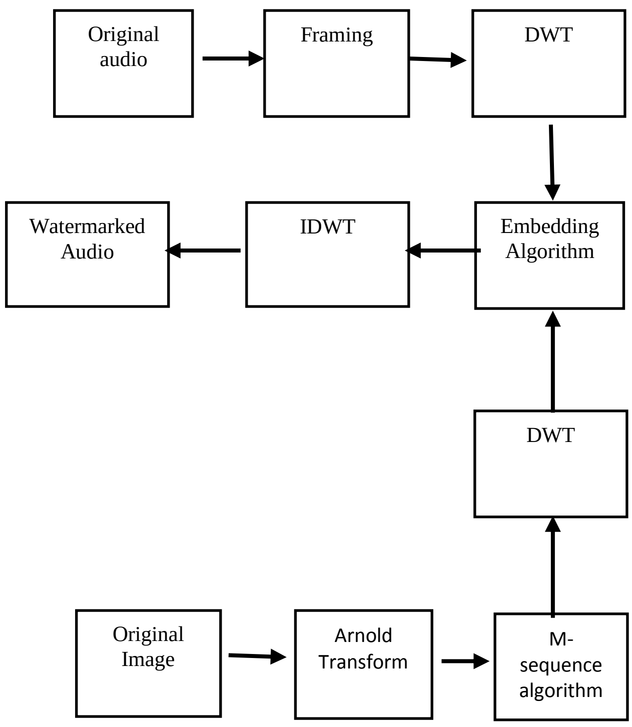

Fig. 3. *Embedding Section*

B. Extracting Section

The extracting process is implemented in the following steps.

Step 1: Watermarked audio signal is sampled at a sampling frequency (fs) and partition the sampled signal into frames each having certain samples.

Step 2: Perform DWT on watermarked audio signal and obtain the DWT coefficients.

Step 3: Transformed watermark can be obtained by using the following equation.

$$W' = \frac{A_W - A}{\alpha} \quad (4)$$

where W' is the extracted watermark image.

Step 4: Apply IDWT to the values obtained in step 3.

Step 5: Apply inverse M-sequence algorithm to the values obtained in step 4.

Step 6: Perform inverse Arnold transform in step 5.

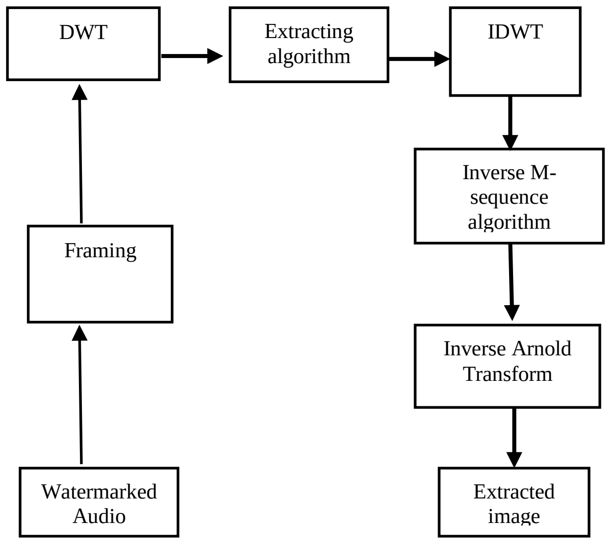

Fig. 4. *Extracting Section*

C. Verification Section

The bits of Original watermark image are compared with those of extracted image. The system verifies the owner when the compared bits match. This procedure is shown below

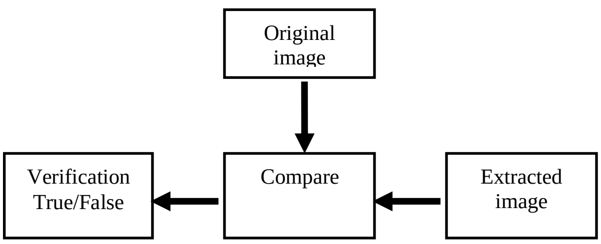

Fig. 5. *Ownership verification System*

IV. EXPERIMENTAL RESULTS

In this paper, we chose an image of size 204×204 as watermark image. Ownership verification is done by evaluating Accuracy Rate. Robustness and imperceptibility are also verified for the proposed watermarking algorithm. In our experiment we chose 9 different audio signals.

A. Results

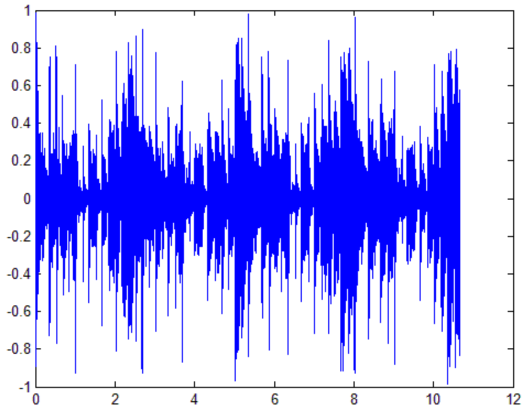

Fig. 6. Input Audio Signal

a.

Fig. 7. Input Image

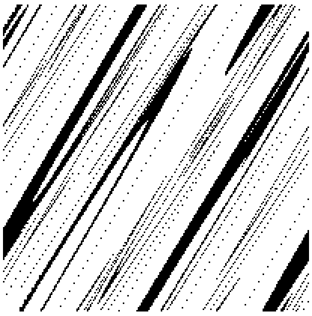

Fig. 8. Scrambled inage using Arnold Transform

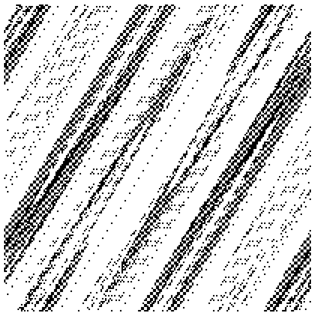

Fig. 9. Scrambled image using M sequence algorithm

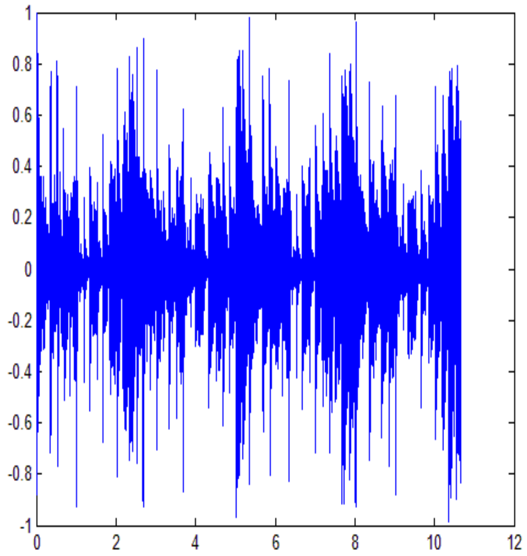

Fig. 10. Watermarked Audio Signal

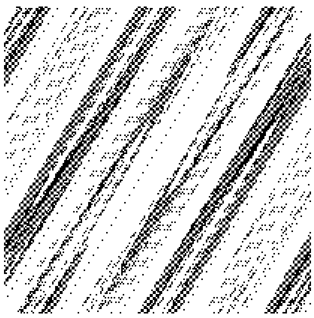

Fig. 11. Descrambled image using M sequence algorithm

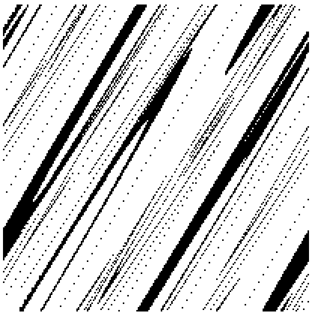

Fig. 12. Descrambled image using Arnold Transform

Fig. 13. Extracted Image

B. *Objective Evaluation*

1) *Signal to Noise Ratio*

Signal to noise ratio (SNR) is a parameter used to compute the amount by which the signal is corrupted by the noise. SNR can be calculated using the equation given below.

$$\text{SNR} = 10 \log \left(\frac{\sum_{a=1}^{M} X^2(a)}{\sum_{a=1}^{M} (X(a) - X'(a))} \right) \quad (5)$$

where X is the un-watermarked audio signal and X' is the watermarked audio signal.

2) *Mean Square Error*

MSE measures the average of the squares of the "errors." The error occurs because of randomness [13]. It is calculated by using the equation given below.

$$\text{MSE}(x, y) = \frac{1}{N} \sum_{i=1}^{N} (x_i - y_i)^2 \quad (6)$$

TABLE I. Represent the comparison of SNR and MSE of 9 audio files

Audio files	*SNR (in dB)*	*MSE*
WAVE 1	86.01	0.000033
WAVE 2	76.51	0.000011
WAVE 3	74.37	0.000021
WAVE 4	71.77	0.000010
WAVE 5	71.09	0.000017
WAVE 6	64.91	0.000037
WAVE 7	64.76	0.000013
WAVE 8	64.39	0.000012
WAVE 9	49.13	0.000082

3) *Normalized Correlation (NC)*

Normalized Correlation is used to estimate the similarity between the original watermark and the extracted watermark. NC value of about 0.7 or above is considered acceptable. The normalized correlation is defined as equation:

$$\gamma = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\sqrt{\sum_m \sum_n (A_{mn} - \bar{A})^2 + \sum_m \sum_n (B_{mn} - \bar{B})^2}} \quad (7)$$

where
γ is the Normalized Correlation
A is the extracted image
B is the original image
$\bar{A}$ and $\bar{B}$ are the means of A and B respectively

4) *Accuracy Rate (AR)*

Accuracy of the proposed method is measured using the following equation

$$AR = (CP)/(NP) \quad (8)$$

where CP is the correct bits that are extracted from attacked audio and NP is the total number of bits in the watermark. According to this method, a higher Accuracy Rate proves the ownership of original audio signal.

V. CONCLUSION

Here we presented a robust DWT-Arnold transform with M-sequence key based audio ownership verification system. To check the imperceptibility and robustness, SNR, MSE, NC and AR are calculated. The value of SNR and MSE satisfies the IFPI requirement. NC of about 0.7 or above is considered acceptable which we have obtained in this. While performing this algorithm on different audio signal, we can conclude that a higher Accuracy Rate verifies the ownership of original audio signal. Thus the proposed method achieves good robustness and imperceptibility. This technique can be extended to analyze the validity of the method on various classes of audio signals, thereby establishing an overall efficient audio watermarking scheme.

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