Audio Watermarking Using Modified Least Significant Bit Technique for Music Signals

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***Abstract*—In this paper a Digital Audio Watermarking system based on modified LSB Technique for music signals has been proposed. The main objective of the proposed method is to enhance the robustness of the watermarked music signals. The methodology of both embedding and extraction processes are discussed and implementation is done via MATLAB. The music signals used for the watermarking process belong to both instrumental and vocal categories. The performance of the proposed method is evaluated by comparing the generic LSB Technique and Modified LSB Technique using signal to noise ratio (SNR) as the parameter. The watermarked audio is subjected to certain signal processing attacks and analyzed to evaluate its robustness.**

Keywords—Least Significant Bit (LSB), Signal-to-Noise Ratio (SNR), Audio Watermarking, Signal Processing Attacks, Watermark Embedding, Audio Signals.

I. Introduction

In recent years there has been a significant rise of digital content creation such as music , short movies, wildlife photographs etc. Ease of processing in software and subsequent ease of widespread distribution of content has greatly contributed for the growth of digital content. While this medium has remained a boon,it brings along with it the responsibility of protecting intellectual property rights.

Unlimited copying and illegal distribution of content is undesirable as it leads to considerable financial loss. Digital piracy is combated with the first line of defence being copyright. In addition, a watermark can be embedded on it, which can serve as a reminder of the copyright. While copyright protection is a major application of watermarking, it is also used for other applications such as data monitoring and tracking. Automatic registration and tracking of broadcasted radio shows are an example of a data monitoring system in which royalties are charged to the IPR owners of broadcast data.[1].

A watermark is a digital code which, in general, contains information about the ownership of the source. In this paper, we confine the source to music signals and the watermark to an image. The watermark is embedded in the source in a way that doesn't affect the perceived quality of the source and is robust against standard data manipulations. The watermark shouldn't affect the perceived quality of the source. Only the owner should be able to extract the watermark.It should be robust to different signal attacks.

An audio watermarking scheme should have certain properties to be effective and used for commercial applications. Some of these properties are mentioned below[3].

- Imperceptibility
- Security
- Robustness
- Verifiability
- Fragile
- Semi Fragile
- Constant Bit-rate

In recent years Audio Watermarking Applications have significantly increased in the field of commercial music with the growth of music streaming apps such as itunes, spotify, wynk etc. More number of artists face copyright violation, piracy issues etc. Some of the applications are mentioned below [4].

- Copyright Protection
- Ownership Protection
- Television Broadcasting
- Authentication and Tempering Detection
- Medical applications
- Communication Enhancement
- Content Filtering
- Airline Traffic Monitoring
- Vendor Identification
- Validation of genuineness

Several methods have been proposed for watermarking in recent years in both frequency domain and spatial domain. Frequency domain techniques include methods based on DCT[2][5], DWT [6][7], SVD[8] or a combination of them [9][10]. Spatial domain methods include those based on LSB,SSM based and patchwork based[11].Advanced watermarking algorithms in the spatial domain directly alter or manipulate the pixel value and for that, they straightforwardly stack the basic information into the original source [12]. This paper focuses on the spatial domain technique of LSB based watermarking of music signals.

In general, the LSB approach modifies the least significant bits of the initial set of samples in an audio document and implants a watermark[11].This concentrates on modifying the bits in one area and this makes it less robust and more vulnerable to attacks.

In this paper a modified LSB based algorithm for audio watermarking is proposed. The watermark image will be embedded on the least significant bits of samples throughout the audio signal instead of being localised to a particular area. LSB's at certain intervals will be replaced by the bits of the watermark image. Intervals are decided by taking the ratio of the size of the audio source and that of the watermark. The overall procedure is implemented using Matlab. A comparison is provided between the existing LSB approach and the proposed Modified LSB approach by evaluating the signal to noise ratio (SNR) of all the audio signals . Robustness is evaluated by subjecting the watermark embedded signals to various signal attacks and analysing the signal to noise ratio.

II. METHODOLOGY

A. LSB Algorithm

Out of the several algorithms available for watermarking,the LSB algorithm is the simplest one. The algorithm involves converting the watermark image into binary form and embedding the image into the last bit plane of the audio samples sequentially. While this may be a method that is rapid and easy to implement and one that works well with gray scale images, it is very weak with respect to robustness and tamper resistance. Fig 1. Shows the overall methodology for this process.

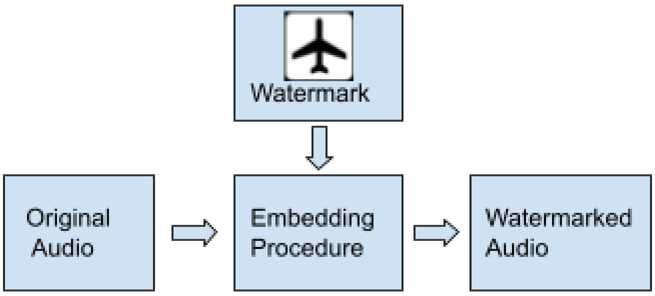

Fig 1. Watermark embedding

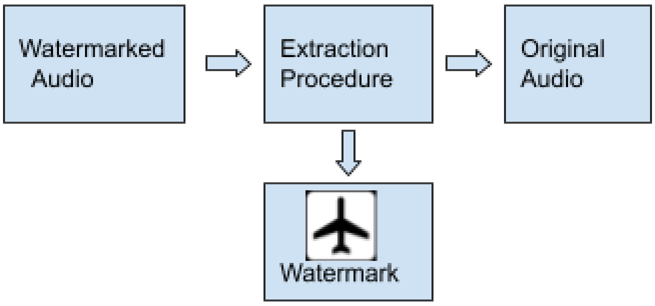

Fig 2. Watermark extraction

B. Embedding Process

This process is to insert the watermark image into the audio signal using the proposed LSB Technique. Inputs for the embedding procedure are image and audio signal.

1. Load and read the audio signal which is to be watermarked.

2. Quantize the audio samples from double [-0.5 to 0.5] to [0 255] range and then convert to binary form, each sample consisting of 8 bits.

3. Load and read the watermark image.

4. Find the length and width of the image and convert the watermark to binary form which is a matrix of [n b] where n is the product of length and width and b is the number of bits.

5. Convert [n b] to 1-D watermark i.e., [(n*b) 1] matrix.

6. Calculate the step size using the following formula.

A = (length of host / length of image) * no of bits

8. Insert the watermark into the least significant bit plane of the host signal at variable positions starting from Ath sample and concurrent samples with step size A.

9. Convert the audio signal back to its original form.

C. Extraction Process.

This process is to extract the image from the audio signal using the proposed technique. Input provided is the dimension (length) of the [(n*b) 1]matrix A as found in embedding procedure and watermarked audio signal.

1.Read the watermarked audio signal to be used for the extraction.

2. Determine the size of the audio file.

3. Convert the audio signal into binary form.

4. Extract the Least Significant bits from the host samples starting from Ath sample and concurrent samples with step size A.

5. Scale the recovered watermark by converting the image into double.

6. Display the recovered image (watermark).

III. IMPLEMENTATION

A. Audio Representation

An audio signal is a representation of sound. It is represented in analog form by its amplitude levels over time. To store this data, it is converted to digital form by sampling it at a given sampling rate Fs followed by quantization. In Matlab, the function 'audioread' reads audio from a specified file and returns the sampled data and a sampling rate for that data. Here the input audio is restricted to be in .wav format and thus each sample in the sampled audio is stored as an 8-bit unsigned integer in the range 0 to 255 by default. Table. 1 contains the information about the audio samples used in the paper. Each audio sample is of 10 second duration.

TABLE 1. Audio Signals

Audio Signal	**Name of the Music Signal**
Audio Signal 1	Jayalakshmi Shekar - Thaye Yesoda
Audio Signal 2	Mysore Brothers - Tillana
Audio Signal 3	Narayanathe Namo Namo
Audio Signal 4	Bismillah Khan - Raga Bahar
Audio Signal 5	Hariprasad Chaurasia - Ahir lalit - Alap Jor Jhala
Audio Signal 6	Kamal Sabri and Sabri Khan and Sarvar Sabri Suhail Yusuf Khan -Raag Megh

B. Signal to Noise Ratio (SNR)

SNR is an abbreviation for signal-to-noise ratio. It is a metric for determining the quality of a given signal. It is the ratio of the desired signal's power to the power of the background noise.

SNR= P_{signal}/P_{noise}

The effectiveness of watermark embedding can be measured by finding the SNR of the watermark embedded audio signal. A higher SNR indicates a lesser impact of watermark on the audio signal's quality.SNR is measured in dB.

C. Signal Processing Attacks

The watermarked audio signals were subjected to three attacks to assess the robustness of the proposed scheme: noise, cropping, and filtering.

During transmission of the audio signal from source to destination noise gets added in the channel and the signal is corrupted. Thus, the watermarking scheme should be resistive to the noise.This is evaluated by adding additive white gaussian noise to the watermarked audio signal and the SNR is calculated.

Another common signal processing attack is filtering. The sensitivity to this attack is measured by filtering the watermarked audio signal with a low pass butterworth filter and calculating and comparing the SNR.

IV. Results

Fig 3,4,5,6,7,8 represent the time domain plots of the audio signals mentioned in Table 1.

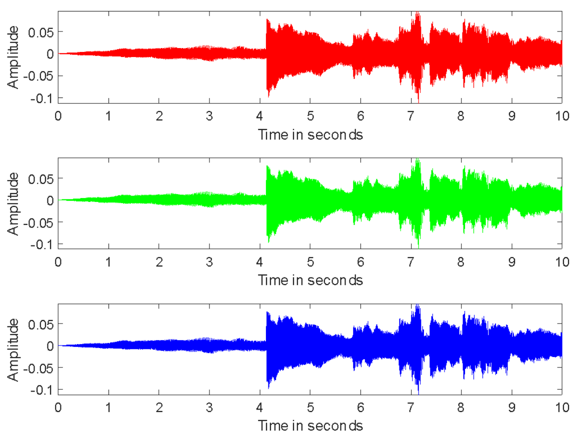

Fig. 3. Audio Signal 1 (Without Watermark, Watermark using LSB Technique, Watermark using Modified LSB Technique).

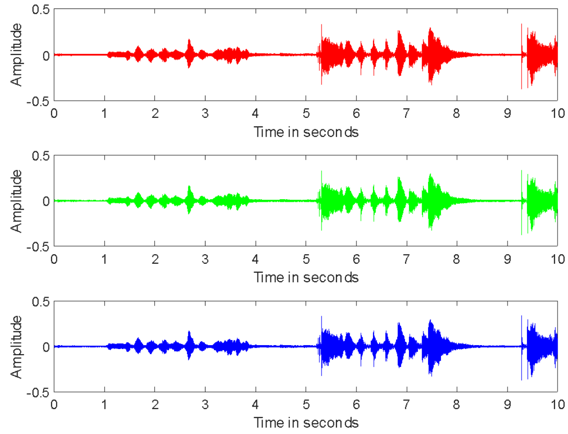

Fig. 4. Audio Signal 2 (Without Watermark, Watermark using LSB Technique, Watermark using Modified LSB Technique).

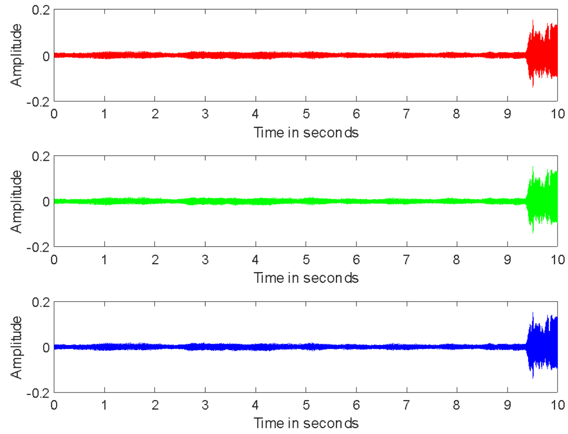

Fig. 5. Audio Signal 3 (Without Watermark, Watermark using LSB Technique, Watermark using Modified LSB Technique).

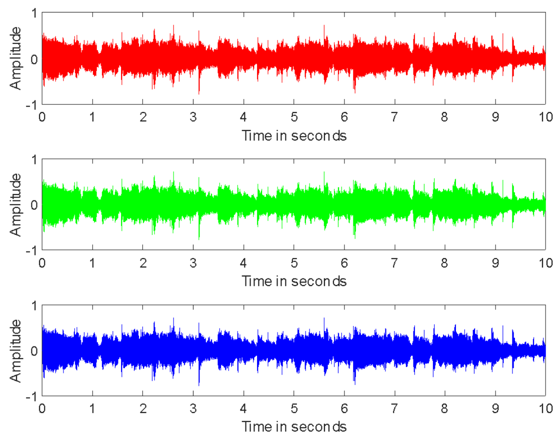

Fig. 6. Audio Signal 4 (Without Watermark, Watermark using LSB Technique, Watermark using Modified LSB Technique).

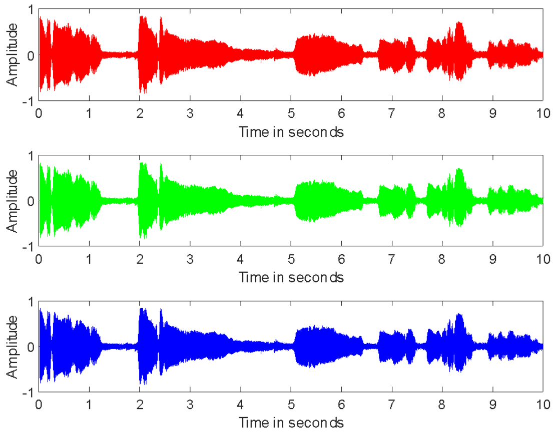

Fig. 7. Audio Signal 5 (Without Watermark, Watermark using LSB Technique, Watermark using Modified LSB Technique.

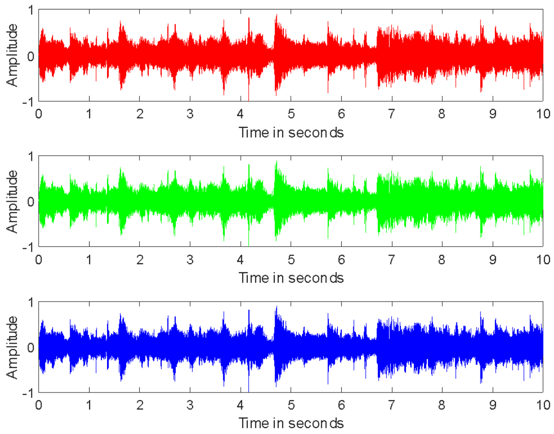

Fig. 8. Audio Signal 6(Without Watermark, Watermark using LSB Technique, Watermark using Modified LSB Technique.

Fig. 9(a). Watermark Image

Fig. 9(b). Extracted Image from watermarked audio.

Fig. 10(a). Watermark Image

Fig. 10(b). Extracted Image from watermarked audio.

From figures 3-8, it can be visualized that the image watermark has very little effect on the audio signals indicating its imperceptibility.Fig 9(a),10(a) and 9(b),10(b) show the watermark remains intact after extracting from the audio signal.

The SNR value for the watermark embedded signal and after subjecting it to signal processing attacks, can be calculated. In this paper the audio signals mentioned in Table 1. have been taken into consideration.

Table 2 and Table 3 represent the snr values for different watermark images for both LSB and Modified LSB Technique. It can be concluded from the tables that the proposed method performs better than the normal LSB method with respect to the SNR for both the test images.

Using these six audio signals as an input, the SNR value is calculated for three attacks namely noise, cropping and filtering.The watermark image in consideration in Table 4,5 is figure 9 and in Table 6,7 is figure 10. From the SNR values in Table 4,5,6 and 7 ,it can be inferred that the proposed watermarking method is quite tolerant to these attacks compared to the normal method.

TABLE 2. SNR comparison of LSB and Modified LSB Technique with Fig 9 as watermark

Audio Signal	**SNR (LSB Technique)**	**SNR (Modified LSB Technique)**
Audio Signal 1	21.5100 dB	22.3798 dB
Audio Signal 2	29.1541 dB	29.5646 dB
Audio Signal 3	20.6106 dB	20.5791 dB
Audio Signal 4	26.8691 dB	30.1547 dB
Audio Signal 5	46.0998 dB	48.5489 dB
Audio Signal 6	21.5757 dB	21.5767 dB

TABLE 3. SNR comparison of LSB and Modified LSB Technique with Fig 10 as watermark.

Audio Signal	**SNR (LSB Technique)**	**SNR (Modified LSB Technique)**
Audio Signal 1	21.8449 dB	22.3055 dB
Audio Signal 2	27.9095 dB	28.2248 dB
Audio Signal 3	21.0115 dB	20.9499 dB
Audio Signal 4	27.1304 dB	20.949 dB
Audio Signal 5	40.2129 dB	40.1413 dB
Audio Signal 6	16.6148 dB	16.6051 dB

TABLE 4. SNR of Watermarked signal (LSB Technique) with different signal Processing Attacks.

Audio Signal	**Noise**	**Cropping**	**Filtering**
Audio Signal 1	9.8662 dB	17.4498 dB	19.0678 dB
Audio Signal 2	9.9646 dB	21.0211 dB	5.5794 dB
Audio Signal 3	9.7629 dB	10.1464 dB	22.0538 dB
Audio Signal 4	10.0212 dB	29.3578 dB	15.6557 dB
Audio Signal 5	9.9971 dB	40.1546 dB	13.7231 dB
Audio Signal 6	10.5129 dB	20.1291 dB	17.9959 dB

TABLE 5. SNR of Watermarked signal (LSB Modified Technique) with different signal Processing Attacks.

Audio Signal	**Noise**	**Cropping**	**Filtering**
Audio Signal 1	9.8901 dB	18.7013 dB	19.0428 dB
Audio Signal 2	9.9700 dB	21.6975 dB	0.0019 dB
Audio Signal 3	9.8130 dB	10.1623 dB	21.9031 dB
Audio Signal 4	10.0645 dB	29.3381 dB	15.6557 dB
Audio Signal 5	10.0337 dB	40.5327 dB	13.7231 dB
Audio Signal 6	10.4662 dB	20.1297 dB	17.9961 dB

TABLE 6. SNR of Watermarked signal (LSB Technique) with different signal Processing Attacks.

Audio Signal	**Noise**	**Cropping**	**Filtering**
Audio Signal 1	9.4581 dB	11.9490 dB	18.9290 dB
Audio Signal 2	9.8840 dB	15.1792 dB	0.0304 dB
Audio Signal 3	9.3508 dB	4.0256 dB	24.4685 dB
Audio Signal 4	10.0189 dB	29.7239 dB	15.6555 dB
Audio Signal 5	9.9935 dB	37.7155 dB	13.7232 dB
Audio Signal 6	10.4778 dB	20.1287 dB	17.9925 dB

TABLE 7. SNR of Watermarked signal (LSB Modified Technique) with different signal Processing Attacks.

Audio Signal	**Noise**	**Cropping**	**Filtering**
Audio Signal 1	9.6090 dB	11.9490 dB	19.0798 dB
Audio Signal 2	9.8785 dB	15.1792 dB	0.0131 dB
Audio Signal 3	9.3863 dB	4.0256 dB	23.2073 dB
Audio Signal 4	9.9714 dB	29.7239 dB	15.6557 dB
Audio Signal 5	10.0094 dB	37.7155 dB	13.7232 dB
Audio Signal 6	10.5094 dB	20.1287 dB	17.9898 dB

V. Conclusion

In the proposed system the watermarking is done by replacing the least significant bits of the audio signal with the bits of the image watermark spread evenly throughout the audio signal. From our analysis, this audio watermarking system is secure and robust to common signal attacks such as noise, cropping and filtering. This method is simple and works well for any grayscale image.The extraction process is unique for different watermark images as it depends on the size of the image.Hence,the source is well-protected from extraction by unauthorised entities. Artists can use this watermarking scheme for a watermark of their choice.

VI. References

[1] F. Hartung and M. Kutter, "Multimedia watermarking techniques," in Proceedings of the IEEE, vol. 87, no. 7, pp. 1079-1107, July 1999, doi: 10.1109/5.771066.

[2] Gaorong Zeng and Z. Qiu, "Audio watermarking in DCT: Embedding strategy and algorithm," 2008 9th International Conference on Signal Processing, 2008, pp. 2193-2196, doi: 10.1109/ICOSP.2008.4697583.

[3] Priyanka Pattanshetti, Prof.Shabda Dongaonkar, Prof. Sharmila Karp "Digital Watermarking in Audio Using Least Significant Bit and Discrete Cosine Transform,"/ (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 6 (4) , 2015, 3688-3692.

[4] R. D. Shelke and M. U. Nemade, "Audio watermarking techniques for copyright protection: A review," 2016 International Conference on Global Trends in Signal Processing, Information Computing and

Communication (ICGTSPICC), 2016, pp. 634-640, doi: 10.1109/ICGTSPICC.2016.7955379.

[5] Hu, H.-T., & Hsu, L.-Y. (2015). Robust, transparent and high-capacity audio watermarking in DCT domain. *Signal Processing*, *109*, 226-235. https://doi.org/10.1016/j.sigpro.2014.11.011.

[6] Al-Haj, Ali, Ahmad A. Mohammad, and Lama Bata. "DWT-based audio watermarking." *Int. Arab J. Inf. Technol.* 8, no. 3 (2011): 326-333.

[7] Attari, Ali Akbar, and Ali Asghar Beheshti Shirazi. "Robust audio watermarking algorithm based on DWT using Fibonacci numbers." *Multimedia Tools and Applications* 77, no. 19 (2018): 25607-25627.

[8] M. Hwang, J. Lee, M. Lee and H. Kang, "SVD-Based Adaptive QIM Watermarking on Stereo Audio Signals," in IEEE Transactions on Multimedia, vol. 20, no. 1, pp. 45-54, Jan. 2018, doi: 10.1109/TMM.2017.2721642.

[9] A. Al-Haj, C. Twal and A. Mohammad, "Hybrid DWT-SVD audio watermarking," 2010 Fifth International Conference on Digital Information Management (ICDIM), 2010, pp. 525-529, doi: 10.1109/ICDIM.2010.5664651.

[10] Y. Yu, M. Lei, Xiaoming Liu, Zhiguo Qu and Cheng Wang, "Novel zero-watermarking scheme based on DWT-DCT," in China Communications, vol. 13, no. 7, pp. 122-126, July 2016, doi: 10.1109/CC.2016.7559084.

[11] Patel, K.N., 2020. *Robust and Secured Digital Audio Watermarking: Using a DWT-SVD-DSSS Hybrid Approach*. Springer Nature.

[12] J. Xuehua, "Digital Watermarking and its Application in Image Copyright Protection," 2010 International Conference on Intelligent Computation Technology and Automation, 2010, pp. 114-117, doi: 10.1109/ICICTA.2010.625.