Audio Watermark insertion and Enrichment of Speech via Kalman Filter and LSB

by Kalaivani S

Submission date: 09-Nov-2022 11:50AM (UTC+0530)
Submission ID: 1948989478
File name: Kalman_Subham.doc (515.5K)
Word count: 2334
Character count: 12380

Audio Watermark insertion and Enrichment of Speech via Kalman Filter and LSB

Atharva Sulakhe[1], Subham Mukherjee[2], Bishwajeet Vishwakarma[3], Dr. Kalaivani S[4]*

[1,2,3,4] *Department of Communication Engineering, School of Electronics Engineering,* Vellore Institute of Technology Vellore 632014, Tamil Nadu, India. [1]sulakheatharv@gmail.com, *kalaivani.s@vit.ac.in

***Abstract*— In today's era, it has become extremely important to protect your data, of any form. Digital media today can be easily hacked and used wrongly with misuse of copyright. In this paper, we have understood the importance and the need for watermarking, which enables verification as well as copyright protection. There are several methods for watermarking of audio signals, but in this paper, we have gone with the Least Significant Bit method (LSB). We have discussed the algorithm for watermark insertion as well as extraction using the method mentioned. At the same time, presence of noise corrupts a speech and degrades its quality. Here comes the need for speech enhancement. We have gone with Kalman filter for this task which is an efficient recursive filter that is capable of calculating the internal state of a linear dynamic system from a number of noisy quantifications.**

***Keywords*— Least Significant bit, Kalman filter, signal processing Introduction**

I. INTRODUCTION

The 21st century has been that of digitization. Technology has advanced to unprecedented limits and as a result, huge bulk of data is being transferred every second. Data is in various forms. Right from signals to audio to image to video. Along with digitization and heavy usage of data come the risks of hacking and privacy issues. In some cases, copyright protection is an important factor as well. This is where the need for Watermarking comes into the picture. In this paper, we deal with audio watermarking of audio signals using an image(watermark). This watermarking should be done without hampering the quality of the speech signal.

Firstly, audio watermarking procedure should be such that it fulfils certain characteristics like-

1. Security
2. Validity
3. Robustness
4. Sustainable
5. Constant bit-rate

Digital audio watermarking has several applications with the number only increasing with time. Some of them are:

1. Television broadcasting
2. Air Traffic Management
3. Authentication
4. Copyright protection and verification [1]

A. Audio Watermarking Techniques

The algorithms for audio watermarking include those in time domain as well as frequency domain. In time domain techniques, the best example is the Least Significant Bit method (LSB). We have employed this method in our research. Here, each 8-bit pixel's least significant bit is embedded with a bit from the watermark. Now in a digital image, information can be inserted readily into each bit of image information. First, we need to separate the LSB bits from the MSB bits, then the image has to be read in binary form, and finally embed the binary form of the image into the audio signal in place of LSB bits. The robustness is decided based on the number of bits that are replaced in the host signal. Since every bit is represented in digitally coded format, hence it is much simpler to replace the bits, which makes this method relatively simple to implement. The biggest advantage of using this method is that it is robust against noise of any sort and does not lower the quality of the speech signal. It is computationally very efficient as well.

Coming to frequency domain techniques for watermarking, they mostly consist of Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT) and Discrete Cosine Form Transform (DCT) [2]. Firstly, the speech signal is transformed into frequency domain and using the magnitude or phase response, the watermark is applied. Finally, inverse transform is taken to get the watermarked audio in the time domain. More specifically, in Discrete Fourier Transform method, the phase difference has to be subtracted when the watermark bit is zero and added when the watermark bit is one. Similarly, in Discrete Wavelet Transform, both time domain and frequency domain signals can be decomposed at the same time. The advantage here is that by applying it to the speech, we are able to localize the in-time frequency.

B. Speech Enhancement

It often happens that speech signals get corrupted or the quality of speech is hampered due to external factors. In this situation, speech enhancement becomes imperative. Adaptive filters are the ones most widely used to perform the task. This includes LMS, NLMS and RLS filters. However, there are cases when these adaptive filters are unable to produce the needed levels for enhancement. This is where a more powerful filter, that is Kalman filter comes to use. While Kalman is also an adaptive filter, it has better performance as compared to Least Mean Square (LMS) filter.

II. BACKGROUND

A. Watermarking process

In general, the watermarking process is divided into 3 parts:

1. Embedding (insertion) [3]

2. Attack
3. Detection (extraction)

The primary step in watermark insertion is embedding. In this, the algorithm will accept or reject the host based on the size in bits of the host signal (speech) and number of bits in the image. This adding of image bits from the least significant bit onwards onto the audio file is known as embedding. This step is relatively secure.

An attack can be explained as the attempt to remove or modify the digital watermark inserted. This can be done through modification during the time of data transmission or even storage. This step is when the signal is insecure and prone to various attacks.

Detection or watermark extraction refers to a process wherein the algorithm which is applied to the attacked signal to extract the watermark from it. Now if during the transmission process, the audio signal which was vulnerable during the attack stage has not been modified or tampered with, then it may now be extracted [4].

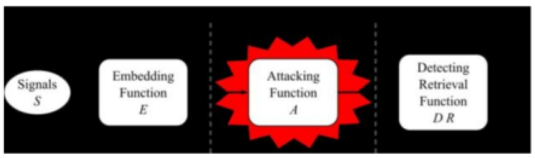

Fig. 1. Watermarking process

As mentioned earlier, the robustness and inaudibility of watermarking are the two factors based on which we judge the performance of the process. Inaudibility, in simple sense, means that the watermarked signal and the original signal must have no difference or error between them. They must be identical. The watermark should survive different types of attacks as well and must be robust in its working. Random cropping, compression, filtering, resampling and re-quantization are some forms of attacks.

The Least Significant Bit method is therefore a suitable technique and offers the following advantages:

1. Relatively straightforward method.
2. It can survive various transformations like cropping, compression and quality degradation.
3. Enhanced security of the signal.

However, this process also has a disadvantage that it is prone to sophisticated attacks that could simply reset the LSBs of each of the pixels to 1. This attack would successfully destroy the insecure watermarked audio file during transmission. [5]

III. METHODOLOGY

A. Audio Watermark Insertion Algorithm

We import the audio file which has to be watermarked using the MATLAB ‘audioread’ function and the watermark image using the ‘imread’ MATLAB function.
Then we convert the audio file into 8-bit unsigned integer form and take its length with the help of length() function and compare it with the size of the watermark image. If the size of the watermark is larger than the length of the 8-bit unsigned integer form of the audio file then the watermarking of the audio file isn’t possible and we exit the program. Otherwise, both the audio and watermark files are converted from their decimal form to binary form. We store the binary form of the audio file in the form of a 1-D array then we replace the least significant bit in the array with a binary bit from the watermark image.
This new LSB bit replaced audio file is converted from binary to decimal and then decimal to double form and is finally exported as a new audio file with .wav extension. [6]

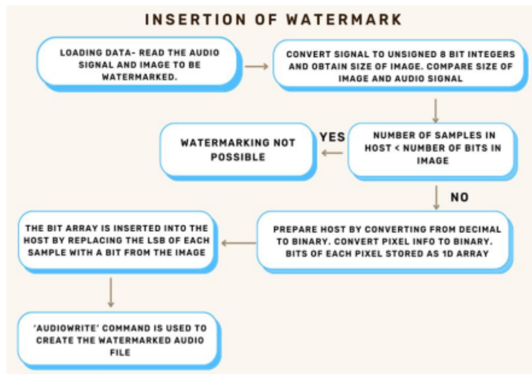

Fig. 2. Watermark insertion algorithm

B. Audio Watermark Extraction Algorithm

We import the watermarked audio file from which watermark image has to be extracted using the MATLAB ‘audioread’ function. Then we can set a reference watermark image size to calculate the number of pixels and dimensions of the image. We convert the audio file from double to binary and store it in a 1D array, then we extract the LSB bits from the array and store them in the reference watermark image. Next, we have to convert the watermark image from binary to decimal form and then use reshape MATLAB function to arrange the data according to the dimensions of the image. Finally, we display the watermark image using the ‘imshow’ MATLAB function.

C. Kalman Filter Algorithm

The Kalman filter algorithm works in a two phase process. The first phase is the prediction phase. Here, the filter gives the estimates of the current state variables. It also provides their probability. Now on finding out the outcome of the next measurement or next part of the signal which might be corrupted and noisy, the filter then updates these estimates with the help of a weighted average wherein more weight is given to the estimate with the highest probability[7].

Fig. 3. Kalman Filter Algorithm

Kalman filter is a recursive scheme. A key calculation value is that of the Kalman gain, which can be called as the weight allotted to the current-state estimate and measurements. This value is tuned to achieve a particular output. Basically, the Kalman gain can tell by how much we want to change the estimate of a given value. This filter is usually associated with linear systems.

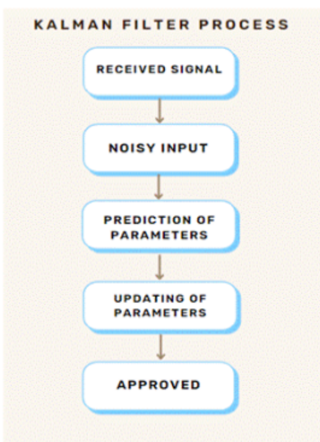

Fig. 4. Kalman Filter Flowchart

Thus, in order to obtain the Kalman gain matrix, we need to find the error covariance matrix at any given time instant. Since the diagonal elements of this error matrix contain the variances of each of the individual elements. Hence, if we want to minimize the uncertainty in the new estimate of the filter, then we need to minimize these diagonal elements. The expressions of this filter are all recursive and hence this loop of estimation and prediction goes on, reducing the noise in the process and enhancing the quality of the audio file [8].

IV. RESULTS AND DISCUSSION

A. Audio Watermark Insertion

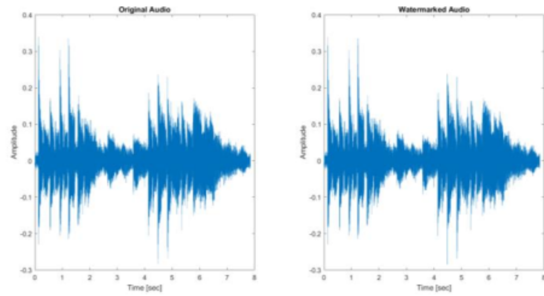

Fig. 5. Amplitude spectrum of original & watermarked audio

Here in the above figure, we have successfully inserted a digital watermark into the audio signal. From the above output, it is clear that the watermarking is unnoticeable to the naked eye. So, the watermark can pass undetected unless it is looked for specifically.

B. Audio Watermark Extraction

Fig. 6. Watermark image

This is a grayscale image in PNG format. Grayscale image shows the intensity of color in each pixel, from 0 depicting black to 255 representing white.

C. Audio enhancement by Kalman filter

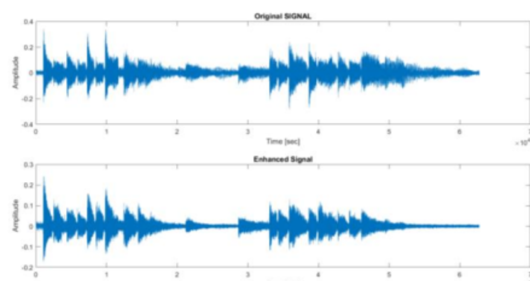

Fig. 7. Original vs Enhanced signal

Here the Kalman filter reduces the noise introduced by the insertion of digital watermark in the LSB bits of the audio signal.

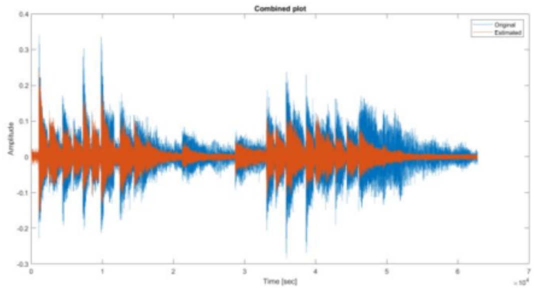

Fig. 8. Estimated signal overlapped on original signal.

In the above figure, we can see the estimated signal in red plotted on top of the original audio signal. It is clear that the Kalman filter has managed to produce significant levels of speech enhancement, has removed the corrupted parts of the signal and has also reduced noise levels.

In conclusion, we can say that the Kalman filter which we chose primarily because it is a time domain filter worked well to improve the quality of our audio file. This filter which works well with both stationary and non-stationary signals was a suitable choice due to the fact that in a practical sense, signals are not always stationary and can vary randomly as well.

As for the watermarking process, the Least Significant Bit technique was suitable due to its simplicity and high-performance value. It also had a very minimal effect on the signal as seen in the result. This type of watermarking process is secure and can survive transformations including cropping, compression, or undesirable noise. Finally using the watermark extraction process, we also managed to extract the grayscale PNG file which was added as the watermark.

V. REFERENCES

[1] M. Chetan, P.P. Bhat, V. Shet 3, S. B. Husenbhai, and A. Bhat, "Audio Watermarking Using Modified Least Significant Bit Technique," 2021 International Conference on Circuits, Controls and Communications (CCUBE), ©2021 IEEE, DOI: 10.1109

[2] Ketcham, M., and Vongpradhip, S. (2007). "Intelligent audio watermarking using genetic algorithm in DWT domain". International Journal Of Intelligent Technology, Vol.2 No.2, pp:135-140.

[3] Y. S. Can, F. Alagoz, and M. E. Burus, "A Novel Spread Spectrum Digital Audio Watermarking Technique," Journal of Advances in Computer Networks, Vol. 2, No. 1, March 2014

[4] R.D. Shelke, 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] P. Pattanshetti, S. Dongaonkar, S. Karp "Digital Watermarking in Audio Using Least Significant Bit and Discrete Cosine Transform,"/ (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 6

[6] Y. Xiong and Z. X. ming, "Covert Communication Audio Watermarking Algorithm Based on LSB," 2006 International Conference on Communication Technology, 2006, pp. 1-4, doi: 10.1109/ICCT.2006.341972.

[7] M. Mathe, S. P. Nandyala and T. Kishore Kumar, "Speech enhancement using Kalman Filter for white, random and color noise," 2012 International Conference on Devices, Circuits and Systems (ICDCS), 2012, pp. 195-198, doi: 10.1109/ICDCSyst.2012.6188703.

[8] Y. Zhang, D.S. Oliver, "Evaluation and error analysis: Kalman gain regularization versus covariance regularization.", Comput Geosci (2011) 15:489–508, Springer series.

[9] Tejash Lad,Kaushal Dosh "A Study of Audio Watermarking Technique in DCT Domain", 2014 International Journal of Engineering Development and Research Volume 2, Issue 1 — ISSN: 2321-9939

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

[11] Verma, Vivek Singh, and Rajib Kumar Jha. "Improved watermarking technique based on significant difference of lifting wavelet coefficients." Signal, Image and Video Processing 9, no. 6 (2015): 1443-1450.

[12] Kamlesh.C.Badhe, Prof Jagruti.R.Panchal "Implementation of Audio Watermarking Using Wavelet Families", IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 4, June 2014

Audio Watermark insertion and Enrichment of Speech via Kalman Filter and LSB

ORIGINALITY REPORT

9%	4%	8%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	R. D. Shelke, Milind 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 Publication	3%
2	Rui Xue, Daniel (Jian) Sun, Shukai Chen. "Short-Term Bus Passenger Demand Prediction Based on Time Series Model and Interactive Multiple Model Approach", Discrete Dynamics in Nature and Society, 2015 Publication	1%
3	Submitted to VIT University Student Paper	1%
4	www.ijrte.org Internet Source	1%
5	Arnaldo Carvalho, João F. Justo, Bruno A. Angélico, Alexandre M. de Oliveira, João Inacio	1%

da Silva Filho. "Paraconsistent State Estimator for a Furuta Pendulum Control", SN Computer Science, 2022
Publication

6	link.springer.com Internet Source		1 %
7	kipdf.com Internet Source		1 %
8	www.sciencepubco.com Internet Source		<1 %

Exclude quotes	On	Exclude matches	< 10 words
Exclude bibliography	On		