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Analysis of Musical Instruments for Signal to Noise Ratio, Distortion and Retained Signal Energy using Wavelet Transform

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Abstract

In Audio Compression there is an inevitable need to effectively decrease the file size of the sample without compromising the quality of the signal. The quality of a signal is observed by the analysis of important parameters such as Signal to Noise Ratio, Distortion and Energy which provides us the measurement of the undesirable sound in the given sample. This paper uses the upcoming technique of Discrete Wavelet Transform[1,6] to analyses the Signal to Noise Ratio, Distortion and Retained Signal Energy for various musical instruments like Tabla, Harmonium and Shehnai.

These parameters are compared for the musical instruments on MATLAB 7.1 R2009 on an Intel i-5 processor based system.

Keywords: DWT, Signal to Noise Ratio, Distortion, Signal Energy, Audio Compression

Introduction

Audio Compression is a technique to represent the audio signal in as fewer bits as possible. This can be achieved by either traditional ways of using Discrete Cosine Transform and Discrete Fourier Transform, or by using the advanced technique of Discrete Wavelet Transform. Regardless of the technique used, there is some loss of the information as well as introduction of noises which deteriorates the signal quality as we perceive. In comparison to DCT and DFT, Discrete Wavelet Transform delivers much better results in terms of signal quality. DWT has been used in this paper to compare the parameters for various musical instruments and determine the variation in output quality at level 3 for deubechies2 wavelet type.

Discrete wavelet transform

DWT is a wavelet transform in which the discretely sampled wavelets decompose the signal into mutually orthogonal set of wavelets. In DWT, the energy is concentrated in time for a small wave providing a tool for analysis of non stationary, transient or time varying phenomenon[2,5].
DWT has a basic concept of signal being divided into low frequency and high frequency components. While the low frequency components store the major information of the signal known as Approximations, the high frequency component imparts the quality to the signal and are known as Details. The original signal is filtered through two complimentary filters and emerges as two signals.[3,6] Concept of down sampling is introduced to avoid doubling of data.
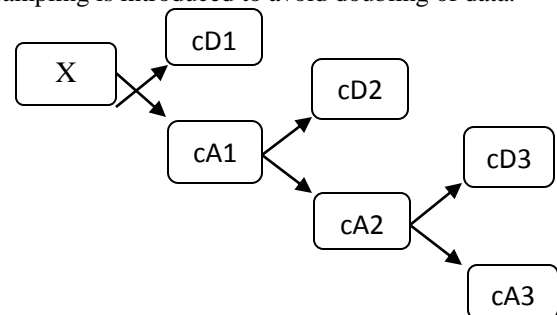
Signal quality parameters

Signal to Noise Ratio

Signal to Noise Ratio is a measure used in Signal Processing that compares the level of a desired signal to the level of background noise. When an audio signal is digitalized, the bits used to represent the signal determine the maximum possible Signal to Noise Ratio. This is because the minimum possible noise level is the error caused due to quantization[7,8].
The theoretical maximum SNR is assumed to be a perfect signal. A ratio more than 1:1 indicates that the power of the desired signal is more than the power of the noise signal.

SNR can be calculated by various means as

SNR= 6.02n+1.761,

for n-bit integers with equal distance between quantization levels.

Also, SNR can be calculated as[2,4]

$$SNR=10\log_{10}\left[\frac{\text{mean square of speech signal}}{\text{Mean square difference between original and reconstructed signal}}\right]$$

Distortion

Distortion refers to the deformation in output audio signal in comparison to the input audio signal. It is usually unwanted clipping, harmonic distortion or inter modulation distortion caused by non linear quantization techniques used.[1] The addition of noise or other undesirable signals to the audio sample are not referred to distortion, though the quantization noises are sometimes deemed as distortion.

$$\text{Distortion}=\left[\frac{(x2^2+x3^2+x4^2+xn^2)^{1/2}}{(x1^2)^{1/2}}\right]$$

where, xn=1 is the fundamental harmonics and xn are the successive harmonics.

Signal Energy

Signal Energy is always equal to the summation across all frequency components of the signal's spectral energy density[4,5]. In signal processing, the energy of a discrete time signal is explained and represented as

$$E=\sum_{-n}^{n}(x[n])^2$$
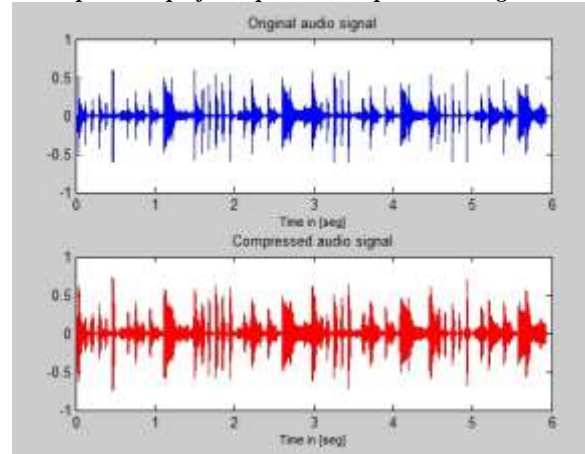
Results and discussion

Tables:

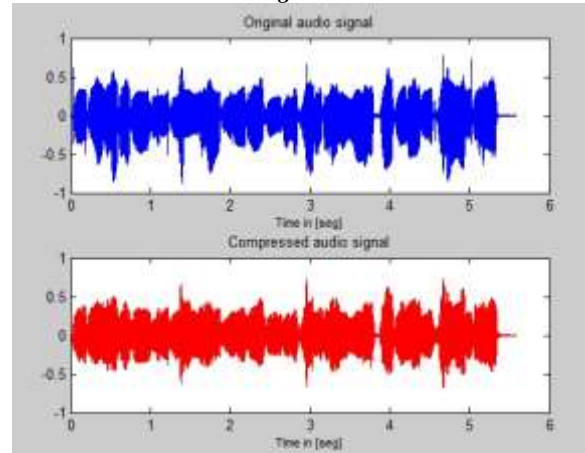*Comparison of instruments for Signal Quality Parameters*

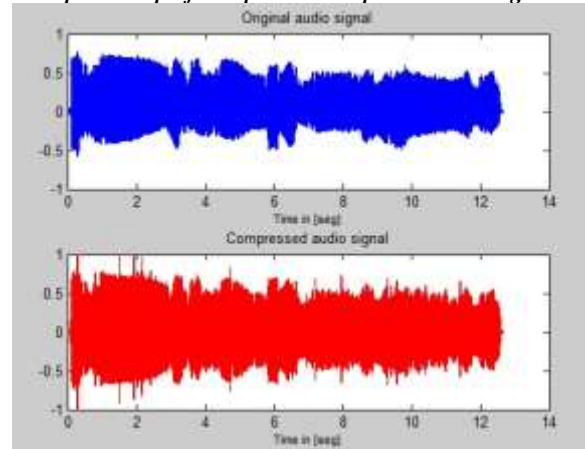| Signal	SNR (dB)	Distortion	Retained Signal Energy	CR
Tabla	15.76	0.0047	78.28%	7.5000
Harmonium	22.60	0.0124	98.7%	4.9286
Shehnai	26.22	0.0296	88.21%	6.4490

Graphs:

Graph 1:Graph for Input and Output Tabla Signals

Graph2: Graph for Input and Output Harmonium Signals

Graph3: Graph for Input and Output Shehnai Signals

Conclusion

In our analysis, the sound samples were compressed using deubechies2 type wavelet using Discrete Wavelet Transform for level 3. We observed the Signal Quality Parameters for Instruments like Tabla, Harmonium and Shehnai which signify Percussion, Keyboard, and Wind type Instrument respectively. Out of the three, Harmonium was observed to have the maximum Retained Signal Energy while Tabla had the minimum Retained Signal Energy. Shehnai was observed to have a better Signal to Noise Ratio. Also, Maximum distortion with considerable deterioration in sound quality was observed in Shehnai. Percussion sound like Tabla was found to deliver better compression ratio but on the cost of the quality parameters. The harmonium imparted better results in terms of the overall Sound Quality.

Acknowledgements

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