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Audio Denoising Using Wavelet

Transform

A Thesis Submitted to the College of Science, Al-Nahrain University in Partial Fulfillment of the Requirements for

The Degree of Master of Science in Computer

Science

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جمهورية العراق وزارة التعليم العالي والبحث العلمي جامعة النهرين كلية العلوم

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Abstract

Audio signals are often contaminated by background environment noise from audio equipments. Audio denoising aims to attenuating the noise while retaining the underlying signals.

The focal point of this thesis is to use digital signal processing techniques based on wavelet transform to reduce the noise from the signal. In this research three types of wavelet transform (Haar, D4 and D6 wavelet transforms) and different thresholding criteria have been investigated to truncate the noise from two types of signal (high and low amplitude audio signals). The denoising results have been analyzed and compared with the original signal in order to find out the best for audio denoising setups. Furthermore, the performance of all considered methods had been evaluated.

The results shown in this thesis indicate that the best denoising results occur when applying scanned thresholding mechanism without making signal framing, and when all coefficients of the detail subbands are thresholded. Among the tested wavelet transforms, the D6 wavelet transform leads to better denoising results.

The best denoising results according to the objective measure mean square error (MSE) occurred when using supersoft thresholding, while the best denoising results according to subjective test is when using semisoft thresholding.

الخلاصه

الأشارات الصوتيه غالباً ما تلوّث بواسطة الضوضاء الناتجه من معدات التسجيل الصوتي . إز الة الضوضاء من الصوت تهدف لتخفيف الضوضاء بينما تبقي الاشاره الاساسيه. إن الهدف الأساسي لهذه الرساله هو إستخدام تقنيات العمل على الاشاره الرقميه المعتمده على تحويل المويجه لتقليل الضوضاء من الاشاره. في هذا البحث تم إستخدام ثلاثة أنواع من تحويل المويجه (D6, D4, Haar) وخمسة أنواع من طرق العتبه وقد تمت دراسة كفاءتها في قطع الضوضاء من نوعين من الاشاره (إشاره صوتيه ذات سعه عاليه و اخرى ذات سعه واطئه). إن نتائج إز الة الضوضاء لحلك تو قورنت مع الاشاره الاصليه من اجل إيجاد أفضل النتائج لاز الة الضوضاء. إضافه الى ذلك تم تقييم الاداء لكل الطرق المدروسه.

النتائج المعروضه في هذا البحث تشير الى ان أفضل نتائج إزالة الضوضاء تظهر عند تطبيق (Thresholding) الية (Scanned Thresholding) بدون تقطيع الاشاره، وعند تطبيق العتبه (Thresholding) على كل معاملات حزمة التحويل المويجي العالية التردد (الحزمه المفصله) و خلال الاختبارات وجد ان التحويل المويجي من نوع D6 يقود الى نتائج افضل لاز الة الضوضاء .

إن افضل نتائج إزالة الضوضاء بحسب المقاييس الموضوعيه (Objective Measures) اشرت إن إستخدام طريقة العتبه من نوع Supersoft هي الافضل، بينما المقاييس الغير موضوعيه (Subjective Measures) اشرت إن طريقة العتبه من نوع Semisoft هي الافضل.

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Appendix A RIFF WAVE (.WAV) File Format

A.1. Waveform Audio File Format (WAVE):

The canonical WAVE format starts with the RIFF header:

Offset	Field name	Length	Contents
0	"RIFF" file description header	4 bytes	Contains the letters "RIFF" in ASCII
4	Size of file	4 bytes	The file size which is less the size of the "RIFF" description (4 bytes) and the size of file description (4 bytes).this is usually: file size-8
8	"WAVE" description header	4 bytes	Contains the letters "WAVE"

Next to the RIFF header comes first chunk 'fmt chunk' which describes the sample format:

Offset	Field name	Length	Contents
12	"fmt" id	4 bytes	Contains the letters "fmt "
16	Size of file	4 bytes	The size of the WAVE type format (2bytes) + number of channels (2bytes) + sample rate (4 bytes) + Byterate (4bytes) + Block alignment (2bytes) + Bitspersample (2 bytes). This is usually 16
20	Audio Format	2 bytes	Type of WAVE format. if 1=PCM (Pulse Code Modulation), values other than 1 indicate some form of compression
22	Number of Channels	2 bytes	Channels :mono=1, stereo=2
24	SampleRate	4 bytes	Sample per Second e.g.8000, 44100
28	ByteRate	4 bytes	Byte per Second or ==SampleRate*number of channels*bitspersample/8
32	BlockAlign	2 bytes	Block alignment: the number of bytes for one sample including all channels. Or ==number of channels*bitspersample/8
34	BitsPerSample	2 bytes	Bits per sample 8 bits=8, 16 bits=16, etc.

Offset	Field name	Length	Contents
36	"data" description header	4 bytes	Contains the letters "data"
40	Size of data chunk	4 bytes	Number of bytes of data is included in the data section == number of samples * number of channels * bitspersample/8

The actual sound data

Finally, the data chunk contains the sample data:

A.2 Data Packing for PCM WAVE Files:

Data

Unspecified

data buffer

In single channel WAVE files, samples are stored consecutively. For stereo WAVE files, channel 0 represents the left channel and channel 1 represents the right channel. In multiple channel WAVE files, samples are interleaved. The following diagrams show the data packing for some common WAVE file formats.

Data packing for 8-bit mono PCM:

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Sample1	Sample2	Sample3	Sample4
Channel 0	Channel 0	Channel 0	Channel 0

Data packing for 8-bit stereo PCM:

Sam	ple1	Sample2		
Channel 0	Channel 1	Channel 0	Channel 1	
(left)	(right)	(left)	(right)	

Data packing for 16-bit mono PCM:

Sam	ple1	Sam	pple2
Channel 0	Channel 1	Channel 0	Channel 1
Low-order byte	High-order byte	Low-order byte	High-order byte

Sample1			
Channel 0	Channel 0	Channel 1	Channel 1
(left)	(left)	(right)	(right)
Low-order byte	High-order byte	Low-order byte	High-order byte

Data packing for 16-bit stereo PCM:

A.3 Data Format of the Samples:

Each audio sample is contained in an integer i. The size of i is the smallest number of bytes required to contain the specified sample size. The least significant byte is stored first. The data format and maximum and minimum values for PCM waveform samples of various sizes are shown in the following table:

Sample Size	Data Format	Maximum Value	Minimum Value
One to eight bits	Unsigned integer	255	0
Nine or more bits	Signed integer	32767	-32768

List of Abbreviations

Abbreviation	Meaning		
ADC	Analog-to-Digital Converter		
CWT	Continuous Wavelet Transform		
D4	Daubechies-4 wavelet family		
D6	Daubechies-6 wavelet family		
DWT	Discrete Wavelet Transform		
FHWT	Forward Haar Wavelet Transform		
HWT	Haar Wavelet Transform		
Hz	Hertz		
IHWT	Inverse Haar Wavelet Transform		
MAD	Median Absolute Deviation		
MP3	Motion Picture experts group format, audio layer 3		
MSE	Mean Square Error		
РСМ	Pulse Code Modulation		
PDF	Probability Density Function		
PSNR	Peak Signal to Noise Ratio		
RA	Real media Audio		
RIFF	Resource Interchange File Format		
SNR	Signal to Noise Ratio		
WAV	Window Audio Visual		
WMA	Window Media Audio		
WT	Wavelet Transform		

List of Symbols

Symbols	Meaning
σ	Standard Deviation
S	Scale Index
Т	Translation Index
h[n]	Low Pass Filter
g[n]	High Pass Filter
X _g	Approximation Coefficients
X _h	Detail (Wavelet) Coefficients
Ν	Total Number of Audio Samples
Li	Low Subband Coefficients
H _i	High Subband Coefficients
у	Wavelet Coefficient
THR(y)	Output Value after Thresholding the Wavelet Coefficient
λ	Threshold Value
Sign(y)	Sign Function
λ_1	Lower Threshold
λ_2	Upper Threshold
α	Attenuation Factor
X	Reconstructed Signal
Х	Original Signal
μ	Mean
ψ(t)	Mother Wavelet
Ne	Maximum Number of Passes
$\sigma_{_J}$	Standard Deviation for Noise Level
1D	One Dimension
2D	Two Dimensions

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