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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
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كلية العلوم

إزالة الضوضاء من التسجيل الصوتي باستخدام تحويل المويجه

رساله
مقدمه الى كلية العلوم في جامعة النهرين كجزء من متطلبات نيل درجة الماجستير في علوم الحاسبات

من قبل
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كانون الاول ٢٠٠٧　　　　ذي الحجه ١٤٢٨

بسم الله الرحمن الرحيم

قَالُواْ سُبْحَانَكَ لاَ عِلْمَ لَنَا إِلاَّ مَا عَلَّمْتَنَا إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقره آية (٣٢)

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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 . إزالة 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 إزالة الضوضاء حُللت و قورنت مع الاشاره الاصليه من اجل إيجاد أفضل النتائج لازالة 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 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 لازالة 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.

Finally, the data chunk contains the sample data:

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
44	Data	Unspecified data buffer	The actual sound data

A.2 Data Packing for PCM WAVE Files:

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:

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

Data packing for 8-bit stereo PCM:

Sample1		Sample2	
Channel 0 (left)	Channel 1 (right)	Channel 0 (left)	Channel 1 (right)

Data packing for 16-bit mono PCM:

Sample1		Sample2	
Channel 0 Low-order byte	Channel 1 High-order byte	Channel 0 Low-order byte	Channel 1 High-order byte

Data packing for 16-bit stereo PCM:

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

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
PCM	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
T	Translation Index
h[n]	Low Pass Filter
g[n]	High Pass Filter
X_g	Approximation Coefficients
X_h	Detail (Wavelet) Coefficients
N	Total Number of Audio Samples
L_i	Low Subband Coefficients
H_i	High Subband Coefficients
y	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
X	Original Signal
µ	Mean
ψ(t)	Mother Wavelet
Ne	Maximum Number of Passes
σ_J	Standard Deviation for Noise Level
1D	One Dimension
2D	Two Dimensions

List of Figures

List of Tables