WaveThresh

User guide

Introduction

WaveThresh is a spectral thresholding plug-in which can be used in any PC based program that supports Steinberg VST 2.0 plug-in technology (such as Steinberg's *Cubase SX* and Emagic's *Logic*) – such programs are known as 'host' programs for plug-ins. This user guide explains how to correctly install the program, what it does and how to operate it. It is essential for correct operation that the installation notes are followed exactly. Once this has been done and you have verified that you can access the plug-in in your host program you may choose to read on to learn more about the plug-in or dive in and start experimenting straight away.

Acknowledgements

WaveThresh is a process which is based on work done by Phillipe Mergen (supervised by Dr. John Szymanski) at the University of York in the summer of 2001. This VST plug-in implementation was written by Jez Wells (also of the University of York) and expands upon the functionality of the original process and makes it available in real time. *WaveThresh* makes use of optimised signal processing routines developed for the Intel *Pentium* class of processors however it has been tested on AMD *Athlon* as well as *Pentium* processors. This user manual was written by Jez Wells.

Installation

In order for this plug-in to run you must have additional Intel .dll files installed on your computer to detect and load the right code for your processor when you run the plug-in. All of the .dll files included with this installation (i.e. in the zipped archive you downloaded) except for WaveThresh.dll should be copied to your windows\system folder (which is usually on drive C:\). WaveThresh.dll should be copied to the folder specified in the instructions for your VST host program. For example if you are using Steinberg Cubase VST then WaveThresh.dll should be copied to this directory: C:\Program Files\Steinberg\Vstplugins

Once all the .dll files have been copied then you are ready to begin using the plug-in in your host application!

Spectral Thresholding

Spectral thresholding is the process of dividing an input signal up into frequency bands (spectral), removing (or reducing) those components that lie above or below a certain level (thresholding) and then constructing the output signal from these modified spectral components. *WaveThresh* is designed to be a creative sound processing tool offering unusual filtering and distortion effects although spectral thresholding can be used as a crude single-ended noise reduction process (not recommended by this author though).

WaveThresh offers two types of analysis technique to obtain a spectral description of the input sound, Fourier and wavelet analysis, and many different types of wavelet are offered (orthogonal and bi-orthogonal). The analysis frame size is fixed at 1024 samples (about 23 ms at a 44.1 kHz sampling rate) but the user can choose to overlap analysis frames and window the input signal, output signal or both. Hard thresholding, where values below the threshold are set to zero, and soft thresholding (where values are reduced according to a ratio) are available.

Parameters

In this section each of the user adjustable parameters in *WaveThresh* are explained and discussed. Further explanations of concepts covered can be found in the sources listed in the 'Further Reading' section of this user guide.

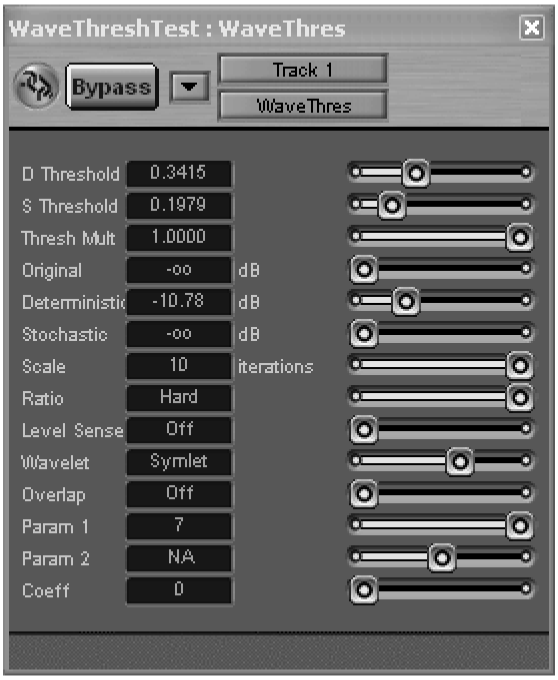

Fig 1: WaveThresh user interface as seen in Emagic Logic Platinum 5.5

<u>D Threshold</u>

Deterministic threshold. One of the things that spectral thresholding can be used for is dividing a signal into a deterministic (prominent narrowband components) part and a stochastic (more random-like broad band components) one. In order to isolate significant components all of those components below a certain threshold can be reduced or set to zero. This threshold is set using the D Threshold control. The output level of this thresholded signal is controlled by the 'Deterministic' fader. The range of values available is 0.0 to 1.0 (with Threshold Multiplier set to 1.0).

<u>S Threshold</u>

Stochastic threshold. In order to isolate noisy and\or broadband components in a sound the significant components of that sound can be removed by reducing, or setting to zero, components above a certain threshold. This threshold is set using the S Threshold control. The output level of this thresholded signal is controlled by the 'Stochastic' fader. The range of values available is 0.0 to 1.0 (with 'Threshold Multiplier' set to 1.0).

<u>Threshold Multiplier</u>

This allows the user to scale the range of values for 'D Threshold' and 'S Threshold'. Sometimes it is useful to work with very small threshold values and making 'Threshold Multiplier' small offers a small range of values for 'D Threshold' and 'S Threshold'. For example with 'Threshold Multiplier' set to 0.5 the range for the two thresholds is 0.0 to 0.5. With ‘Threshold Multiplier’ set to 1.0 the maximum range of 0.0 to 1.0 is available.

Original

This controls the amount of the original (unaltered signal) fed to the output.

Deterministic

This controls the amount of the deterministic thresholded signal fed to the output.

Stochastic

This controls the amount of the stochastic thresholded signal fed to the output.

Scale

This controls the number of scales (or analysis levels) the Wavelet analysis derives from the input signal. With a frame size of 1024 the maximum scale is 10 (as 1024 is 2 raised to the power 10). The Fast Wavelet Transform (FWT) is a computationally efficient way of performing wavelet analysis. The only restriction of the FWT is that the frame size must be a power of 2 (the same as for the Fast Fourier Transform). The FWT firstly performs a high and low pass filtering operation on the input signal. The parameters of the filter are determined by the type of wavelet. The high pass filtered signal is then down-sampled by a factor of 2 to give the highest scale coefficients. The low pass filtered signal is then down-sampled (again by a factor of 2) and the whole process is repeated on this signal to give the coefficients of the next scale. The process can continue until there is one single coefficient remaining (which is the lowest scale). We can choose to halt the process at any stage from the highest scale (scale = 1) to when the lowest scale is found (scale = 10). Note that this parameter has no effect when Fourier analysis is being performed.

Ratio

This parameter determines how thresholded coefficients are processed. If this is set to ‘hard’ than values below (for deterministic) or above (for stochastic) the threshold are set to zero. The next two figures illustrate this.

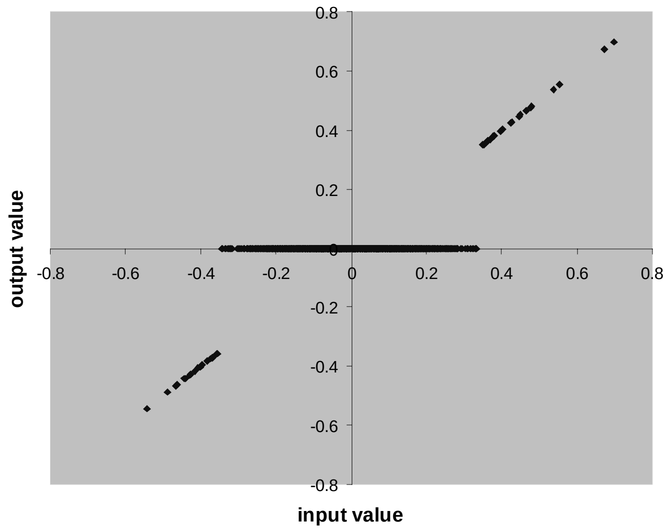

Fig 2: Plot of input and output deterministic coefficients with a ‘D Threshold’ of .375 and a hard ‘Ratio’

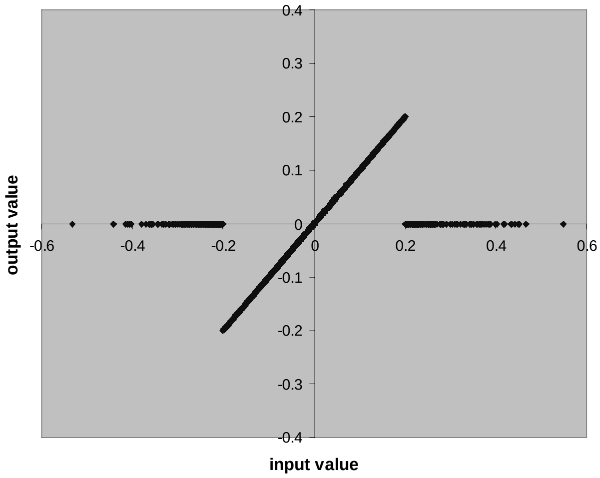

Fig 3: Plot of input and output stochastic coefficients with an ‘S Threshold’ of 0.2 and a hard ‘Ratio’

If the ratio is set at value between 1 and 16 then coefficients are ‘soft’ thresholded. The ratio is the ratio of change in output to change in input (as for regular audio compression). The next two figures illustrate soft thresholding.

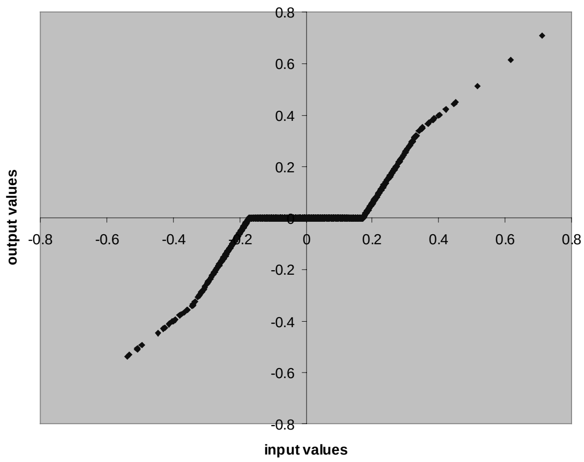

Fig 4: Plot of input and output deterministic coefficients with a ‘S Threshold’ of 0.2 and a soft ‘Ratio’ of 2.0

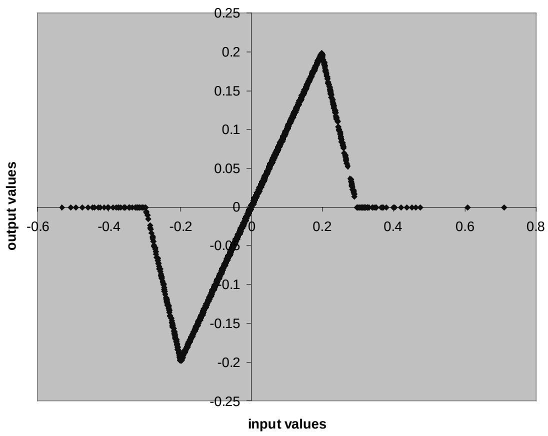

Fig 5: Plot of input and output stochastic coefficients with an ‘S Threshold’ of 0.2 and a soft ‘Ratio’ of 2.0.

Level Sense

This can be switched to either ‘on’ or ‘off’. When switched to ‘on’ the ‘D Threshold’ and ‘S Threshold’ adapt to any variations in the level of the input signal (i.e. the threshold is lower for quieter signals and higher for louder signals). When switched to ‘off’ the level of the incoming signal is ignored and the ‘D Threshold’ and ‘S Threshold’ values remain fixed.

Wavelet

This allows the user to select the type of analysis wavelet used or to choose ‘Fourier’ analysis instead of wavelet analysis (there is only one type of Fourier analysis offered here – that of the classic ‘Fast Fourier Transform’). Those who do not want to delve into the theoretical mathematics of wavelet types and their suitability for different types of signal can try them out and see what they sound like. Fourier analysis is often better suited to harmonic sounds whereas wavelets are often better suited to sounds containing broad band signal components such as noise or transients.

The following options are offered:

Haar – The Haar wavelet. This is the simplest kind of wavelet and is shaped like a square wave. Par 1 and Par 2 (see later in this section) are not used with this wavelet.

Daub – The Daubechies family of wavelets, named after Ingrid Daubechies. These are orthogonal but not symmetric. Par 1 controls the order of the wavelet. The higher the order the smoother the wavelet.

Symlet – The Symmlet fmaily of wavelets. These wavelets are designed to be more symmetric (although they are not perfectly symmetric), whilst remaining orthogonal, than those of the Debauchies family. Par 1 controls the order of the wavelet.

Coifman – The Coifman family of wavelets. These wavelets are similar to Debauchies wavelets but they have different scaling functions. Par 1 controls the order of the wavelet.

Vaid – Vaidyanathan wavelet. A wavelet that gives good frequency localisation. Par 1 and Par 2 are not used with this wavelet.

Spline – B-Spline wavelets. These are non-symmetrical and bi-orthogonal. Bi-orthogonal wavelets are desirable for audio processing since they do not introduce phase errors. Par 1 controls the order of the analysis wavelet and Par 2 controls the order of the re-synthesis wavelet. Only certain combinations of (Par1, Par2) are permitted. They are (1,1), (1,3), (1,5), (2,2), (2,4), (2,6), (2, 8), (3,1), (3,3), (3,5), (3,7) and (3,9).

SplineD – Dual B-Spline wavelets. Symmetrical and bi-orthogonal wavelets. Par 1 and Par2 can be set as for B-Spline wavelets.

Overlap

This determines whether analysis frames are overlapped and windowed. There are four possible settings:

off – The analysis and re-synthesis frames are not overlapped
ip – Both the analysis and re-synthesis frames are overlapped. A windowing function (square root Hann) is applied to the input frame prior to analysis.
op - Both the analysis and re-synthesis frames are overlapped. A windowing function (square root Hann) is applied to the re-synthesised output frame.
both – Both the analysis and re-synthesis frames are overlapped by a factor of 2. A windowing function (square root Hann) is applied to both the analysis and re-synthesis frame.

The purpose of overlapping\windowed frames is to prevent discontinuities between frame boundaries which can cause clicks (windowing tapers the signal towards zero at the frame boundaries). Windowing both the input and output is advisable for Fourier analysis. Note that when frames are overlapped (ip, op and both) the CPU load is doubled.

<u>Par 1</u> and <u>Par 2</u>
Wavelet parameters. Their use depends on the type of wavelet used (see previous description of wavelet types). If these controls do not apply to the particular wavelet selected then 'NA' (not available) will appear in the display.

<u>Coeff</u>
Number of 'exempted' coefficients. This determines how many coefficients for each frame are exempted from thresholding. When set to 0 (the default) thresholding is applied to all coefficients. This number can be adjusted (in powers of two) up to 1024 at which point no coefficients are thresholded and the process is effectively bypassed. This control allows you to determine the at which decomposition level the thresholding is applied. For example, when set to 512, thresholding is only applied to the first decomposition level.

Further Reading
Frequency analysis, modification and re-synthesis is a vast and often complicated subject. You don't need to be familiar with the subject or understand all of this manual to be able to use this plug-in but it can help. The following list contins some pointers to sources of information should you want to look into Fourier and wavelet analysis in more detail.

The Computer Music Tutorial – Curtis Roads
A good introduction to the concepts of time\frequency and time\scale analysis. Fourier analysis is dealt with much more thoroughly than wavelets though.

Introduction to Time-Frequency and Wavelet Transforms – Shie Qian
A more mathematically orientated text aimed at signal processing engineers. Gives a through overview of the main concepts though.

<u>http://www.wavelet.org</u>
On line resource about wavelets.

If you experience problems
Email me at <u>jez@mp3some.co.uk</u> if you experience any difficulties with operating this program and I will do my best to assist. Please feel free to send any examples of sounds designed using this plug-in.