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Distortion has been used as a musical effect since the 1950's and has been a tool used by musicians for crafting personal sounds, responsible for shaping the evolution of rock, metal and punk styles alike. [1]

The non-linear effect can be achieved by driving the gain of a signal until its peaks become clipped; dynamic range is reduced and these peaks begin to square. To which degree determines the amount of distortion, and the type of distortion. Soft-clipping is often dubbed associated with the Overdrive effect, hard-clipping outputs Distortion, and the Fuzz effect is often characterized by the significant squaring of a very hard-clipped signal. Gain, equalization and output are the most common parameters in distortion units [2].

As performance, musicianship and experimentation with tone have progressed, so has technology and its empowering affordance to capture and model classic sound effects like distortion - digital signal processing has, and will continue to afford new tools welcomed and embraced by musicians and producers alike with modeling classic units and the creation of new ones.

Problem Description:

While many distortion effects have been made available to consumers, a limitation to the degree of control available with the effect is due to predetermined ratios of gain and equalization parameters.

Most units offer swappable equalization stage(s) with a predefined bandwidth that limits control over the cuts and boosts of frequencies either side of the desired center frequency that is also affected by the predetermined slope. Furthermore, if a user desires further distortion but runs out of available gain at supplied by his/her unit, the application of multiple distortion effects in parallel succession can enable the desired boost(s), but the consequence of this application means that sonic artifacts from prior stages of alternative clipping techniques will become reshaped by the ensuing processing.

Supplying musicians and producers with a flexible digital distortion unit with the ability to grant undefined equalizing freedom while also providing the breadth of all three distortion stages, spanning soft-clipping overdrive often associated with blues, to an apparent untamed beastly squaring fuzz effect would require a parameter that pushes the input gain while retaining complete transparency when bypassed would answer a solution to these restraints.

Specification:

Creating a distortion without these limitations to gain can be achieved by adding a second gain parameter that multiplies the desired distortion further if required. The beauty of working with a digital algorithm means that unlike any electronic analog unit, we can easily supply this parameter to the consumer without affecting the signal when bypassed. The mathematical summation of the second gain stage is completely dependent on the gain stage's prior setting. Stability of the system's function means that subtle drive can be achieved as alike any distortion unit, but also includes with additional boost the distortion furthermore to whichever degree desired without needing to adjust the initial gain setting that may be used more prominently. For lead sections, or for alternative changes in the amount of gain throughout song or expression, there will be no need to use more than one single drive effect in succession again.

Opting for parametric equalization over shelving or peaking systems open up a new level of tonal flexibility. Hi/Lo-pass filters, boosts/cuts to any frequency at any bandwidth could offer musicians and producers the tool required to hone in on an array of interest of sonic detail.

Implementation:

Tests with a fully functioning Matlab code 'Chainstawton.m' have been generated and concluded that the digital signal processing with solutions to the aforementioned obstructions have been achieved. Provision for musicians and producers with these extra capacities are available.

'Chainstawton's algorithm was designed upon alterations and integration of Steve McGovern's gdist.m (Mathworks.com: 2003) [2] and equalization by M. Holters - 'pealdf.m' – (DAFX: 2011 – Chapter 2) [2]. The effect additional gain parameter has been tentatively named "Hell", and is completely stable with both mono / stereo inputs, or can be used in a chain - Opportunities for the effect to be used as a stand-alone unit, or within a link of digital amplification, simulated impulses and/or other dynamic and modular effects with complete stability is all part of its flexibility.

The three stages of processing can be expressed by:
The following mathematical equations detail these digital processing stages:

**Gain**

\[
 f(x) = \text{sgn}(x) \left( 1 - e^{-|x|} \right)
\]

[2].

**Parametric Equalization:**

\[
\begin{align*}
x_a(n) &= x(n) - d(1 - c_{B/C})x_a(n - 1) + c_{B/C}x_a(n - 2) \\
y_1(n) &= -c_{B/C}x_a(n) + d(1 - c_{B/C})x_a(n - 1) + x_a(n - 2) \\
y(n) &= \frac{H_0}{2} \left[ x(n) - y_1(n) \right] + x(n).
\end{align*}
\]

Where **center frequency** is parameter \(d\) and the coefficient \(H_0\) is given by:

\[
\begin{align*}
d &= -\cos(2\pi f_c/f_s) \\
V_0 &= H_0 \left( e^{2\pi f_c/f_s} \right) = 10^{G/20} \\
H_0 &= V_0 - 1.
\end{align*}
\]

Where **bandwidth** \(fb\) is adjusted through the parameters \(c_B\) and \(c_C\) for boost and cut given by:

\[
\begin{align*}
c_B &= \frac{\tan(\pi f_b/f_s) - 1}{\tan(\pi f_b/f_s) + 1} \\
c_C &= \frac{\tan(\pi f_b/f_s) - V_0}{\tan(\pi f_b/f_s) + V_0}
\end{align*}
\]

**Gain:** Peak filter design with \(K = \tan(\pi f_c/f_s)\) and \(V_0 = 10^{G/20}\)

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<tr>
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<th>Boost</th>
<th>Cut</th>
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[2].
Clipping and reduction of dynamic range:

Evaluation:

Input arguments to the algorithm’s corresponding distortion presets are easily altered and demonstrations of the effect have been included. This effect has been trialed with a variety of different instrument inputs [4], all with different playing styles and has proven successful at producing a variety quality dynamic audio, however feedback on the sonic quality produced by the product is essential in providing potential consumers with a processor that works as its marketed, and as its needed.

An important strategy in assuring that any final developments to the product can be addressed prior to launch can be conducted by implementing an assessment of how Chainstwation performs with a calculated demographic of potential customers. It’s of importance to ensure that this listening group contribute an even number of subjects; equal halves musicians, and sound engineers. The reason for this is to avoid problematic lexicon articulating crucial sonic descriptions so that coherent research can be undertaken away to further expand on perceptive control development inspired by research in drive output timbre [5], and how other factors such as playing techniques affect the perceived effect [6]. Assessments will be based upon two key considerations:

1. Aural Assessment.

Subjects will be played 4 variations of 5 different tracks. Each track will be a truncated (20-30 seconds) of stylistically differentiated song.

1. Bass – Funk - Mono
2. Guitar – Blues – Mono
5. Guitar – Noise – Feedback loops.

Variations on these 5 tracks will incur different degrees of distortion and equalization alterations solely to the instrument(s) listed and a questionnaire will be for the subjects to freely comment on which ’tones’ they liked/disliked, and why.

2. Usability.

For this evaluation the subjects will be requested to interact with the effect personally by shaping the effect to their own discretion with the same sounds. Two evaluations will be conducted. The first half of this test will require the subjects to freely ‘play’ with the effect, and to be rated on a scale of 1-5 under the following criteria:

- Ease of use
- Understanding of the parameters
- Flexibility of tone.
Conducting person(s) will then provide descriptive calibration goals to the subjects and the resultant parameter settings and copy of the processed signal audio shall be taken away for further analysis. These tonal description requests will include:

- Rough
- Sharp
- Fat
- Edge
- Wet
- Crunch
- Round
- Heat
- Wildness

A second questionnaire will be provided with room for elaboration how close the subjects feel they got to achieving the goal tone with additional space to illustrate which parameter(s) repress the effect’s capacity to achieve these goals.

**Conclusion**

Dependent on the information provided by the assessment tests, Chainstawtion could be ready to launch with minimal turnover time. Multiple stages of parametric equalization can be supplied; a determination of just how many is required awaits clarification, and these final developments can be addressed.

A potential face for a Chainstawtion plug-in and a variety of suggested presets and their relative demonstrations have been included.

**References:**

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   Anthony DeCurtis, Present Tense, Pages. 13-38

   Edited by Udo Zolzer.
   Helmut Schmidt University – University of the Federal Armed Forces, Hamburg, Germany – 2011.

   http://www.mathworks.com/matlabcentral/fileexchange/6639-guitar-distortion-effect

[4]. The Free Sound Project: www.freesound.org

“Blues”
https://www.freesound.org/people/eriatarka/sounds/15752/

“Bass”
https://www.freesound.org/people/mrwolf14/sounds/51197/

“Riff”
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[5]. Perceptual and Semantic Scaling for User-Centered Control Over Distortion-Based Guitar Effects
   Marui Atsushi and William L. Martens
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[6]. Investigating Factors that Guitar Players Perceive Depending on Amount of Distortion in Timbre
   Koji Tsumoto, Atsushi Marui and Toru Kamekawa.
   Tokyo University of the Arts, 1-25-1 Senju, Adachi-ku, Tokyo, 120-0034 Japan
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