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EUCLIDEAN ALGORITHM FOR SOUND GENERATION

Euclidean algorithm is known by humanity for more than two thousand years. During this period many applications for it were found, covering different disciplines and music is one of those. Such algorithm application in music first appeared in 2005 when researchers found a correlation between world music rhythm and the Euclidean algorithm result, defining Euclidean rhythms as the concept.

In the modern world, music could be created using many approaches. The first one being the simple analogue, the analogue signal is just a sound wave that emitted due to vibration of a certain medium, the one that is being recorded onto a computer hard drive or other digital storage called digital and has methods of digital signal processing applied. Having the ability to convert the analogue signal or create and modulate digital sounds creates a lot of possibilities for sound design and production, where sonic characteristics were never accessible because of limitations in sound development by the analogue devices or instruments, nowadays become true. Sound generation process, which usually consists of modulating waveform and frequency and can be influenced by many factors like oscillation, FX pipeline and so on. The programs that influence synthesised or recorded signal called VST plugins and they are utilising the concepts of digital signal processing.

This paper aims to research the possible application of Euclidean rhythms and integrate those in the sound generation process by creating a VST plugin that oscillates incoming signal with one of the four basic wave shapes in order to achieve unique sonic qualities. The varying function allows modulation with one out of four basic wave shapes such as sine, triangle, square and sawtooth, depending on the value received from the Euclidean rhythm generator; switching modulating functions introduces subharmonics, with the resulting richer and tighter sound which could be seen on the spectrograms provided in the publication.

Keywords: Euclidean algorithm, sound, sound generation, VST-plugin.

Introduction

The Euclidian algorithm has been known by humanity for more than 2000 years so far, and its further development, together with understanding the ways it could be used, lead to many new inventions and improvements in various sciences.

In 2005 the application of the Euclidean algorithm found its way in music, especially, explaining and generating traditional musical rhythms, using the simple concept of finding the greatest common divisor. Given the ability to generate rhythm pattern it gives a ground for implementation of plugin, that can oscillate incoming signal with varying OSC-function defined by rhythm generated by Euclidean algorithm.

Music Theory and Sound generation

Music itself consists of many disciplines, which cover most of the parts about what music is and how to make one.

To get deeper understanding of what music theory is and how sounds could be generated, let's start with definition of sound.

Sound is a vibration of any surface that creates an acoustic wave through medium which usually is air, but could be any liquid or even soil. Once the vibration is there, the medium is impacted with sound wave of certain frequency and function. The function could vary a lot, but as major 4 sound forms distinguish:

Having the ability to oscillate waveform with Fourier series, we can get an approximation of desired shape, including subharmonics that is being introduced.

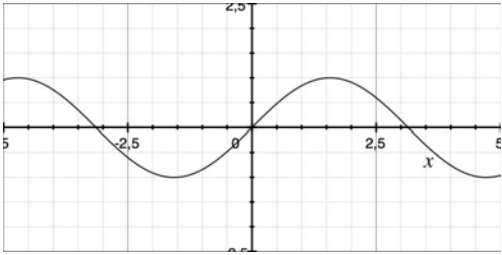
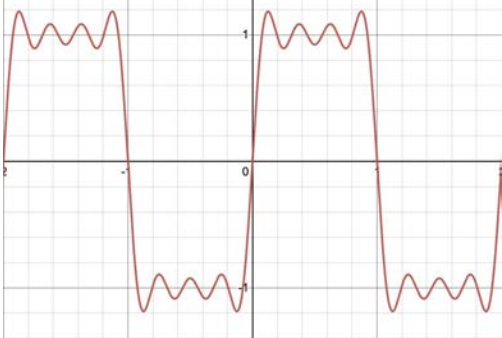
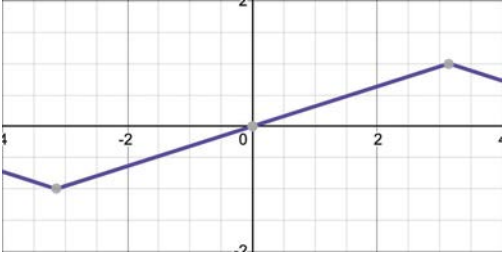
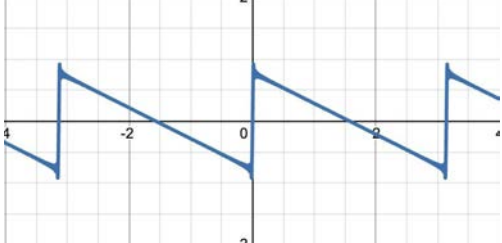
The Euclidean Algorithm for Sound Generation

The Euclidean algorithm can be used as the way to define rhythm in music composition by creating patterns for hits and silences in a given size, as been described in the paper «The Euclidean algorithm Generates Traditional Musical Rhythms» by Godfried Toussaint.

The idea is simple to define the musical size for cycle rhythm and place the pulses of music (tones that will introduce most tension) by application of Euclidean algorithm. In this case, number of pulses

Table 1

Waveforms and formulas

Name	Image	Formula
Sine wave		$y(t) = \sin(t)$
Square wave		$y(t) = \frac{4}{\pi} \sum_{k=1}^{\infty} \frac{\sin(2\pi(2k-1)ft)}{2k-1}$
Triangle wave		$y(t) = \frac{2a}{\pi} \arcsin\left(\sin\left(\frac{2\pi}{p}t\right)\right)$
Sawtooth wave		$y(t) = \sum_{n=1}^{\infty} \frac{\sin((2n)t)}{2n}$

has to be less than number of steps in cycle. Let's assume we want to place the 5 pulses over the size of 16 steps, this will give us musical size combining 4/4 and 3/4, and by application of Euclidean algorithm we get resulting pattern like this (1 is moment of pulse, and 0 is moment of silence):

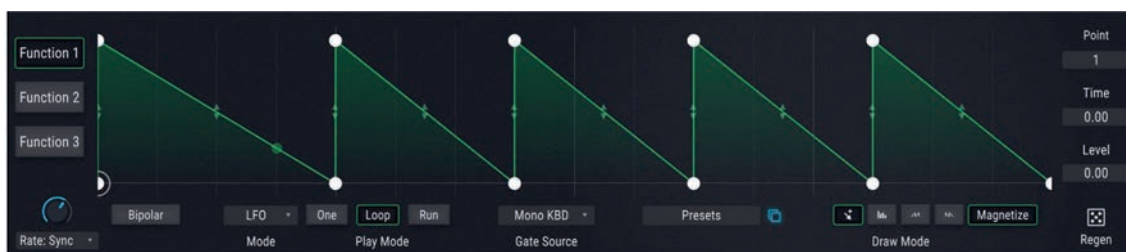
- 1 step: [1 1 1 1 1 0 0 0 0 0 0 0 0 0 0]
- 2 step: [1 0][1 0][1 0][1 0][1 0][0][0][0][0][0][0]
- 3 step: [1 0 0][1 0 0][1 0 0][1 0 0][1 0 0][0]
- 4 step: [1 0 0 0][1 0 0][1 0 0][1 0 0][1 0 0]
- Final result E(5, 16): [1 0 0 0 1 0 0 1 0 0 1 0 0 1 0 0]

Given the output with 0s and 1s, we can leverage those 1s for oscillation function change.

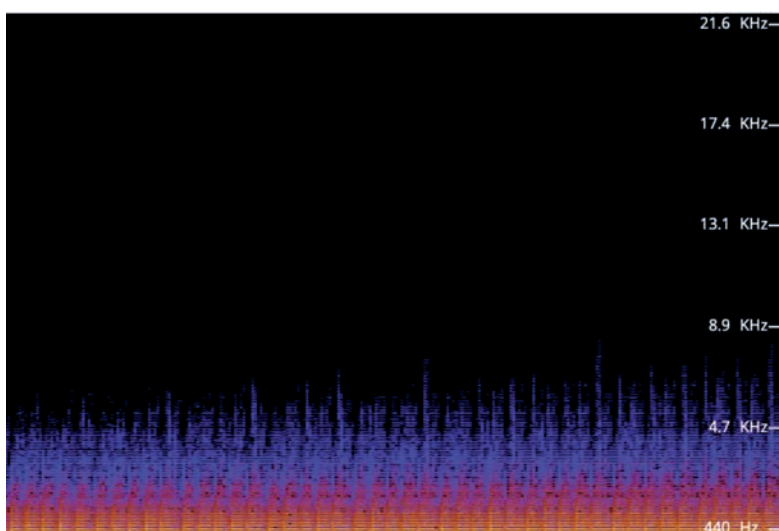
Waveshaping with the Euclidean algorithm

Apart from creating the rhythm for percussion elements and actual movements in sound, we can take the same approach of defining stepping of 1 and 0 over a given number of pulses, to develop the pulse patterns inside of the wave shapes, transforming them into more complex sounds.

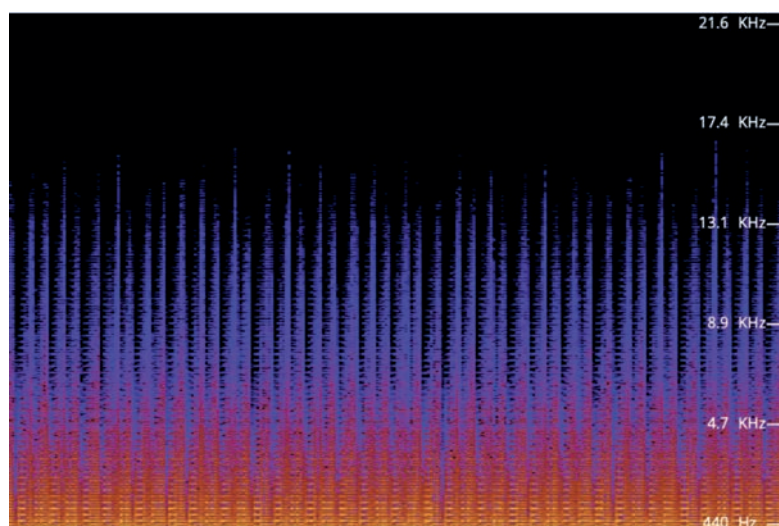
We can take the basic LFO (low-frequency oscillator) and use it as our envelope during the process of waveshaping. The base function for wave folding will be one of 4 waveforms we've defined previously (sine, square, triangle, sawtooth). From there we will take peak values of those functions and treat them as *true* or 1 in our euclidean algorithm result, and 0 values as the release ones. The



Picture 1. Function 1 with E(5,16) and sawtooth OSC waveform



Picture 2. Spectrogram of the clean signal



Picture 3. Spectrogram of the processed signal

number of LFO pulses per second could be defined by the size of note and number passed in Euclidean algorithm function, in this example, we're passing 16 pulses with 5 «hits» over one second of LFO oscillation.

Plugin behaviour

Based on theoretical knowledge about Euclidean algorithm and digital signal processing author de-

veloped the plugin, which has a simple, yet functional behaviour.

First, the VST program receives the input signal, mono or stereo(2 * mono). Once the signal is in, depending on current position of Euclidean algorithm (either 0 or 1), the signal is being oscillated. By default, the oscillating wave is sine, but when algorithm reaches to 1, the waveform is being changed to sawtooth and decays until the next 1 is in sequence being hit.

Having the varying function (from sine to saw and back), the resulting sound is begins to be more dynamic and «rich» due to subharmonics that added by the oscillated wave.

Conclusion

Conducted research gave the ability to explore possible usage of the Euclidean algorithm as a help-

ing function for sound generation process, together with definition of new creative way for digital music production. Following improvements into algorithm that morphs oscillating function together with more controls over the whole process, like ADRS-curve (Attack, Decay, Release, Sustain) or custom waveform definition can bring new layer of functionality and usability, because of possibility for granular tuning.

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АЛГОРИТМ ЕВКЛІДА ДЛЯ СТВОРЕННЯ ЗВУКУ

Алгоритм Евкліда вже відомий людству понад 2 тисячі років, його використовують у найрізноманітніших дисциплінах, однією з яких є музика. Цей алгоритм лежить в основі поняття Евклідового ритму, відкритого у 2005 р.

Мета цієї публікації полягає у вивченні способів застосування Евклідового алгоритму та Евклідових ритмів для впливу на процес генерації звуку.

У сучасному світі звук та музику загалом поділяють на цифрову, яка була створена з використанням цифрових застосунків та обладнання, і аналогову, створену з використанням аналогових інструментів. Завдяки можливостям цифрового оброблення звуку стає можливим застосування раніше не доступних методів, для впливу на вхідний сигнал та його подальшого оброблення. У цій статті розглянуто способи модуляції вхідного сигналу за допомогою варіативної функції, яка може змінюватись від синусоїди до пили, відповідно до поточної позиції у Евклідовому ритмі. Через незвичний підхід до модуляції сигналу можна побачити суттєвий вплив на результуючий сигнал на наведених спектограмах.

Розкрито можливості модуляції сигналу за допомогою варіативної функції, що своєю чергою створює простір для креативності та надає інструменти для впливу на звук, яких не було раніше.

Ключові слова: Алгоритм Евкліда, звук, генерація звуку, VST-плагін.



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