Lecture 7: Synthesis of Audio Signals

Introduction

Lecture on synthesis of audio signals was given by Fabián Esqueda from Native Instruments and it covered relevant methods to perform audio synthesis, but also digitally model existing analog equipment using various virtual analog modeling techniques. In this diary I will give an overview of the lecture's most important topics and provide an implementation example for a DWP Algorithm followed by spectrum analysis of each step of the algorithm.

VA Modeling

Virtual analog modeling encompasses various methods used to turn physical (analog) instruments into virtual (digital) ones. Although there is a wide variety of techniques, they boil down to two distinctive approaches. First of which is so called top-down (black-box) modelling. This approach aims to replicate input-output behaviour of the device without considering its internal mechanics and the way they behave and as a result it's purely based on input-output measurements. On the other hand, there's a bottom-up (white-box) modelling approach which involves approaching the modelling analytically and gaining an insight into circuit schematics. It is worth noting that in practice a mixture of both is most commonly used.

ML in VA Modeling

Machine learning has become increasingly popular in the VA modeling domain. Previously, the circuit equations had to be written down, rearranged into differential equations, discretized and then solved numerically. However, by utilizing machine learning models it is now possible to directly feed measurements from various points in circle into the model. Most popular such network architecture is State Trajectory Network (STN) which can also be interpreted as a modified and more specialized version of Recurrent Neural Network (RNN). This network architecture uses a stack of fully connected layers intervened with activation functions (tahn or ReLU). Blocks of those layers are also connected with skip connections and feedback loops. Through a training procedure this type of architecture is able to capture existing modulations and nonlinearities that an analog circuit might possess. As a result it has an ability to replicate an analog circuit in a very convincing manner.

Subtractive Synthesis

Development of subtractive synthesis techniques can be attributed to two synthesis movements, East Coast synthesis started by Bob Moog in the 60s in New York and West Coast synthesis started by Don Buchla in California.

East coast synthesis relies on the idea that we start with a signal that is rich in frequency spectrum and process it using variety of filters in order to achieve the desired result. It's based on a source-filer model where one or more oscillators are typically used as the source with second or fourth order resonant lowpass filters used as the filter. It also uses envelope generators (ADSR[1]) for modulation.

[1] ADSR - Attach, Decay, Sustain, Release

On the other hand, west coast synthesis takes a different approach by starting with a poor harmonic spectrum (such as sinewave or triangle) and expanding their spectrum using waveshaper or pitch modulations. By doing this we can go from a signal that is very poor in harmonic content to a signal rich with harmonics. Moreover, west coast synthesis is often associated with lowpass gates which are filter/amplifier structures controlled by light sensitive resistor packaged with an LED. LPG has an ability to produce naturally sounding acoustic-like plucks, but it is important to mention that no two vactrols (LEDs) produce the same sound.

DPW Algorithm

DPW (Differentiated Parabolic Wave) algorithm is a method used to solve the issue of aliasing when generating a sawtooth wave using trivial methods. It relies on squaring the sawtooth signal and then differentiating it. As a result, it reduces the amount of aliasing in the generated signals. The implementation of the algorithm along with the relevant plots for each step can be seen in the provided jupyter notebook.