Landon Viator

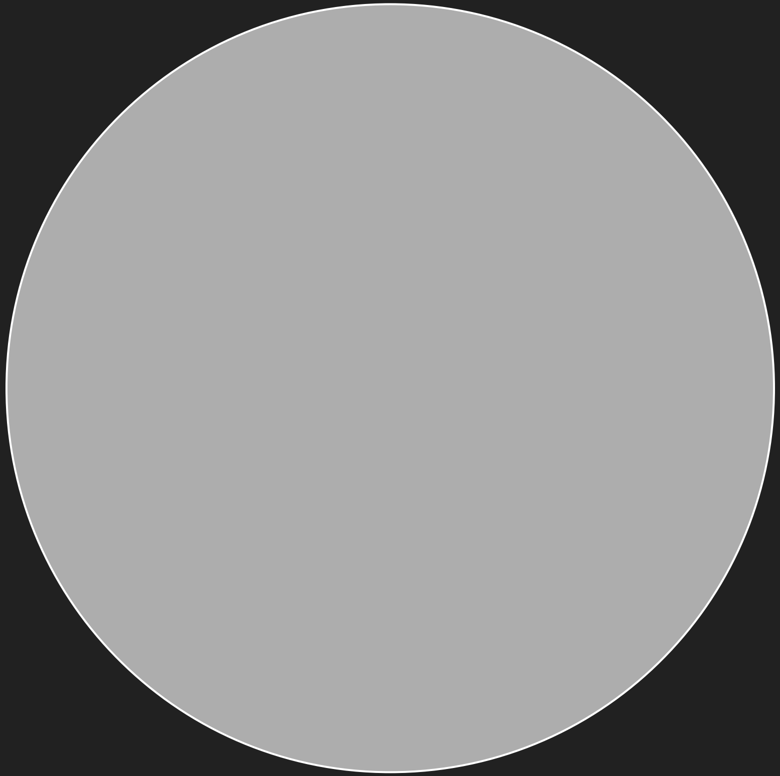
FINDING MUSIC IN CHAOS: DESIGNING AND COMPOSING WITH VIRTUAL INSTRUMENTS INSPIRED BY CHAOTIC SYSTEMS

Chaos Theory

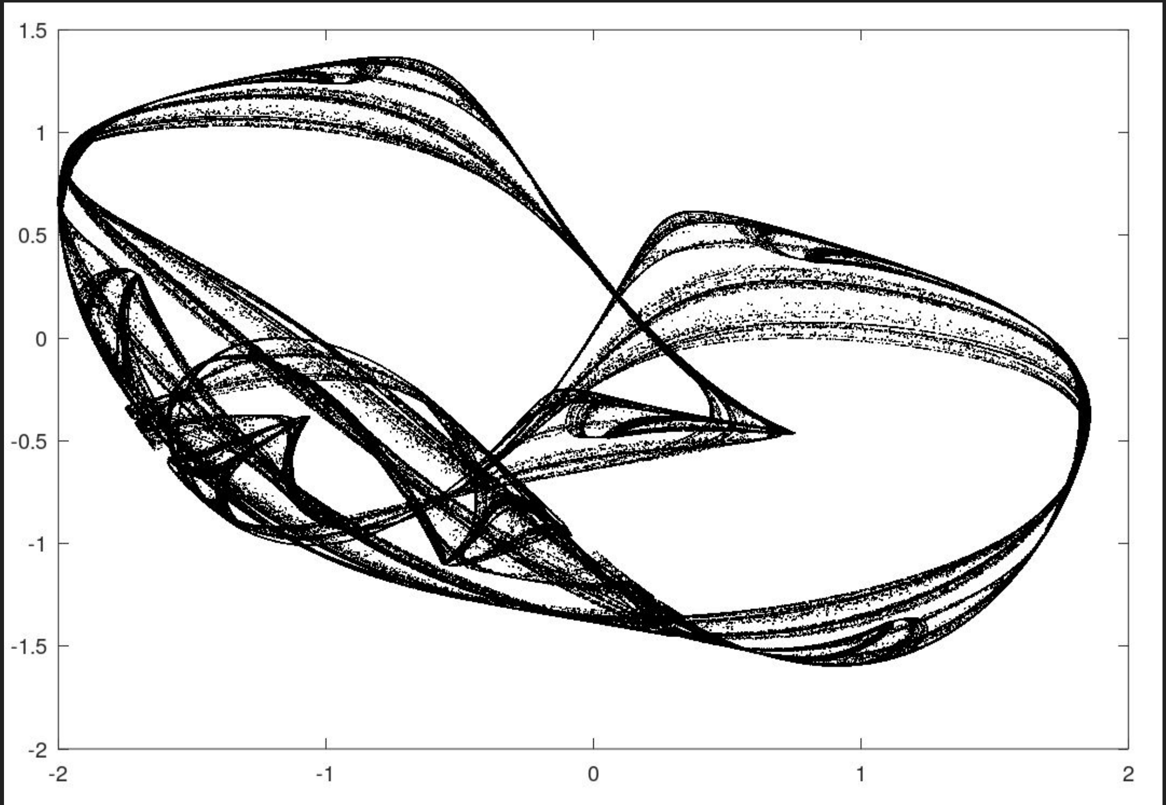
- Chaos theory is a field of mathematics that models and calculates certain kinds of nonlinear dynamical systems; systems whose states change.
- Cartwright defines chaos as "order without predictability"
- Many chaotic dynamical systems display highly sensitive and unpredictable behavior when the system's parameters or initial conditions are changed.
- Chaotic behavior in nonlinear dynamical system are more easily visualized when used in contrast with the mapping of a sinusoidal oscillator in (x, y) space.

See (Cartwright1991)

Sinusoidal Oscillator in (x, y) space



Chaotic System in (x, y) space



Dejong Map

$X_n = \sin(a * y_{n+1}) - \cos(b * x_{n+1})$

$Y_n = \sin(c * x_{n+1}) - \cos(d * y_{n+1})$

a = 1.3

b = 1.4

c = 0.33

d = 1.9

See Dewdney, 1987

Overview

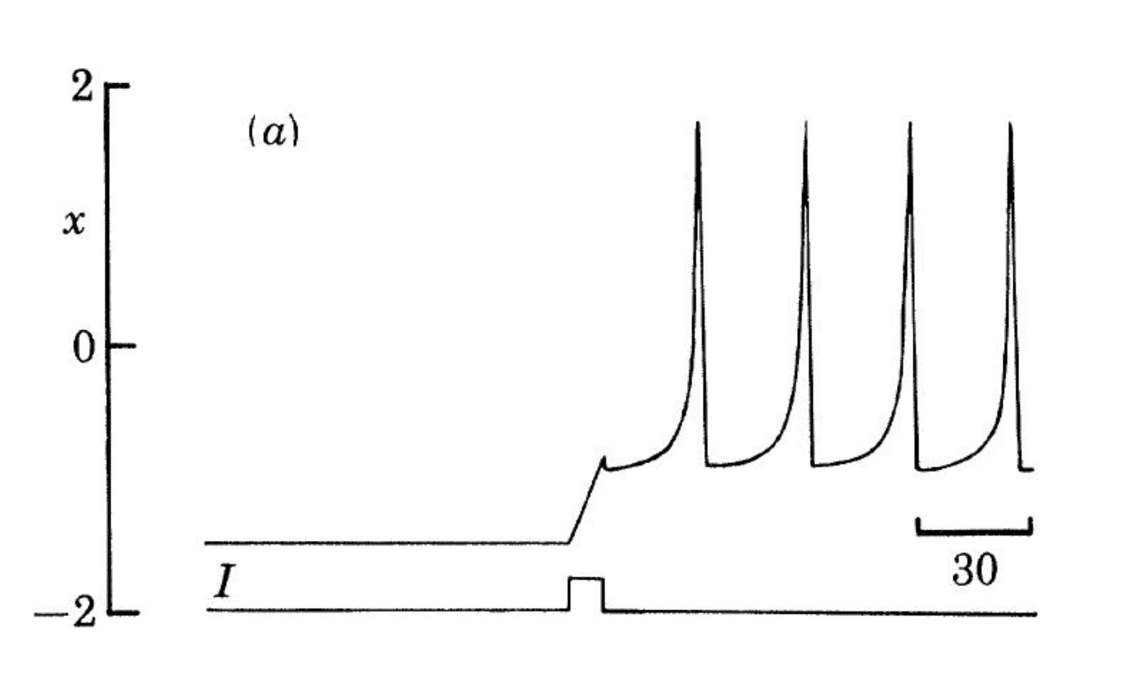
- Using chaos theory to design novel audio synthesis engines has been explored little in computer music.
- One way to remedy these issues is to connect chaotic equations to individual parts of the synthesis engine in a stable, predetermined state.
- The goal of this project is to design physically-inspired virtual instruments based on conceptual instrument models that utilize chaos theory in the synthesis engine to explore novel sounds in a reliable, repeatable way for other composers and performers to use.

Hindmarsh-Rose Chaotic System

This chaotic system was first described by Hindmarsh and Rose in 1982. This model described the behavior of a brain cell discovered in a pond snail that when depolarized by a short pulse of current, an action potential (burst) was created with a short after potential decay. To produce the behavior in the cell, the introduction of a small electrical current is used.

See (Hindmarsh-Rose 1984)

Hindmarsh-Rose Chaotic Bursting Example



Hindmarsh-Rose Equations

$dx/dt = y - a * (x^3) + b * (x^2) + I;$

$dy/dt = c - d * (x^2) - y;$

$dz/dt = r * (s * (dx - x) - z);$

I is the most important parameter conceptully because it defines the current sent through the brain cell.

Circle Map

- A one-dimensional chaotic map, circle maps belong to a family of chaotic maps used to describe the behavior of driven mechanical motors.
- $\theta_{n+1} = \theta_n + \Omega - (\kappa/2\pi)\sin(2\pi\theta_n) \,\%\, 1.0$
- In this equation, the most important parameters is κ which describes the non-linear behavior of the circle map.
- Ω describes the driving force of the motor.

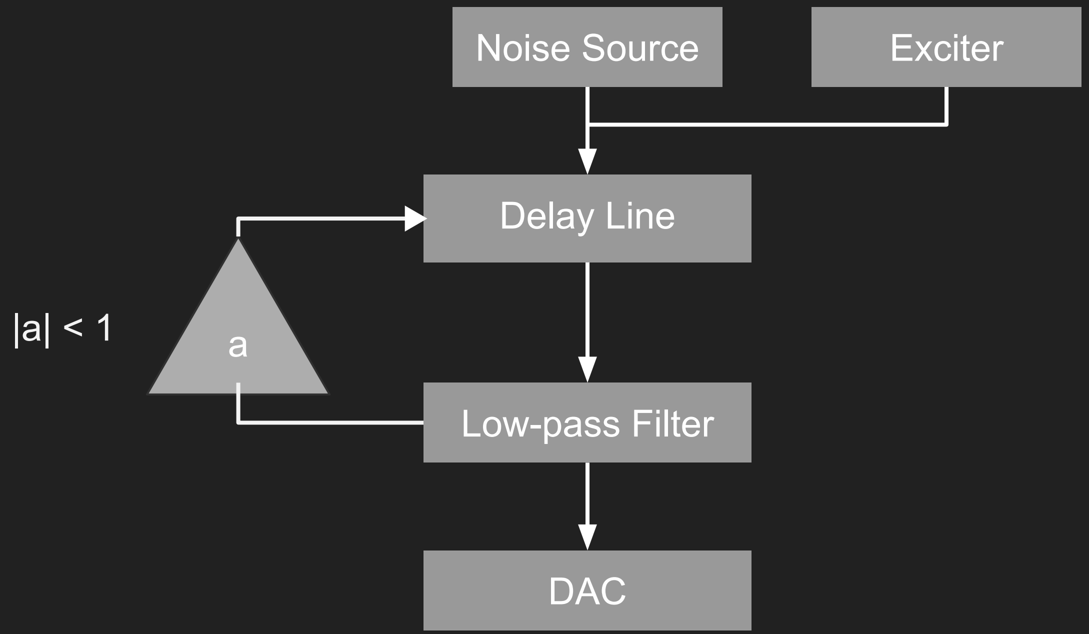
Physical Modeling

- Physical modeling is a type of audio synthesis that digitally simulates the physics that control the behavior of physical, vibrating objects
- These objects are modeled to behave like the instrument they are modeling, so different parts of the equations that produce the physical model can be manipulated to change the behavior of the instruments based on the desired response
- The main advantage to creating physical models of instruments as opposed to other methods of synthesis is that physical modeling attempts to acquire the same expressive and dynamic qualities inherent in real instruments and allows for intuitive control of the physical phenomena in those models

Physical Modeling Example

- Digital waveguide synthesis simulates waves traveling through a physical medium
- Karplus-Strong

String Model With Digital Waveguide

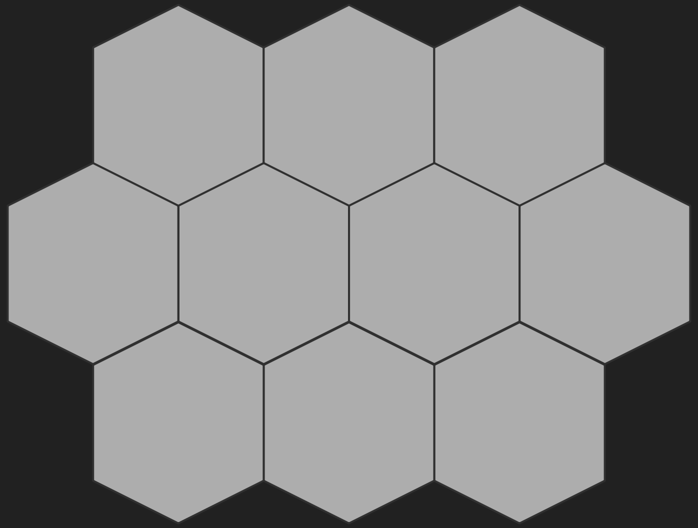


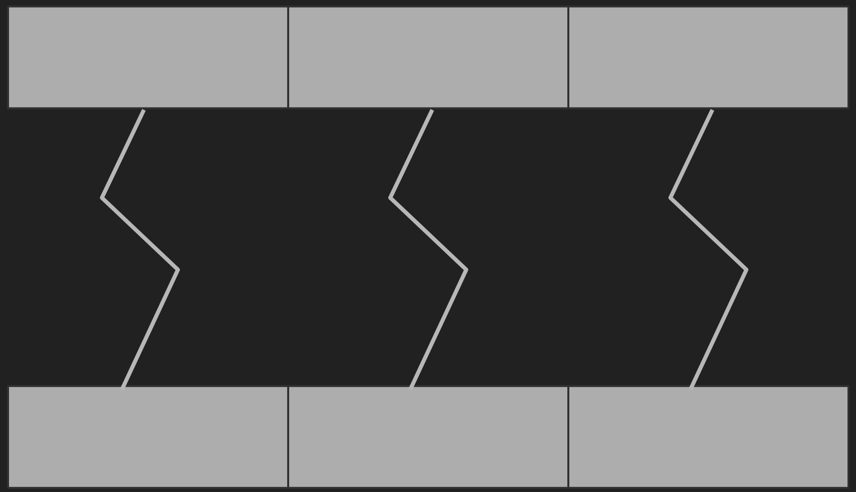
See (Karplus-Strong 1983)

Mapping

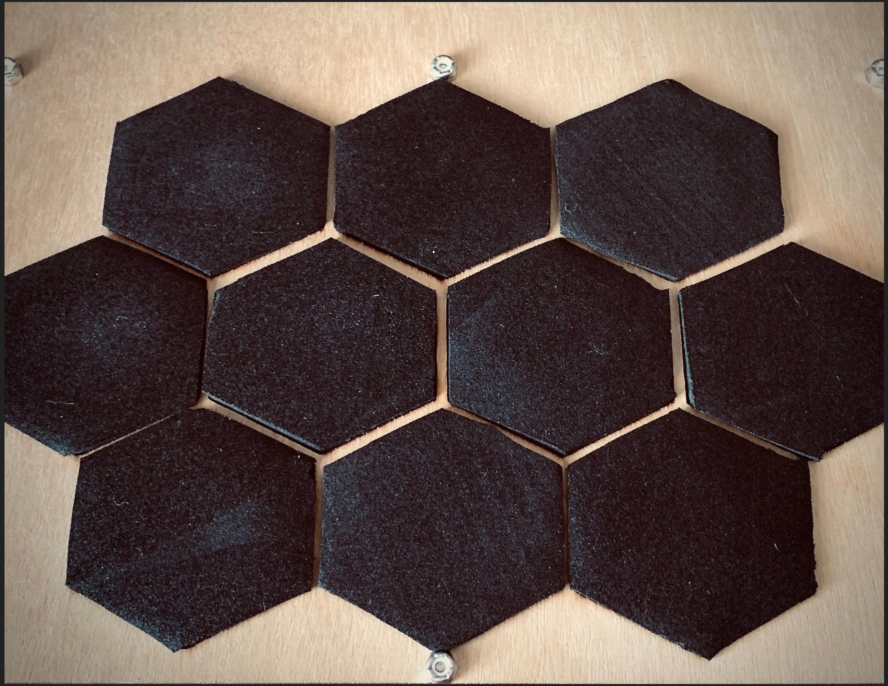
- The process of connecting sound-producing sources with an interface for the performer to interact with in a range that fits the need of the interaction
- Violin pitch

Instrument Concept





Interface



Resonator

T = 1 / sampleRate;

C = -exp(-2 * PI * BW * T);

B = 2exp(-PI * BW * T) * cos(2 * PI * F * T);

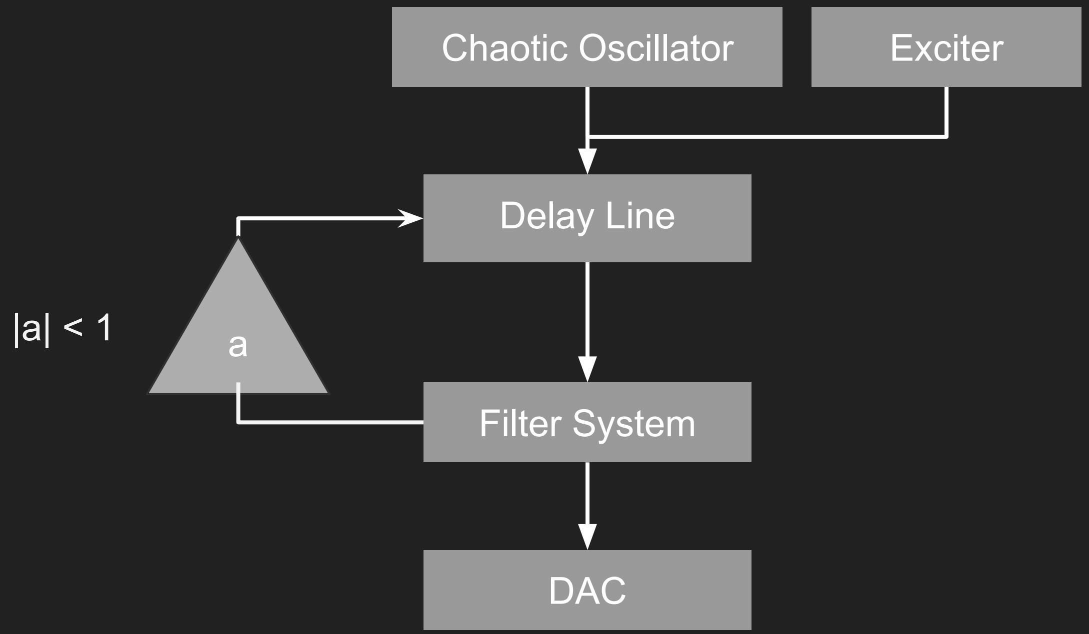
A = 1 - B - C;

y(nT) = Ax(nT)+By(nT-T)+Cy(nT-2T);

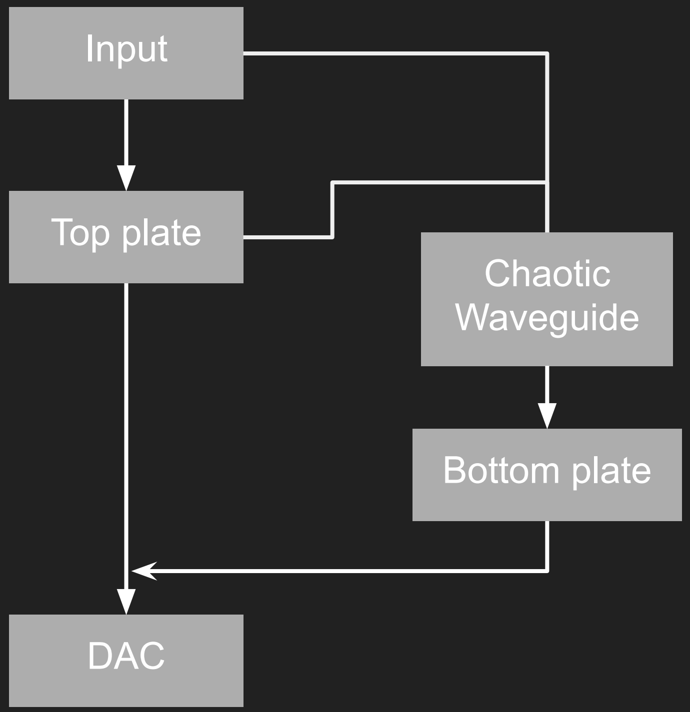
Where F = fundamental frequency and BW = bandwidth

See (Klatt 1980)

Chaotic Waveguide



Combined Synthesis Algorithm



The Compositions

- Two Pieces.
- Hexapad and the virtual instrument previously described, titled *VIII Tractuum*.
- Piece for guitar and fixed media experimenting with using chaotic oscillators as tonal synthesizers, since they can be difficult to tune, as well as experimenting with using chaotic oscillators as electronic sound effects titled *Ferrum*.

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