An Experimental Composition Tool Using the DeJong Chaotic Attractor to Manipulate Audio Using an AU Plugin Implementation

ABSTRACT

The DeJong plugin is an AU plugin that can be used in any DAW on Mac OS which applies the discrete-time De Jong chaotic attractor equation first proposed by Peter De Jong to incoming audio in stereo. The sonic output is captivating, experimental, and diverse. The plugin can be used as easily as any other common effect plugin, such as distortion and equalization, with the ability to automate parameters in real-time.

1. PRIOR WORK

DrawJong 2.0 [1] is a synthesizer and visualizer created by Matthew Hetrick specifically designed to sonify and visualize chaotic attractors.

The reacTable uses control data flows to synthesize audio which includes chaotic and fractal generators.[2]

Berdahl, Pfalz, Sheffield, and Morasco also connect chaotic maps, including the DeJong attractor, with digital waveguides to synthesize audio. [3]

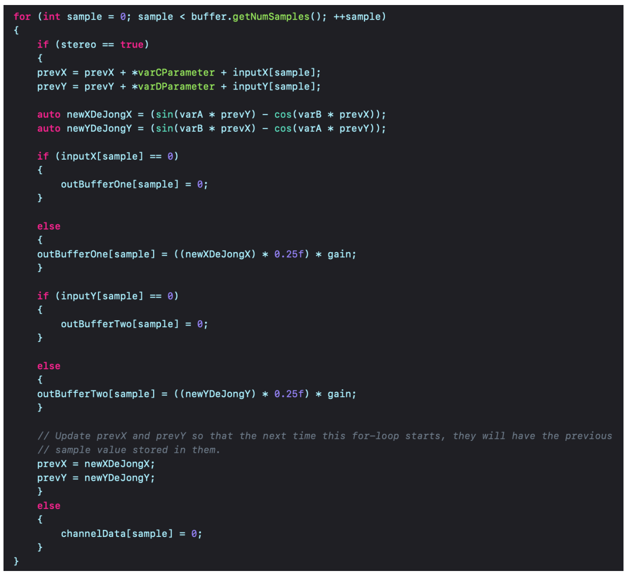
2. DEJONG CHAOTIC ATTRACTOR

The DeJong chaotic attractor is given as[1]:

$$\mathrm{x}_n = sin(a * y_{n-1}) - cos(b * x_{n-1})$$
$$y_n = sin(c * x_{n-1}) - cos(d * y_{n-1})$$

In Hetrick's DrawJong, xn and yn equal the next point to be plotted on the respective axis with xn-1 and yn-1 being the previously plotted points. Variables a, b, c, and d are parameters that can be constants or dynamic, but Hetrick's implementation used these variables as constants. The images created by this equation are truly beautiful and can be seen in Hetrick's paper.

In my interpretation of this equation for audio, xn is equal to the left channel's output and yn equals the right channel's output. xn-1 and yn-1 represent the previous sample in each channel and I used variables a and b in the plugin replacing variable c with variable a and replacing variable d with variable b.



```
for (int sample = 0; sample < buffer.getNumSamples(); ++sample)
{
    if (stereo == true)
    {
    prevX = prevX + *varCParameter + inputX[sample];
    prevY = prevY + *varDParameter + inputY[sample];

    auto newXDeJongX = (sin(varA * prevY) - cos(varB * prevX));
    auto newYDeJongY = (sin(varB * prevX) - cos(varA * prevY));

    if (inputX[sample] == 0)
    {
        outBufferOne[sample] = 0;
    }

    else
    {
    outBufferOne[sample] = ((newXDeJongX) * 0.25f) * gain;
    }

    if (inputY[sample] == 0)
    {
        outBufferTwo[sample] = 0;
    }

    else
    {
    outBufferTwo[sample] = ((newYDeJongY) * 0.25f) * gain;
    }

    // Update prevX and prevY so that the next time this for-loop starts, they will have the previous
    // sample value stored in them.
    prevX = newXDeJongX;
    prevY = newYDeJongY;
    }
    else
    {
        channelData[sample] = 0;
    }
}
```

Figure 1. The process block method in Juce.

The significance of using a discrete-time chaotic attractor as an audio plugin is creating a new experimental composition tool that is easy to use inside of any DAW by anyone regardless of how familiar they are with experimental music making techniques.

3. THE JUCE FRAMEWORK AND PLUGIN DESIGN

I used the open source Juce framework with C++ to build both the visual component and dsp component of this plugin. [4] In this framework, Juce includes a method that handles all of the plugins dsp called the processBlock which is shown in figure 1. This method iterates through each audio sample coming through the input with a for loop given as:

for (int sample = 0; sample ¡ buffer.getNumSamples(); ++sample).

This is where I was able to apply processing to each sample. Before I implemented the equation, I created a way to dynamically access previous samples from the input. I created two variables named prevX and prevY to store the current sample from the input so that after each iteration, the samples contain in prexV and prevY are what came before each iteration through the for loop. This was done by implementing the code:

prevX = prevX + *varCParameter + inputX[sample];

prevY = prevY + *varDParameter + inputY[sample];.

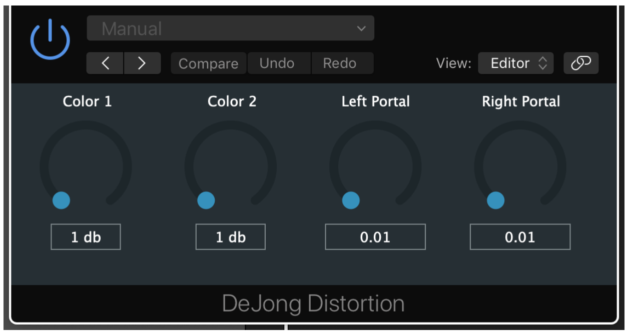
Adding in the varCParameter and varDParameter, which link to dials on the graphic part of the plugin, allowed me to choose how far back in the prevX and prevY address I can pull from. Finally, I implemented the actual De Jong equation for $x_n andy_n with$:

$autonewXDeJongX = (sin(varA*prevY)-cos(varB*prevX));$
$autonewYDeJongY = (sin(varB*prevX)-cos(varA*prevY));$

After each iteration of the for loop, I stored the processed sample in prevX and prevY by implementing:

prevX = newXDeJongX;
prevY = newYDeJongY;

This is where I am able to pull from previous samples. One difference that one notices in this implementation is that I am using only variables a and b in place of variables c and d from the original De Jong equation. This is because in my testing, I found that having four variables did not make any sonic difference from having only two variables. Figure 2 shows the user interface I created for the plugin.



Color 1: 1 db
Color 2: 1 db
Left Portal: 0.01
Right Portal: 0.01

Figure 2. Current interface for the experimental DeJong distortion plugin.

I named variables a and b as "Color 1" and "Color 2" and prevX and prevY as "Left Portal" and "Right Portal" since they are essentially pulling samples from back in time. Finally, I pass each equation to the left and right output buffer with the code:

outBufferOne[sample] = ((newXDeJongX) * 0.25f) * gain;
outBufferTwo[sample] = ((newYDeJongY) * 0.25f) * gain;

Each side is multiplied by 0.25 to compensate for the volume increase inherent in using this equation. It is also multiplied by a gain parameter that I have not implemented in this demo. This will serve as an output volume in the finished product. Unlike any of the previously cited works, this implementation applies the De Jong chaotic attractor to incoming audio instead of synthesizing audio which makes this plugin dynamic and ideal for a composition tool.

4. SOUND RESULTS

The sonic effect of this plugin and equation in general is captivating and erratic. Figure 3 shows a comparison between a dry drum loop and the same drum loop passing through the plugin using MaxMSP.

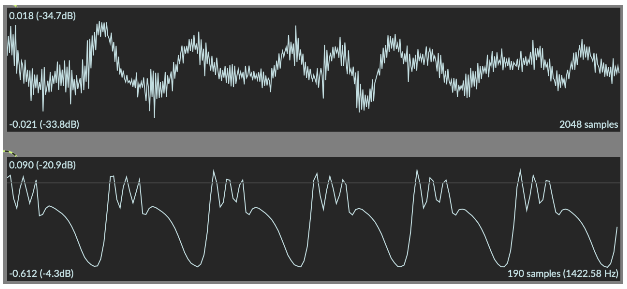


Figure 3. Comparison between a dry drum loop and an affected drum loop.

The top level is the dry drum loop and the bottom level is the affected drum loop. You can see how the dry drum loop looks fairly asymmetrical and dynamic, but the affected drum loop is so distorted that the waveform looks like perfect copies of itself. In terms of timbre, this plugin turns the signal into a thin, bright fuzz that resembles static and feedback. However, changing the color parameters shift the fundamental sound around drastically. The dry signal is still somewhat retained in the affected signal which makes this plugin very dynamic and useful in composition projects.

5. FUTURE WORK AND DESIGN IMPROVEMENTS

In future conceptions, I would like to add an output volume parameter, connecting to he gain variable, to control the volume of the plugin. I also want to add a wet/dry control to the plugin to change how much of the wet signal and how much of the dry signal passes through to the outputs which is a common control for most effect plugins. [5]

6. REFERENCES

[1] M. Hetrick, "DrawJong 2.0," 2011.

[2] M. Kaltenbrunner, G. Geiger, and S. Jordà, "Dynamic patches for live musical performance," in *Proceedings of the 2004 conference on New interfaces for musical expression*. National University of Singapore, 2004, pp. 19–22.

[3] E. Berdahl, E. Sheffield, A. Pfalz, and A. T. Marasco, "Widening the Razor-Thin Edge of Chaos Into a Musical Highway: Connecting Chaotic Maps to Digital Waveguides."

[4] WeAreRoli/Juce, "Juce Framework," https://github.com/WeAreROLI/JUCE, 2018.

[5] V. Goudard and R. Muller, "Real-time audio plugin architectures," *Comparative study. IRCAM-Centre Pompidou. France*, 2003.