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Sound Creation based on Multi-oscillation Dynamics

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Abstract

This paper presents sound creation with nonlinear differential equations including frequencies generated from several kinds of attractor. An attractor has own frequency characteristic. Then, by using the various kinds of attractor frequencies, many kinds of sound including various fluctuation can be expected to create. Specifically, the method is to combine the note-depending Fourier series and the no-note-depending Fourier series where the no-note-depending means corresponding to the attractor frequencies. Attractor frequencies are generated from the circuit simulator SDP (Sound Dynamics Program). Step size, determined in that process, seems to be one of the important parameters to change the quality of new sound. There are various parameters and coefficients in this research, especially chaos parameters. The created sounds can be evaluated by listening and comparing frequency spectrum. Harmonic overtones are created and the sound difference based on each attractor can be confirmed.

1. Introduction

Recently there are many types of electronic musical instrument, such as synthesizers. Synthesizers are classified into the analog synthesizers and the digital ones. Analog sounds are created based on recording wave data and the digital sounds are based on simple waves those were created artificially such as sin waves, then these basic waves are manipulated by signal processing. There are so many functions to modulate the sounds, AM (Amplitude Modulation), FM (frequency Modulation), delay, phaser equalizer and so on, these functions are also created by signal processing. On the other hand, traditional instruments such as grand pianos and violins have their own specific shapes, The tone colors corresponding to the waveforms are effected by harmonic overtones, harmonic overtones are created by reflecting the each instrument's construction, so the difference of instrument's shape corresponds to the difference of tone color. Moreover, ways of wave's reflections are slightly changed by the musician's delicate movement such as timing, strength of fingers, arms, breath and so on. Music performed by musicians, especially professional musicians has comfortable, unique or artistic shaking that is created by musician's feelings and emotions. Of course, the way of vibration is different every performance even the same songs, even by the same person, that is often called $1/f$ fluctuation. However to realize such delicate movement by only signal processing is limited. Then the new methods to realize unique movement may be kind of beating or vibration are needed, so it is the main purpose of this research. As mentioned above, music has some kinds of fluctuation such as harmonic overtones, timing, strength and so on. In this time, modulations of amplitude and frequency are focused on, that correspond strength and kind of round frequencies. We pursue the suitable and various vibration by using frequencies which are generated from some circuits.

In our previous research [1] , several kinds of chaos such as Nishio chaos [2] , Roessler chaos and Lorenz chaos are used to create FM, frequency modulation and AM, amplitude modulation as Eq.(1)

$$f_b[t] = (e^{\frac{-t}{length}} - e^{-1}) \times 2^{13} \times g(t) \sin 2\pi f t \qquad (1)$$

By this equation, round frequency can be created, furthermore about amplitude, in other words, vibration can be also appeared. Nevertheless, by this method, harmonic overtones or higher harmonics cannot be created, so the difference between the chaoses is hard to feel. The spectrum is shown in Figure 1. The left one is the spectrum in case of using Nishio chaos, and the right one is of Lorenz chaos.

Figure 2 shows the attractors of Nishio and Lorenz, these corresponds to the each spectrum of Figure 1. The left attractor is nishio chaos, and the right one is Lorenz chaos. Though

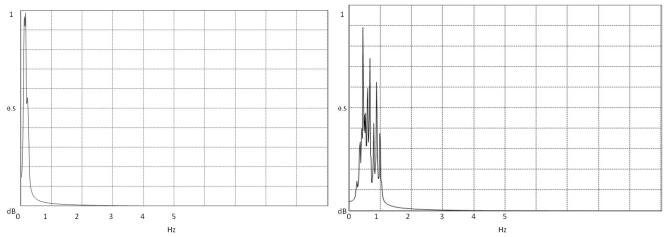

Figure 1: *Spectrum of Nishio and Lorenz for Eq.(1)*

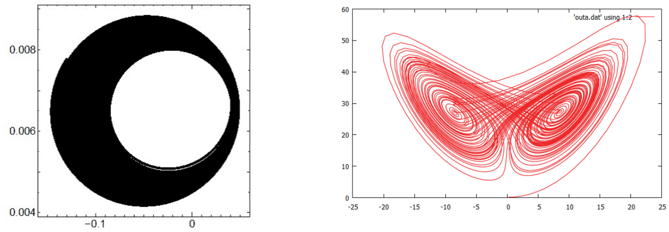

Figure 2: *Attractors of nishio and lorenz*

the shapes of attractors are different so much, the tone color, spectrum for Eq.(1) are almost the same. To consider that tone color depends on harmonic overtones, sound creation from only one sine wave such as Eq.(1) is almost unrealistic. Harmonics contain so many kinds of frequencies, then to use the Fourier series can be expected to solve the lacking of harmonics. The detail of new method [3] is to combine the note-depending Fourier series and the no-note-depending Fourier series from circuit frequencies, as Eq.(2)

$$B(x) = f_b(x) + f_c(x). \qquad (2)$$

Moreover in this time, frequencies generated from circuit are not limited only chaos, a circuit in which diodes are removed from Nishio circuit is tried. We find the suitable FFT (Fast Fourier Transform) coefficients from the methods of solving the circuit equations, which are the kinds of the differential equations.

2. Data and Method

First of all, information of songs, such as which note to play and each note's duration time, must be input to the program. Usually music player uses the scores. In case of this research, MIDI (Musical Instrument Digital Interface) information made by excel as follows plays the role of score. MIDI note number is defined based on note-A4 of 440Hz, each frequency can be calculated from the Eq.(3)

$$frequency = 440.0 \times 2.0^{\frac{notenumber-69.0}{12.0}}. \qquad (3)$$

Table 1 is in case of a single melody. The first line means to play the notenumber 52 for 0.25 seconds. In this time, since a quarter note is defined to 1 seconds, 0.25 seconds means 1/16 note.

Table 1: *MIDI information*

MIDI number	length
52	0.25
57	0.25
57	0.25
59	0.25
60	0.5
62	0.5
64	1
60	0.5
57	0.5
71	1

In this time, we realize to play several notes simultaneously, it means that not only the melody line, but with chords. By reflecting different kinds of chaos, to each layer, the sounds, harmony comes to be like an orchestra, each part are played by each musicians. The following MIDI information in Table 1 is in case of melody with chords, and this MIDI information corresponds to the score as shown in Figure 3. In addition, when 3000 is substituted as notenumber in Eq.(3), the frequency is much higher, it's above the range that human can hear, so note number 3000 can play the role of rest.

Table 2: *MIDI information in chord*

52	0.25	3000	4	57	4	60	4	64	4
57	0.25	3000	0	3000	0	3000	0	3000	0
57	0.25	3000	0	3000	0	3000	0	3000	0
59	0.25	3000	0	3000	0	3000	0	3000	0
60	0.5	3000	0	3000	0	3000	0	3000	0
62	0.5	3000	0	3000	0	3000	0	3000	0
64	1	3000	0	3000	0	3000	0	3000	0
60	0.5	3000	0	3000	0	3000	0	3000	0
57	0.5	3000	0	3000	0	3000	0	3000	0
71	1	3000	2	52	4	55	4	59	4
67	0.5	52	0.25	3000	0	3000	0	3000	0
64	0.25	52	0.25	3000	0	3000	0	3000	0
67	2.25	52	0.5	3000	0	3000	0	3000	0
67	0	55	0.5	3000	0	3000	0	3000	0
3000	0	59	0.5	3000	0	3000	0	3000	0

As this 'Amagigoe score' shows music score has many cells, and the performance time of each cell must be fixed to the same. In this score, it takes 4 seconds for each cell. However in case of MIDI information, 'cell' cannot be seen,

Figure 3: *Amagigoe score*

that means once the duration time is mistaken, time lag is kept to the end of the song. It's the one of the problems but is not solved yet.

Next, the attractors used in this time are as follows. Figure 4 is a circuit model of Nishio circuit, and the attractor is Figure 5. Figure 6 is in which diodes are removed from Nishio circuit. By the comparison of the two sounds and spectrum, how effects the difference of the construction of circuit can be expected to appear. In addition, SDP (Sound Dynamics Program) is used to solve each circuit, the construction of each circuit can be expressed in net list. Figure 7 is the net list of nishio circuit, and Figure 8 is of the circuit removed diode from nishio circuit.

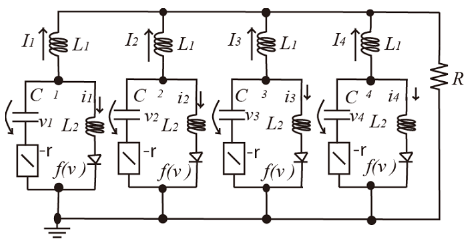

Figure 4: *Circuit model with diode*

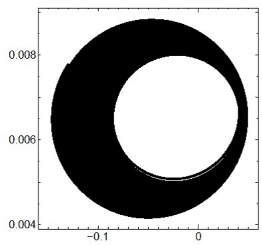

Figure 5: *Attractor with diode*

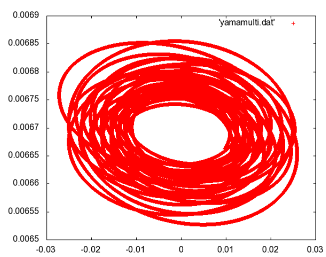

Figure 6: *Attractor without diode*

```
Circuit NishioN
 Input
  Vdd=5
  G=0
  Vin=0
 end


Macro osc1(in,out)
branch
  L(in,2,3,G;10.31E-3) {Original}
 {D(2,out,G;id=2.52e-9;cac=0) } {Its OK}
 {C(2,out;1E-12)} { if there is C, Jump}
  FUNC(2,out;"2.52E-14*(EXP(v/0.026)-1")
  {FUNC(2,out;"2.0/(1+EXP(-v))-1")}
   {FUNC(2,G;"0.04*(-1+exp(-v/2))")}
  {C(1,out;34.9E-6)}
   C(in,1;34.9E-6)
  PWL(1,out;-0.0002994)  {its OK for original=-0.002994, -334ohm}

 end
end

branch
  osc1(2,G)
  osc1(3,G)
  osc1(4,G)
  osc1(5,G)
 R(1,G;26.2378)
 {R(1,G;10.0)}
  L(1,2,6,G;100.7E-3) {original}
  L(1,3,7,G;100.7E-3) {original}
  L(1,4,8,G;100.7E-3) {original}
  L(1,5,9,G;100.7E-3) {original}


 end
end
```

Figure 7: *SDP net list of A*

```
Circuit yt
 Input
  Vdd=5
  G=0
  Vin=0
 end


 Macro osc1(in,out)
branch
  L(in,out,2,G;10.31E-3) {Original}
 {D(2,out,G;id=2.52e-9;cac=0) } [Its OK]
 {C(2,out;1E-12)} { if there is C, Jump}
  {FUNC(2,out;"2.52E-14*(EXP(v/0.026)-1")}
  {FUNC(2,out;"2.0/(1+EXP(-v))-1")}
   {FUNC(2,G;"0.04*(-1+exp(-v/2))")}
  {C(1,out;34.9E-6)}
   C(in,out;34.9E-6)
  PWL(1,out;-0.000002994)  {its OK for original=-0.002994, -334ohm}

 end
end

 Macro osc2(in,out)
branch
  L(in,out,2,G;10.31E-3) {Original}
 {D(2,out,G;id=2.52e-9;cac=0) } [Its OK]
 {C(2,out;1E-12)} { if there is C, Jump}
  {FUNC(2,out;"2.52E-14*(EXP(v/0.026)-1")}
  {FUNC(2,out;"2.0/(1+EXP(-v))-1")}
   {FUNC(2,G;"0.04*(-1+exp(-v/2))")}
  {C(1,out;50.0E-6)}
   C(in,out;44.9E-6)
  PWL(1,out;-0.000002994)  {its OK for original=-0.002994, -334ohm}

 end
end

 Macro osc3(in,out)
branch
  L(in,out,2,G;10.31E-3) {Original}
 {D(2,out,G;id=2.52e-9;cac=0) } [Its OK]
 {C(2,out;1E-12)} { if there is C, Jump}
  {FUNC(2,out;"2.52E-14*(EXP(v/0.026)-1")}
  {FUNC(2,out;"2.0/(1+EXP(-v))-1")}
   {FUNC(2,G;"0.04*(-1+exp(-v/2))")}
  {C(1,out;34.9E-6)}
   C(in,out;54.9E-6)
  PWL(1,out;-0.000002994)  {its OK for original=-0.002994, -334ohm}

 end
end
 Macro osc4(in,out)
branch
  L(in,out,2,G;10.31E-3) {Original}
 {D(2,out,G;id=2.52e-9;cac=0) } [Its OK]
 {C(2,out;1E-12)} { if there is C, Jump}
  {FUNC(2,out;"2.52E-14*(EXP(v/0.026)-1")}
  {FUNC(2,out;"2.0/(1+EXP(-v))-1")}
   {FUNC(2,G;"0.04*(-1+exp(-v/2))")}
  {C(1,out;34.9E-6)}
   C(in,out;64.9E-6)
  PWL(1,out;-0.000002994)  {its OK for original=-0.002994, -334ohm}

 end
end


branch
  osc1(2,G)
  osc2(3,G)
  osc3(4,G)
  osc4(5,G)
 {R(1,G;0.0000152378)}
  R(1,G;26.2378)

  L(1,2,6,G;100.7E-3) {original}
  L(1,3,7,G;100.7E-3) {original}
  L(1,4,8,G;100.7E-3) {original}
  L(1,5,9,G;100.7E-3) {original}


 end
end
```

Figure 8: *SDP net list of B*

By using these attractors generated from each circuit, and control the parameters such as step size and so on, characteristics of each circuit are expected to be reflected to each sound faithfully. The method is proposed by expressing each note waveform as

$$B(x) = f_b(x) + f_c(x) \tag{4}$$

where

$$f_b(x_b) = \frac{b_0}{2} + \sum_{i=1}^{m}(b_i \cos ix_b + \hat{b_i} \sin ix_b)$$

$$f_c(x_c) = \frac{c_0}{2} + \sum_{i=1}^{m}(c_i \cos ix_c + \hat{c_i} \sin ix_c).$$

$$m = 4096 \times 4 \tag{5}$$

$$x_b = 2\pi \check{f}_b t$$

$$x_c = 2\pi \check{f}_c t$$

Here, the coefficient b_i and $\hat{b_i}$ are selected appropriately to generate the basic form $1/f$ for note frequency as

$$\check{f}_b = 440.0 \times 2.0^{\frac{notenumber-69.0}{12.0}}, \tag{6}$$

The coefficient c$_i$,$\hat{c_i}$ are

$$c_i = \frac{1}{\pi}\int_{-\pi}^{\pi} g(t)\cos ix_c dt, (i = 0, 1, 2, 3, ...)$$
$$\hat{c_i} = \frac{1}{\pi}\int_{-\pi}^{\pi} g(t)\sin ix_c dt, (i = 1, 2, 3, ...) \tag{7}$$

can be derived by using FFT algorithm, for the circuit variable $g(t)$ from SDP.

3. Result

The created sounds are evaluated by listening them and frequency spectrum as follows. Figure 9 is the sound spectrum of Nishio circuit, and the Figure 10 is that of removed diodes from Nishio circuit. It can be described that the difference of the circuit's construction effects the way of sound fluctuation and the creation of harmonics. However in case of using the same original circuit, the created sounds are similar, because the frequency characteristics are also similar. Multi-oscillation mode can be generated, shown in the attractor of Figure 6 and the multi-frequency characteristic of Figure 10 for all cells with different capacitances and without diodes in the Nishio Circuit.

4. Conclusion

There are many types of attractor. Each attractor is generated from differential equations of a circuit which has many characteristic circuit frequencies. It is important to change the original circuit frequencies to sound frequencies from about 100Hz to 10000Hz by mapping virtually time step 2.26757E-5 corresponding to 44100Hz. It is found that multi-oscillation dynamics from a circuit including chaos are used to create new sounds because of having many frequencies.

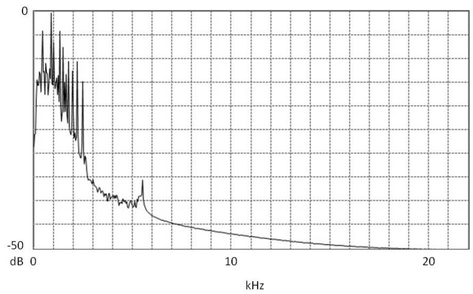

Figure 9: *Spectrum A*

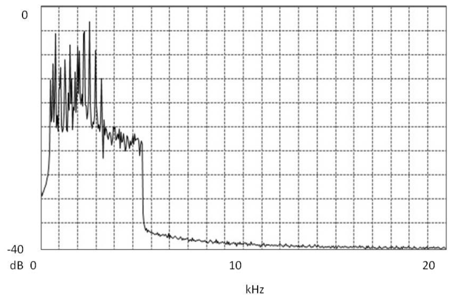

Figure 10: *Spectrum B*

References

[1] N. Fujii, M. Bandai, Y. Nishio and M. Tanaka, "Sound Creation Based on Different Chaos Attractors", RISP International Workshop on Nonlinear Circuits, Communications and Signal Processing NCSP'2014, Honolulu, Hawaii, USA. February 28 - March 3, 2014, pp.689-692.

[2] Y. Nishio and A. Ushida, "Chaotic Wandering and its Analysis in Simple Coupled Chaotic Circuits ", IEICE Transactions on Fundamentals, vol.E85-A, no.1, pp.248-255, Jan. 2002.

[3] N. Fujii, M. Bandai and M. Tanaka, "Sound Creation based on Several Chaos Attractors", IEEE Workshop on Nonlinear Circuit Networks, pp.55-58, December 12-13, 2014.