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Sound Creation Based on Different Chaos Attractors

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Abstract

This paper describes sound creation without signal processing but with nonlinear differential equations. Usually sound creation is realized by using signal processing. However to understand the signal processing completely is difficult for amature users. And the quality of sounds is artificial than the sounds of real instruments like grand pianos and violins. So the purpose of this research is to create more natural and artistic sounds. So as to consider about natural and artistic sounds, $1/f$ fluctuation is also important element. Sound that gives good feelings for human's ears includes kind of shaking. To realize that, using chaoses is so effective method. Then considering about to create various kinds of sound by using chaoses, it comes to necessary to think about frequency characteristics and other elements each chaos has.

1. Introduction

Music should be artistic. There are many kinds of electronic instrument like a synthesizer and those instruments have so many functions as modulation, delay, equalizer and so on. Those functions are usually realized based on signal processing. However actually, such sounds are quite different from those of traditional instruments as grand pianos, violins, drums and so on. Traditional instruments can express the feelings of players, because of these instrument's composition. For example piano has keys, strings and hammers, then they are connected. When a player strikes a key of a piano, the connected hammer strikes the corresponded strings. So, the delicate movement of fingers affects the quality of sounds as players emotions and skills. Violins or other string instruments are also same. In case of wind instruments, of course we can say the same thing. Player's breath affects the sound quality as their feelings. It is impossible for any musicians to play completely same nuance again. That is the art. So we want to realize such a real instrument.

In our previous research, by using the nonlinear differential equation, we succeeded to play the music. However the sound was generated from only sine waves so quality of that was like a electronic one. Then in order to make the sound to be more natural or artistic one, we tried to add kind of shaking. Kind of shaking can be realized by using chaos, since the chaos has various random frequencies. Therefore, it can be expected to work as moderate beats and make the better quality of sound.

By the emotion, sensitivity, something of feelings, or interpretation of the performer, the quality of sound changes. Then once a music has been performed, it is quite impossible to do the same performance again, even by the same person. When we pay attention to the waveform by signal processing, they contain several frequencies these are kind of harmonic overtone or so on. And the rate of each frequency also changes with the passing of time. Furthermore, as for amplitude of vibration, it's clearly changes. It means that if changes of frequency and amplitude of vibration were added to the basic sine wave, quality of sound and envelope will be changed, As a result, music comes to more artistic. This research is to create sound that is from non-linear differential equation, and to make the sound more artistic.

We would like to challenge to create the music based on the nonlinear differential equations without signal processing. Especially, each note sound should be generated from the chaos equations to insert the basic equation with the note frequency made by MIDI. The MIDI note frequencies and its time length are generated from the EXCEL. And in this research $1/f$ fluctuation is also important key point. There are many natural phenomena those are related $1/f$ fluctuation in the world. For example, the intervals of our heart's beating, tremor of candlelight, jolting of cars, the murmuring of a stream, the movement of the pupil of the eyes and so on. They came to be the strong hints in case of music and in this research.

2. Basic Equation

$$y[t] = (e^{\frac{-t}{length}} - e^{-1}) \times 2^{13} \times \sin 2\pi ft \quad (1)$$

By using this equation(1), sin waves of each note are created.

However to create it, frequencies of each note are needed. $'f'$ in the last of equation(1) means 'frequency'. frequencies of each note can be calculated by using other equation(2) as follows.

$$frequency = 440.0 \times 2.0^{\frac{notenumber-69.0}{12.0}} \quad (2)$$

The table.1 shows the relation between MIDI note number

and frequency that is result of the calculation.

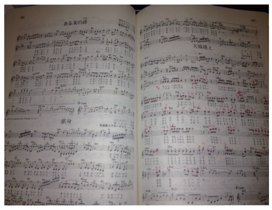
Table 1: Relation between notenumber and frequency

name of note	MIDI number	frequency
C	60	261.6256
C#/D♭	61	277.1826
D	62	293.6648
D#/E♭	63	311.1270
E	64	329.6276
F	65	349.2282
F#/G♭	66	369.9944
G	67	391.9954
G#/A♭	68	415.3047
A	69	440
A#/B♭	70	466.1638
B	71	493.8883
C	72	523.2511

MIDI note number is corresponding to each note and the frequency of each note is determined completely, for example the frequency of the middle A is determined to 440Hz like table.1. That enables to work as a score. The next section is the property of MIDI.

3. MIDI

First of all, information of songs must be input to the program. Usually players use the scores as follws photo.



In case of this research, MIDI information as follows plays the role of score.

Table 2: MIDI information

MIDI number	length
64	0.25
62	0.25
64	3.5
63	0.5
30000	3
64	0.25

Table 3: MIDI information in chord

MIDI number	64	62	64	30000
length	0.25	0.25	0.5	3
MIDI number	57		58	
MIDI number	55		56	
MIDI number	53		54	
MIDI number			52	
length	0.5		3.5	

The Table.2 is in case of single melody, and the Table.3 is in case of melody with chord. MIDI consists of both note number and its time length. Note number starts from 0 to 127. The lowest note of piano keys is note number 21 and the highest key is note number 108. So MIDI can cover a wide area of notes. It ' s the definition of note number. From inputting this MIDI information, simulation of this research starts. Each note number has its frequency, and the frequency is also based on temperament. What is temperament? You know, before orchestra starts the performance, they usually do tuning with the note of 'A' so, everyone possess in the same frequency. But as for piano, it's too difficult to do tuning in a short time. That's why turning of piano is finished based on a certain frequency previously. It's called "temperament". In case of piano, one key is corresponding to one hammer, and one hammer strikes several strings. The several strings are tuned to little different each other, for example the middle one is 440Hz, the right one is 442Hz, and the left one is 438Hz. That's reason why piano can play the correct tone without orchestra tuning. This idea came to the hint that we added the round frequency by using chaos.

4. $1/f$ Fluctuation

In this research, $1/f$ fluctuation is one of the important key words. After all, what is the $1/f$ fluctuation? the f of $1/f$ fluctuation means frequency, so it's so small value. It indicates the delicate changes in much small range. That can be discovered in natural phenomena. For example, the intervals of our heart's beating, tremor of candlelight, jolting of cars, the murmuring of a stream, the movement of the pupil of the eyes and so on. Recently $1/f$ fluctuation is said to cause the phenomenon that strawberry grown with Mozart music tastes good. As for music, $1/f$ fluctuation is the most important element. The emotion, sensitivity of performer are the point what people feel comfortable. In other words, by means of that irregular movements are mixed to regular movement, we cannot expect the next movement or something of law, it gives good feelings for human's ears. In this research, we are expecting that chaos can work as $1/f$ fluctuation.

5. Circuits and Chaoses

In this research two kinds of chaos are used, Nishio chaos and Lorenz chaos. Both chaoses have characteristic shape of attractor. In case of Nishio attractor, it has smooth ring shape. Compared to that, the shape of Lorenz attractor is like a butterfly. Figure.1 and Figure.2 are the attractors of each chaos. The following equation is Formalized Nishio circuit equation.

$$\begin{cases} \frac{dx_k}{d\tau} = \beta(x_k + y_k) - z_k - \gamma \sum_{j=1}^{4} x_j \\ \frac{dy_k}{d\tau} = \alpha\beta(x_k + y_k) - z_k - f(y_k) \\ \frac{dz_k}{d\tau} = x_k + y_k \\ (k = 1, 2, 3, 4) \end{cases}$$

where

$$f(y_k) = 0.5(\delta y_k + 1 - |\delta y_k - 1|)$$

Formalized Nishio circuit equation

And the equation of Lorenz is as follows.

$$\begin{cases} \frac{dx}{dt} = -px + py \\ \frac{dy}{dt} = -xz + rx - y \\ \frac{dz}{dt} = xy - bz \\ p = 10.0 \quad r = 28.0 \quad b = \frac{8.0}{3.0} \end{cases}$$

Lorenz circuit equation

Following figure.1 is the ring attractor generated from nishio circuit.

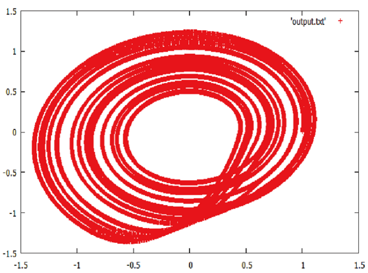


Figure 1: Nishio attractor

And the figure.2 is the attractor generated from Lorenz equation.

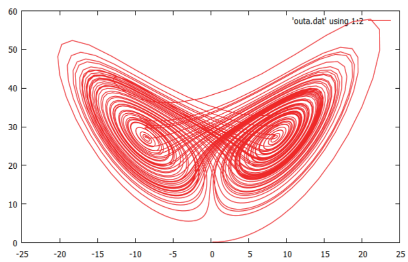


Figure 2: Lorenz attractor

Figure.3 is the circuit model of Formalized Nishio circuit.

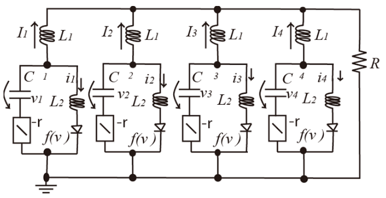


Figure 3: Modified Nishio Circuit model

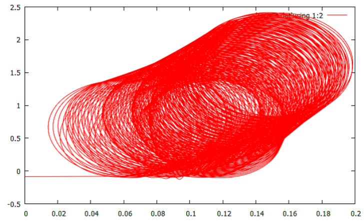


Figure 5: Nishio attractor parameter changed

6. Simmulation and Result

To create various kinds of sound by using several chaoses is very difficult. In case of Nishio chaos and Lorenz chaos, the shape of attractors is different completely. But as for the frequency characteristics of both chaoses, it can be thought that they are similar. So to change the sound within the range that human can recognize the difference is difficult. In case of only Nishio chaos, by changing the parameters for example as figure 4, it is possible to create different sounds.

```
Circuit Nishio↓
 Input↓
  Vdd=5↓
  G=0↓
  Vin=0↓
 end↓
↓
Macro osc1(in,out)↓
branch↓
  L(in,2,3,G;10.31E-12)↓
 {FUNC(2,out;"0.00000000252*(EXP(v/0.026)-1")}↓
 {D(2,out,G;id=2.52e-12;cac=1e-6)}  {Its OK}↓
 {C(2,out;1E-6)} [ if there is C, Jump]↓
  FUNC(2,out;"2.52E-12*(EXP(v/0.026)-1")↓
  {FUNC(2,out;"2/(1+EXP(-v))-1")}↓
  C(in,1;34.9E-12)  ↓
  PWL(1,out;-0.002994)  {original=-0.002994, -334ohm}↓
  {R(in,1;-8.0)}↓
 end↓
end↓
↓
branch↓
  osc1(2,G)↓
  osc1(3,G)↓
  osc1(4,G)↓
  osc1(5,G)↓
  R(1,G;26.2378)↓
  {R(1,G;0.000001)}↓
  L(1,2,6,G;1.7E-12)↓
  L(1,3,7,G;1.7E-12)↓
  L(1,4,8,G;1.7E-12)↓
  L(1,5,9,G;1.7E-12)↓
↓
 end↓
end[EOF]
```

Figure 4: parameter code

The following figure.5 is the attractor that was generated from parameter changed Nishio circuit. Ring attractor changed to shell shape attractor, and the sound also changed.

7. Conclusion

The difference between sounds of different chaoses depends on several elements as the envelope waveform, characteristics of each chaos has and so on. However by changing the parameters of circuit, to create various kinds of sound can be realized. We expect that to create more various kinds of sound by considering several elements each chaos has. Moreover by mixing several chaoses, the possibility of sound creation will be growing.

References

[1] 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.