New approach of global environmental data expression using "Bridge" ~Data conversion software of Time-series data to MIDI data~

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Abstract

This research presents an idea of expression with time-series data for detecting invisible information by utilizing musical sense of human. In this paper, we have tried to find some relationships between 2 kinds of time-series data. Both data relates environmental data about CO_2 emissions. For now, we had met a situation that we need to deal a lot of information at the same time. Not only that, we also need to find some relationships between these data to find important things; i.e. relationships between amount of CO_2 emission, economic growth of a developing countries, frequency of terrorism. We have confirmed that Bridge can use for any kinds of time-series data for musical expression and have some possibility for data mining. By utilizing human sense of musical expression a perception ability, we set a hypothesis that human can detect some relationships which are hidden in time-series data. We had added some new control section on this new version of software. And these functions on this software are expected for acquiring more flexibility in future.

Keywords: Music psychology; Acoustic psychology; sonification; Max/MSP; Digital Signal Processing

INTRODUCTION

In this research, we have used environmental data that relate to one of an environmental problem. Environmental problem itself contains lots kind of issue. For example, global warming relates to mainly CO_2 emission. CO_2 emission relates to population increasing, air pollution, human daily activities…etc. The factor of air pollution, it has been occurred by chemical substances that come from each country all over the world. Not only that, deforestation is also deeply connected to the problem. Increasing population all the world relates the problem as other factor.

As we have explained, even single phenomena of global environmental problem have many factors from global to domestic issue. So we need to be tense to detect even a little difference of many kinds of data that seemed to be relating to actual environmental problem. These kind of research that use variety of time-series data will become more difficult to identify relationships of numbers of each factor data. Because of data amounts increase by technical advances; sensor improvements, advances of big data.

We have used sonification method [1]. And there are many researches of data analysis method using sound. However, we couldn't find any researches of re-sampling time-series data to musical scale data for analysis. From the view of music analysis, we have a lot of researches using such as MFCCs (Mel Frequency Cepstrul Co-efficients). We tried to analyze multi dimensional data as music and analyze it using human sense. [2,3] Our approach is different from previous research of sonification works which use noise or non-musical scale pitch. [4,5,6]

As a solution way, we have developed software which name is "Bridge". [7] It enables users who want to express their data more easy understanding (we call them "composer"). We set an approach way of the data expression as audio. Our ears have ability to detect different pitch and melody at the same time. And also we can detect repetition of melody. Controlling random time-series data is very difficult to compose melodic music. To solve the problem, we set some parameter to convert random data to melodic MIDI data. For example, by using the function, composers can easy to use time-series data that contains random data to express relationship of different kinds of data. The details of the conversion algorithm will be discussed in following section on this paper. (Shunsuke Hananoi, 2016).

SOFTWARE ARCHITECTURE

Our software has brief 4 sections to convert time-series data to MIDI file with simple interface [Fig 1, Fig 2].

1. Import file which users want to convert to MIDI data
2. Managing extraction functions
3. Conversion
4. Export as MIDI data

We have added new function about MIDI control system that has added in part 3. We will introduce it and the other functions in following context in this paper.

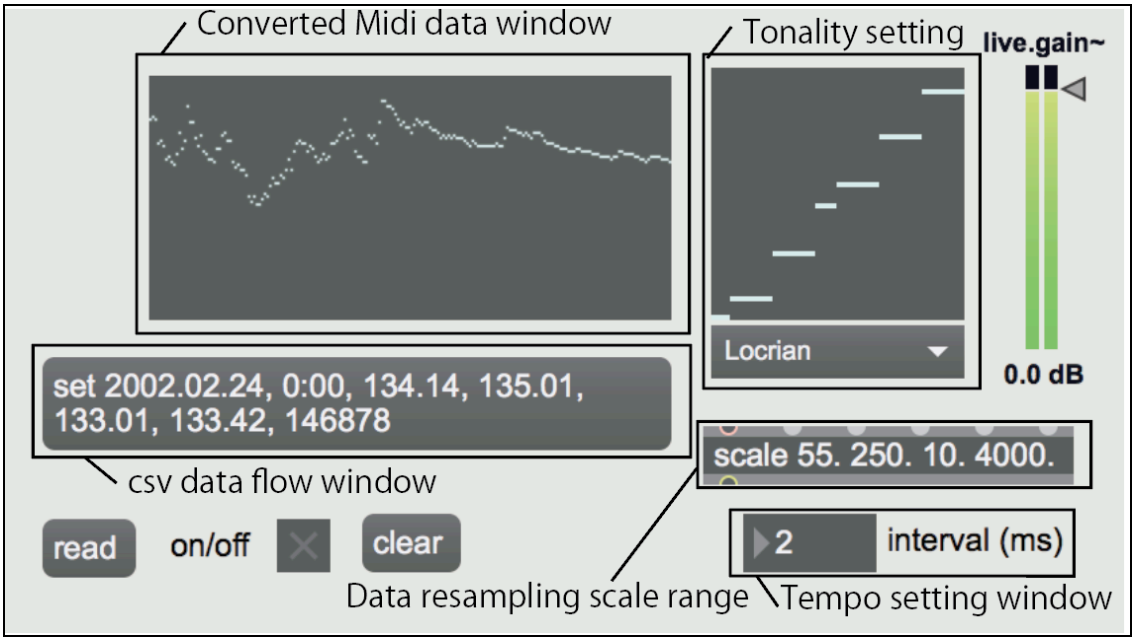


Figure-1. Software Interface of "Bridge" version 0.1

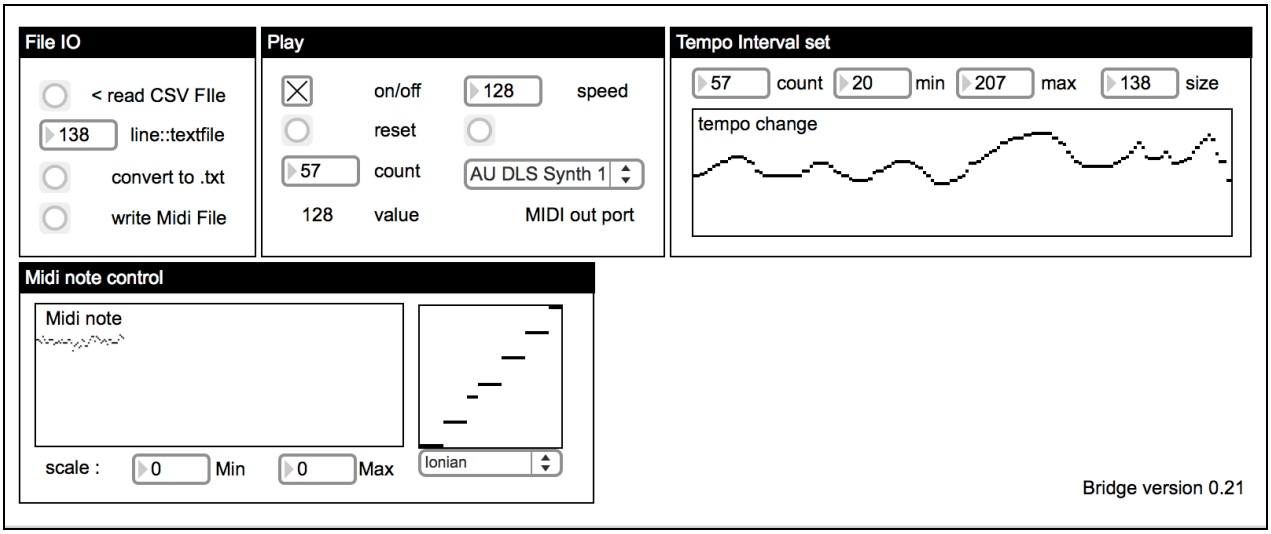


Figure-2. Software Interface of "Bridge" version 0.21

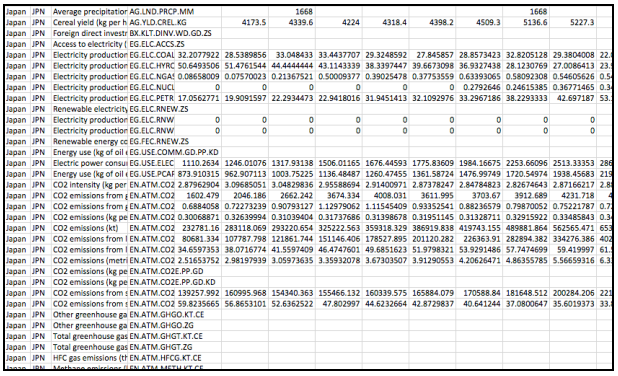
FILE CONTROL INSTRUCTION

This software requires data file (i.e. CSV file). And its data need to be arranged properly. In this paper, we use monthly CO_2 emission data for the instruction of this software usage steps. We will introduce how to control and adjust example CSV data to proper data.

1. Choose a duration of data conversion
2. Delete all data which you don't need to use
3. Import your data to Bridge
4. Confirm data expression and modify it

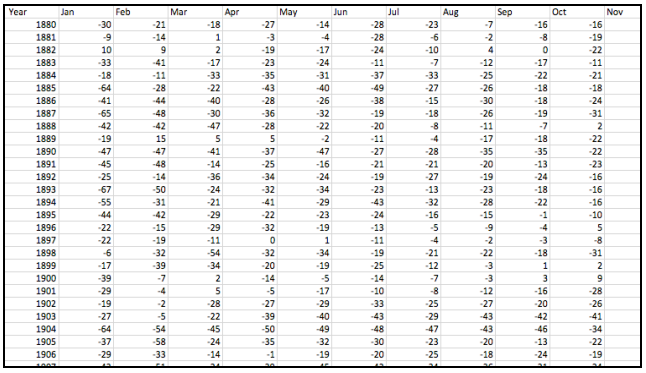
1. Choose time duration of data

This software can convert time-series data but cannot control duration yet. We will add functions in future but we have still been not able to control data structure on present version yet. We use 2 data in this research. CO_2 emission amount [8] and surface air temperature data [9]. Their data structures are totally different. [Fig 3, Fig 4]



Japan	JPN	Average precipitation	AG.LND.PRCP.MM		1668				1668	
Japan	JPN	Cereal yield (kg per h	AG.YLD.CREL.KG	4173.5	4339.6	4224	4318.4	4398.2	4509.3	5136.6	5227.3
Japan	JPN	Foreign direct investr	BX.KLT.DINV.WD.GD.ZS								
Japan	JPN	Access to electricity (	EG.ELC.ACCS.ZS								
Japan	JPN	Electricity production	EG.ELC.COAL	32.2077922	28.5389856	33.048433	33.4437707	29.3248592	27.845857	28.8573423	32.8205128	29.3804008	22.6
Japan	JPN	Electricity production	EG.ELC.HYRC	50.6493506	51.4761544	44.4444444	43.1143339	38.3397447	39.6673098	36.9327438	28.1230769	27.0086413	23.1
Japan	JPN	Electricity production	EG.ELC.NGAS	0.08658009	0.07570023	0.21367521	0.50009377	0.39025478	0.37753559	0.63393065	0.58092308	0.54605626	0.54
Japan	JPN	Electricity production	EG.ELC.NUCL	0	0	0	0	0	0	0.2792646	0.24615385	0.36771465	0.34
Japan	JPN	Electricity production	EG.ELC.PETR	17.0562771	19.9091597	22.2934473	22.9418016	31.9451413	32.1092976	33.2967186	38.2293333	42.697187	53.1
Japan	JPN	Renewable electricity	EG.ELC.RNEW.ZS										
Japan	JPN	Electricity production	EG.ELC.RNW	0	0	0	0	0	0	0	0	0	
Japan	JPN	Electricity production	EG.ELC.RNW	0	0	0	0	0	0	0	0	0	
Japan	JPN	Renewable energy co	EG.FEC.RNEW.ZS										
Japan	JPN	Energy use (kg of oil e	EG.USE.COMM.GD.PP.KD										
Japan	JPN	Electric power consu	EG.USE.ELEC	1110.2634	1246.01076	1317.93138	1506.01165	1676.44593	1775.83609	1984.16675	2253.66096	2513.33353	286
Japan	JPN	Energy use (kg of oil e	EG.USE.PCAP	873.910315	962.907113	1003.75225	1136.48487	1260.47455	1361.58724	1476.99749	1720.54974	1938.45683	219
Japan	JPN	CO2 intensity (kg per	EN.ATM.CO2	2.87962904	3.09685051	3.04829836	2.95588694	2.91400971	2.87378247	2.84784823	2.82674643	2.87166217	2.8
Japan	JPN	CO2 emissions from g	EN.ATM.CO2	1602.479	2046.186	2662.242	3674.334	4008.031	3611.995	3703.67	3912.689	4231.718	4
Japan	JPN	CO2 emissions from g	EN.ATM.CO2	0.6884058	0.72273239	0.90793127	1.12979062	1.11545409	0.93352541	0.88236579	0.79870052	0.75221787	0.7
Japan	JPN	CO2 emissions (kg pe	EN.ATM.CO2	0.30068871	0.32639994	0.31039404	0.31737686	0.31398678	0.31951145	0.31328711	0.32915922	0.33485843	0.3
Japan	JPN	CO2 emissions (kt)	EN.ATM.CO2	232781.16	283118.069	293220.654	325222.563	359318.329	386919.838	419743.155	489881.864	562565.471	653
Japan	JPN	CO2 emissions from l	EN.ATM.CO2	80681.334	107787.798	121861.744	151146.406	178527.895	201120.282	226363.91	282894.382	334276.386	402
Japan	JPN	CO2 emissions from l	EN.ATM.CO2	34.6597353	38.0716774	41.5597409	46.4747601	49.6851623	51.9798321	53.9291486	57.7474699	59.419997	61.1
Japan	JPN	CO2 emissions (metri	EN.ATM.CO2	2.51653752	2.98197939	3.05973635	3.35932078	3.67303507	3.91290553	4.20626471	4.86355785	5.56659316	6.3
Japan	JPN	CO2 emissions (kg pe	EN.ATM.CO2E.PP.GD										
Japan	JPN	CO2 emissions (kg pe	EN.ATM.CO2E.PP.GD.KD										
Japan	JPN	CO2 emissions from s	EN.ATM.CO2	139257.992	160995.968	154340.363	155466.132	160339.575	165884.079	170588.84	181648.512	200284.206	221
Japan	JPN	CO2 emissions from s	EN.ATM.CO2	59.8235665	56.8653101	52.6362522	47.802997	44.6232664	42.8729837	40.641244	37.0800647	35.6019373	33.8
Japan	JPN	Other greenhouse ga	EN.ATM.GHGO.KT.CE										
Japan	JPN	Other greenhouse ga	EN.ATM.GHGO.ZG										
Japan	JPN	Total greenhouse gas	EN.ATM.GHGT.KT.CE										
Japan	JPN	Total greenhouse gas	EN.ATM.GHGT.ZG										
Japan	JPN	HFC gas emissions (tl	EN.ATM.HFCG.KT.CE										
Japan	JPN	Methane emissions (t	EN.ATM.METH.KT.CE										

Figure-3. CO_2 emission data structure

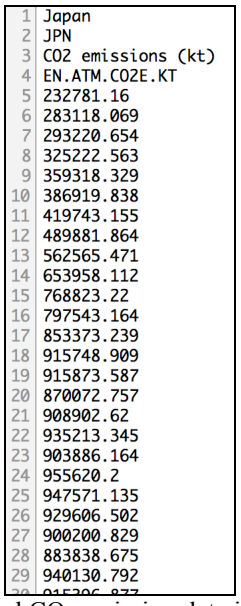


Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1880	-30	-21	-18	-27	-14	-28	-23	-7	-16	-16	
1881	-9	-14	1	-3	-4	-28	-6	-2	-8	-19	
1882	10	9	2	-19	-17	-24	-10	4	0	-22	
1883	-33	-41	-17	-23	-24	-11	-7	-12	-17	-11	
1884	-18	-11	-33	-35	-31	-37	-33	-25	-22	-21	
1885	-64	-28	-22	-43	-40	-49	-27	-26	-18	-18	
1886	-41	-44	-40	-28	-26	-38	-15	-30	-18	-24	
1887	-65	-48	-30	-36	-32	-19	-18	-26	-19	-31	
1888	-42	-42	-47	-28	-22	-20	-8	-11	-7	2	
1889	-19	15	5	5	-2	-11	-4	-17	-18	-22	
1890	-47	-47	-41	-37	-47	-27	-28	-35	-35	-22	
1891	-45	-48	-14	-25	-16	-21	-21	-20	-13	-23	
1892	-25	-14	-36	-34	-24	-19	-27	-19	-24	-16	
1893	-67	-50	-24	-32	-34	-23	-13	-23	-18	-16	
1894	-55	-31	-21	-41	-29	-43	-32	-28	-22	-16	
1895	-44	-42	-29	-22	-23	-24	-16	-15	-1	-10	
1896	-22	-15	-29	-32	-19	-13	-5	-9	-4	5	
1897	-22	-19	-11	0	1	-11	-4	-2	-3	-8	
1898	-6	-32	-54	-32	-34	-19	-21	-22	-18	-31	
1899	-17	-39	-34	-20	-19	-25	-12	-3	1	2	
1900	-39	-7	2	-14	-5	-14	-7	-3	3	9	
1901	-29	-4	5	-5	-17	-10	-8	-12	-16	-28	
1902	-19	-2	-28	-27	-29	-33	-25	-27	-20	-26	
1903	-27	-5	-22	-39	-40	-43	-29	-43	-42	-41	
1904	-64	-54	-45	-50	-49	-48	-47	-43	-46	-34	
1905	-37	-58	-24	-35	-32	-30	-23	-20	-13	-22	
1906	-29	-33	-14	-1	-19	-20	-25	-18	-24	-19	

Figure-4. Surface air temperature data structure

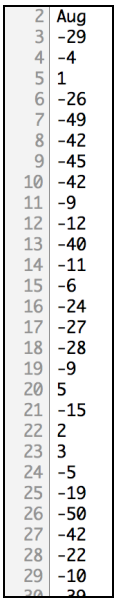
2. Delete all data which you don't need to use

After selection of data, we need to modify the data structure for proper conversion. In this case, we delete some matrix from the raw data. By correcting each data correctly, we can express the relationship of each data. We adjust start and end of the duration of data [Fig 5, Fig 6].



```
Japan
JPN
CO2 emissions (kt)
EN.ATM.CO2E.KT
232781.16
283118.069
293220.654
325222.563
359318.329
386919.838
419743.155
489881.864
562565.471
653958.112
768823.22
797543.164
853373.239
915748.909
915873.587
870072.757
908902.62
935213.345
903886.164
955620.2
947571.135
929606.502
900200.829
883838.675
940130.792
```

Figure-5. Modified CO_2 emission data in Japan structure



```
Aug
-29
-4
1
-26
-49
-42
-45
-42
-9
-12
-40
-11
-6
-24
-27
-28
-9
5
-15
2
3
-5
-19
-50
-42
-22
-10
```

Figure-6. Modified Surface air temperature data structure

3. Import your data to Bridge

After modifying your data, we can input it to Bridge. Bridge can convert the data to MIDI data. Normally, the data conversion is processed as same duration between each note. However, composer can change its rhythm in real-time if composer want to change the tempo dynamically. [Fig 5] This software use mainly csv file to create MIDI data. The processing algorithm is very simple.[Fig 7] In this paper, we used CO_2 emission data and surface air temperature data.

4. Confirm data expression and modify it in other software

This software doesn't have any function that likes digital audio workstation. For example, if composer want to add original sound or effect to each note, composer need to use other software: such as digital audio workstation. In this research, we have used DAW software name "Pro Tools" (developed by "AVID") and "Live" (developed by "Ableton"). These software are often used in a field of computer music.

The length of MIDI notes express not length. And lower position of note means low frequency note and higher position is vice versa.

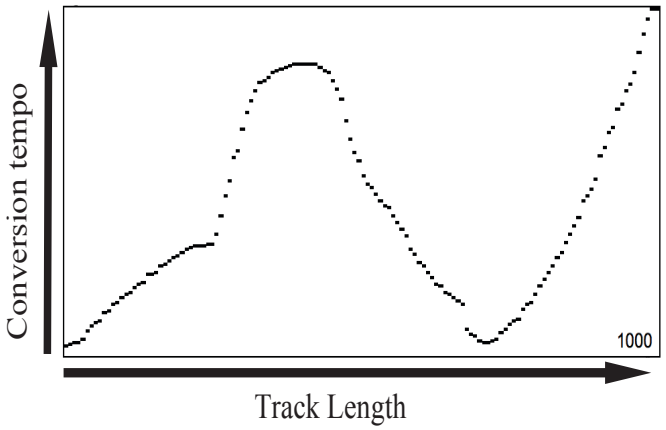


Figure-5. Real-time tempo change part

Midi $= f(\mathcal{D}, P1, P2, P3, P4)\ \{$

$\mathcal{D}$: csv

P1 = minimum csv parametr

P2 = max csv parameter

P3 = minimum frequency value

P4 = max frequency value

$\}$

Figure-6. Processing Algorithm

EXPERIMENT

We have experimented this software to express environmental data as audio. In this research, we have used CO_2 emission data and surface temperature data on earth. We have tried to express these two kinds of data as MIDI note. (As we have shown in Figure-4) And we have tried to find invisible information behind the data between them.

We have confirmed how the data reliability was changed from csv data file to MIDI file.

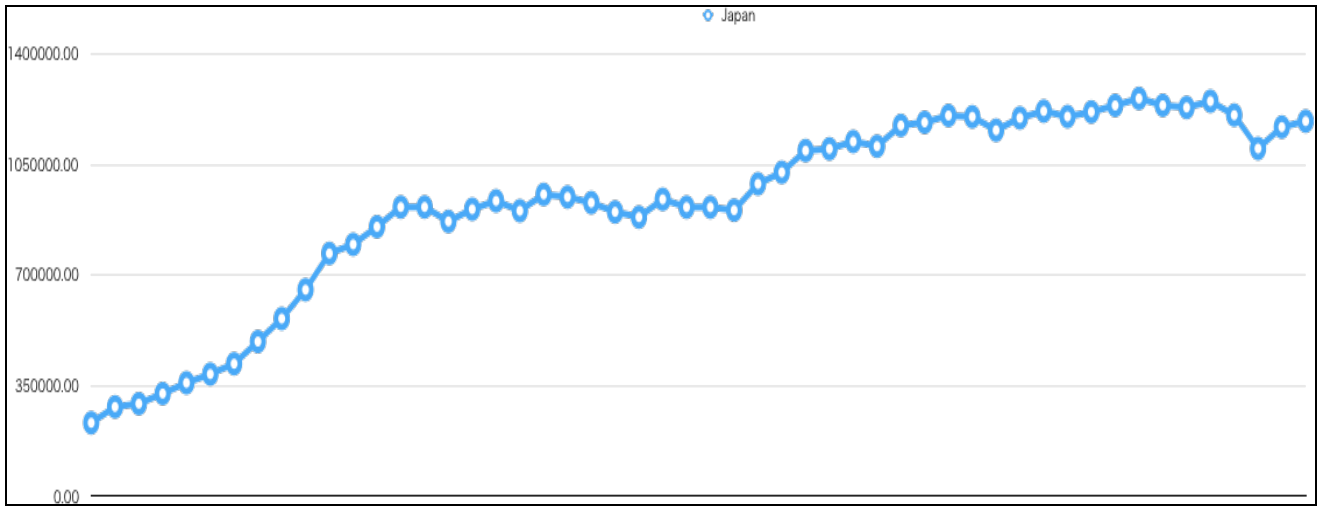


Figure-8. CO_2 emission data in Japan 2D graph

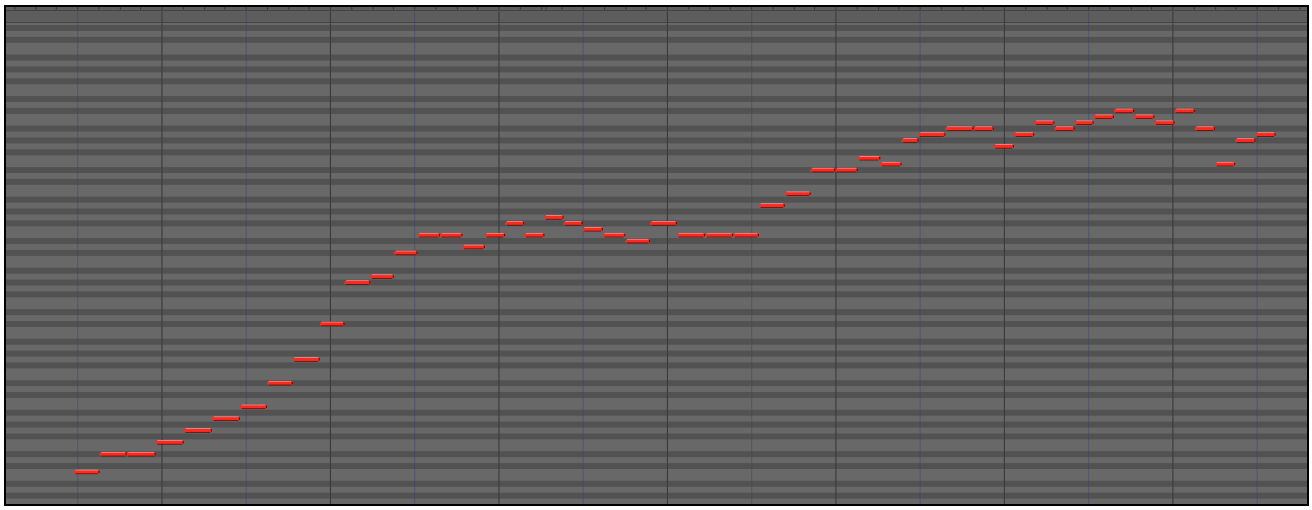


Figure-7. CO_2 emission data in Japan in MIDI data

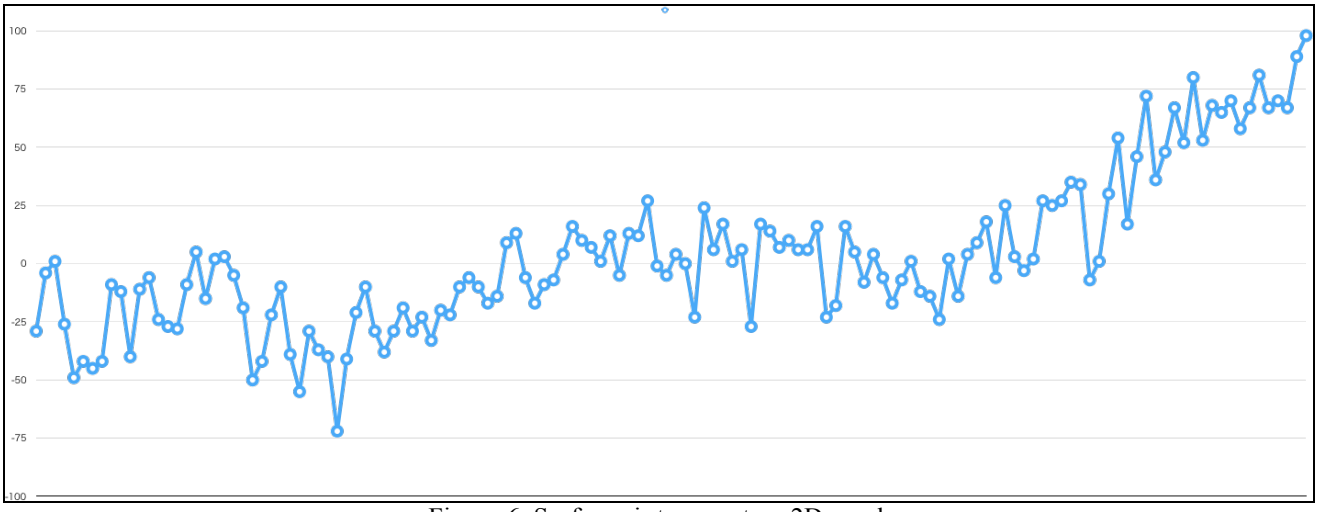


Figure-6. Surface air temperature 2D graph

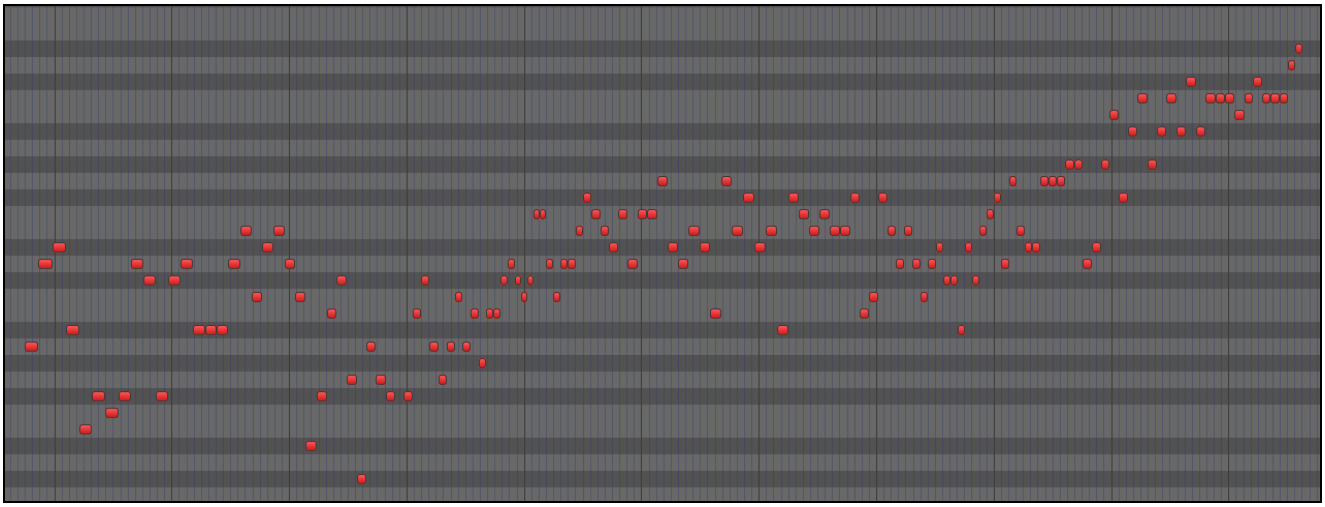


Figure-7. Modified Surface air temperature in MIDI data

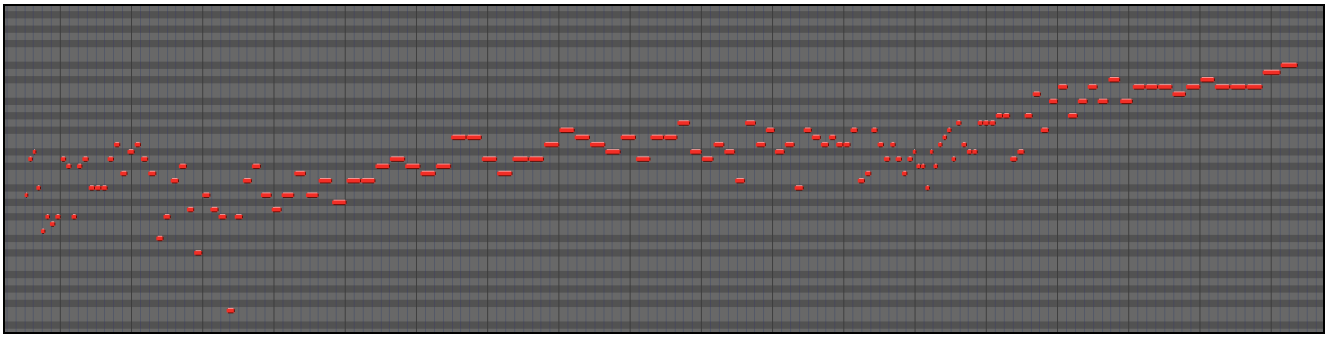


Figure-8. Modified Surface air temperature in MIDI data, tempo modified

As new function, we added tempo modifier. Comparing Figure-7 and Figure-8, these two MIDI data is generated same csv data but tempo is different. This function is just a trial but will be used as recognition control.

This approach of data conversion is based on an idea of sonification. And main topic of this approach is change the view of analysis from random numbers of time series data to musical time-series MIDI data. It means, we can use musical analysis method to analyze big data. Musical analysis methods have already researched in many ways. However, the combination of these two methods for analysis is new. The point of discussion is potential of this software for research. To extend the potential, some researchers use MFCCs or other statistical methods.

After conversion, we put these 2 data to DAW. [Figure-8] And listen the data in a song. These 2 data has same features. Both pitches go high. We should have prepared more dimensions of data. In next research, we will prepare at least 4 to 5 data in a song.

CONCLUSION

We have confirmed possibility of our new function in Bridge. This research is for finding possibility of multi-dimension data analysis. We will meet more data from lots kinds of sensors, satellites and other devices or services in future. Bridge enables to combine them and find their relationships using human musical sense. For now, we only can convert time-series data to MIDI. We need to set some evaluation method for this software.

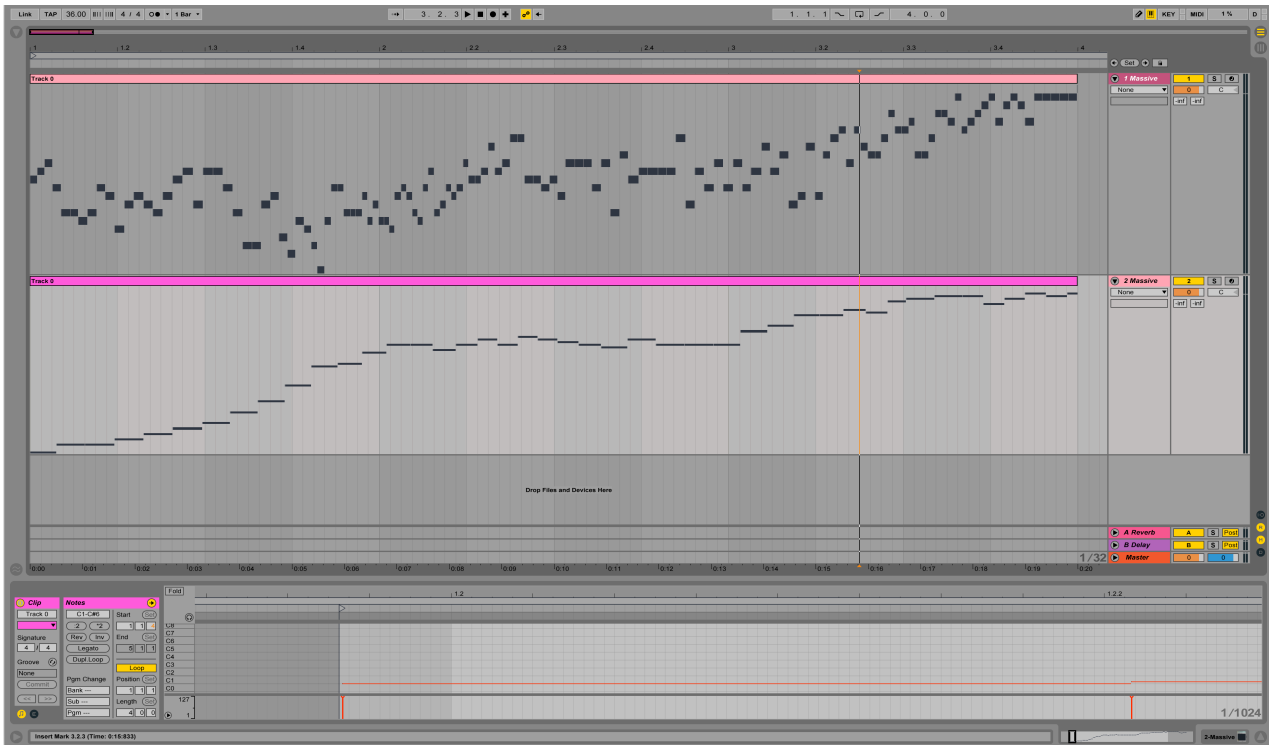


Figure-8. MIDI data in DAW (Ableton live)

FUTURE WORKS

In this research, we have tried to express time-series data that relate to global warming to find their relationships using new MIDI conversion feature. This approach that is combination of analysis and recognition is just started. So we have many things to confirm such as software usability, aspect of psychology and recognition, definition of invisible information, point of strength and weakness etc.

We will analyze how affect this software for composers when they want to use time-series data in future research. Also, we will discuss the analysis algorithms that used in music analysis. [11,12]

For now, this software can use for static data only. We now are developing software for real-time conversion. We will present about it in future paper.

REFERENCES

[1] Thomas Hermann, Andy Hunt, John G. Neuhoff, "The Sonification Handbook", Logos Verlag Berlin GmbH, ISBN 978-3-8325-2819-5, pp.29-52, 2011.

[2] Sahidullah, Md, and Goutam Saha. "Design, analysis and experimental evaluation of block based transformation in MFCC computation for speaker recognition." *Speech Communication* 54.4 (2012): 543-565.

[3] Ittichaichareon, Chadawan, Siwat Suksri, and Thaweesak Yingthawornsuk. "Speech recognition using MFCC." *International Conference on Computer Graphics, Simulation and Modeling (ICGSM'2012) July*. 2012.

[4] Janata, Petr, and Edward Childs. "Marketbuzz: Sonification of real-time financial data." 2004.

[5] Kramer, Gregory, et al. "Sonification report: Status of the field and research agenda." 2010.

[6] Hermann, Thomas, and Andy Hunt. "An introduction to interactive sonification."*IEEE multimedia* pp20-24, 2005.

[7] Shunsuke Hananoi, Kazuki Muraoka, Yasushi Kiyoki, "A music composition system with time-series data for sound design in next-generation sonification environment", International Electronics Symposium (IES) 2016

[8] The World Bank, CO2 emissions (metric tons per capita), http://data.worldbank.org/indicator/EN.ATM.CO2E.PC

[9] GISS Surface Temperature Analysis (GISTEMP), National Aeronautics and Space Administration Goddard Institute for Space Studies, http://data.giss.nasa.gov/gistemp/

[10] Wu, Zhaohua, and Norden E. Huang. "Ensemble empirical mode decomposition: a noise-assisted data analysis method." *Advances in adaptive data analysis* 1.01, 1-41, 2009

[11] Arnold Schoenberg, "Fundamentals of Musical Composition", ISBN978-4276106208, 1998

[12] Krumhansl, Carol L. "The psychological representation of musical pitch in a tonal context." *Cognitive Psychology* 11.3, pp346-374,1979.

A music composition system with time-series data for sound design in next-generation sonification environment

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***Abstract*— This research suggests an idea of synthesizing time series data and human sense. This software can help human to know environmental invisible changes that human cannot detect. Player can use time series data for music composition. We have already had a way of sonification as relating research. However, this research aims having more flexibility in composition. For the motivation, we set player flexibility as tonality editing and data conversion range control system. In our software, player can edit melody and its range of sampling. For example, if composer want to express data as bright atmosphere music, you can edit some settings in the tool and play it. We have tried to use this software to use foreign exchange data. In future work, we try to use this software in virtual reality. And we will test the listener recognition change.**

Keywords—Music psychology; Acoustic psychology; sonification; Max/MSP; Digital Signal Processing:

I. INTRODUCTION

Nowadays, Virtual Reality (VR) becomes popular keyword in academic and industrial fields, and there are many researches in these fields. In VR researches, it is important to focus on the relationship between human recognition and the sound from environmental information surrounding human. However, there are still a few expression methods with audio and data communication. Some researchers define the rules of musical expression using time series data called "sonification". "Sonification is the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation"[1]. [Sonification is the use of non-speech audio to convey information or perceptual data. Auditory perception has advantages in temporal, spatial, amplitude, and frequency resolution that open possibilities as an alternative or complement to visualization techniques. By Wiki]. These researchers in the field of sonification have discussed the topics about how we notice daily changes of our surroundings and their conversion to audio. Though, it is not enough to discuss what music or sound creator/editor can do and their possibility in this new field. Of course, the quality of the created music or sound depends on the composers' abilities, ideas and inspirations. So we should also think about the usability of the software interface to realize their ideas, not to kill their ideas. Because the most of the composers still use digital audio workstation (DAW) for their composition or designing sound, the software should export data as controllable format to DAW use. Also, we have not been able to imagine the next generation expression in the unchanged situation yet. Sonification is a good way for the definition of sound to show the possibility. So, we have adopted the idea and make system that can convert csv data to MIDI data for composition. This research objective is utilizing human sense of music. Past researches that use sound to analyze big data are not focused on utilizing composition methods.[2] We have tried to realize combine research fields of art and analysis using re-sampled musical sound scale.

II. FEATURES OF THE SYSTEM

This system produces a very simple solution for composers. They do not need to think about any programming ideas. We have focused on using tonality for simple way to express random data as musical data. This trial aims to provide a fast and simple solution for composers.

Generally speaking, composers do not always have knowledge about music or acoustic psychology. However, they know how tonality sounds. So, the composition created by this system is based on a tonality control. This idea is suit for not only for normal usage of composition but also for 3D or multi channel. This system outputs MIDI data from csv files. From the view of the system, this is very flexible for composer because they can edit the detail of the data after conversion from the time-series data to MIDI data. This system aims to realize composition freedom with limited data control.

The feature of this system is that the grasping of the data is not critical. In the related researches, some researchers grasp financial data with sonification [3]. The other research mentions the three topics [4].

a) Psychological research in perception and cognition
b) Development of sonification tools for research and application
c) Sonification design and application.

Recent researches in sonification, especially the definition of interactive sonification, are described as followings, "*The use of sound within a tightly closed human–computer interface where the auditory signal provides information about data under analysis, or about the interaction itself, which is useful for refining the activity* "[5].

Still, the problems that needed to be improved are remained. We need to handle a lot of data at the same time. How do we express the massive data in one song? We set a merit of this system as a tool to answer the question in the followings.

a) A way of expression using many kinds of data and a way of finding their relationships.

b) Expression of relationship of multi data that have big difference of absolute value.

c) Expression of large numbers of data and their relationship.

About improvements of these contents, many researchers express these data by 2D graph, 3D graph or liner graph to logarithm graph etc. This system provides a solution as a tool for composition. As commonly known, human ear can do FFT Fast Fourier transform) when they are listening sounds. So we have tried to combine musical composition methods and sonification methods through this software.

III. System Architecture

This system uses Max/MSP which is a programming environment developed by a company called Cycling 74'. This is a commercial software but the user can download application runtime from company website. So everyone can use this application for free.

This system is a useful tool either for a person who has or who does not have enough composition skills and the knowledge of composition methods. The system uses time series data for composition, so that composer can create the music without the methods as they normally use when they compose music [6]. The objective of this system is to find the ways of composition using time-series data. By limiting the way of composition method, composer can concentrate the way of expression using the data.

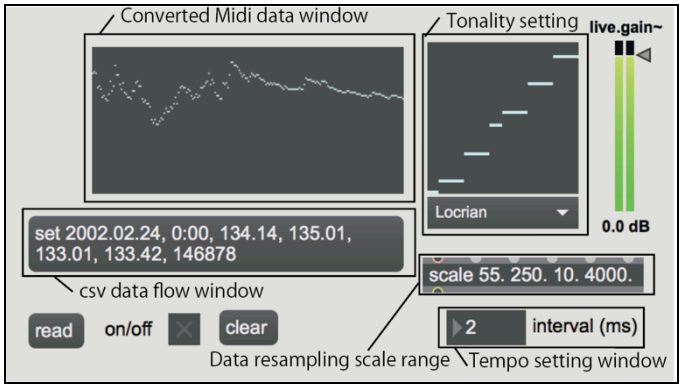

Figure 1. Screen-Capture from the Prototype System

We aim to realize user-friendly software design by simplify. Not to decline composer's idea during switching or changing parameters of each functions.

In this implementation, we used foreign exchange (FX) data for composition because the data have time information and clear to understand what they are. And, we have used cross JPY data. It means that the work shows the FX movement view from Japan. The process is shown in Figure 2. There are so many kinds of research about pitch of sound in the field of music composition and analysis. For example, a research of musical pitches in a tonal context [7], associations of sound and light [8] or basic research about human ability of pitch recognition. We have utilized these research results as the knowledge of composition methods in this system and implement as software. We explain the details of the architecture as followings.

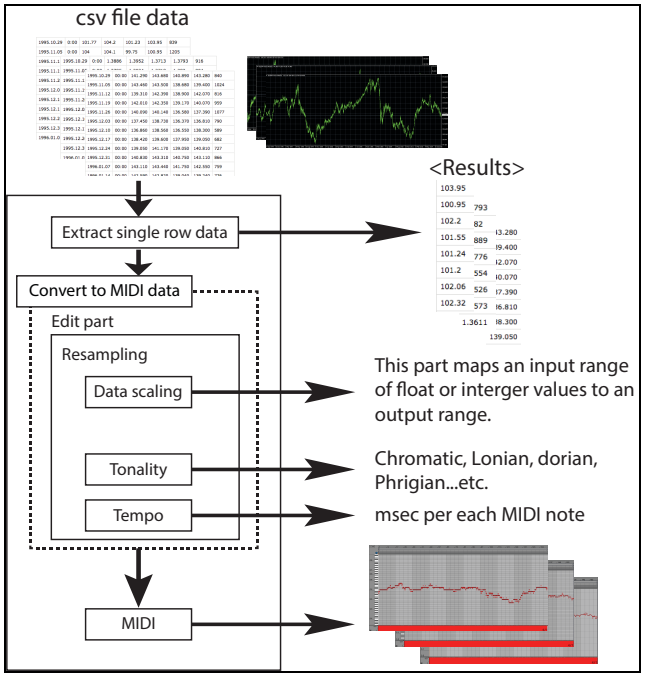

Figure 2. Overview of the System architecture

A. *Converstion Architecture*

This system creates MIDI data from time series .csv format data. The flow of data conversion of the time series data to MIDI data using foreign exchange data is described as bellows.

1. Prepare .csv data and import to this software. The data don't have to be separated to individual data series. (Time, Date, Price…etc.)
2. Separate csv data cells into single information data cell that defines by composer.
3. Rewrite these data into new single row csv file.
4. Convert the file (step.3) into MIDI file. Users can edit the tempo, tonality and length of MIDI data.

In this paper, we have used foreign exchange data for this software as sample case (Figure 3). This data has many types of information. As example, I have chosen the closing price for conversion (Figure 4).

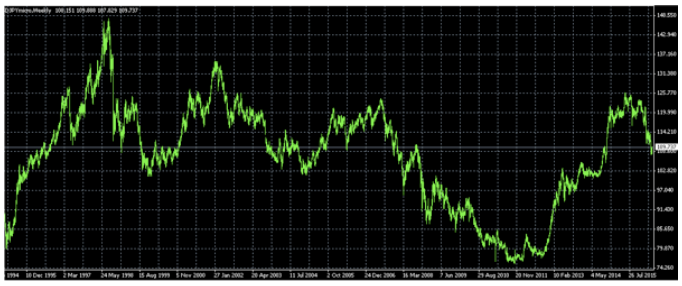

Figure 3. Sample trading file of foreign exchange (USD/YEN monthly)

1995.10.29	0:00	101.77	104.2	101.23	103.95	839
1995.11.05	0:00	104	104.1	99.75	100.95	1205
1995.11.12	0:00	100.75	102.5	100.08	102.2	1026
1995.11.19	0:00	102.11	102.85	100.4	101.55	911
1995.11.26	0:00	101.63	102.35	100.83	101.24	853
1995.12.03	0:00	101.35	101.75	100.5	101.2	723
1995.12.10	0:00	101.14	102.35	100.68	102.06	621
1995.12.17	0:00	101.9	102.92	101.3	102.32	554
1995.12.24	0:00	102.43	103.6	102.04	103.54	579
1995.12.31	0:00	103.41	106.63	103.07	105.44	875
1996.01.07	0:00	105.53	105.83	104.08	105.3	778
1996.01.14	0:00	105.31	106.31	104.8	105.41	714

Figure 4. Sample csv file of foreign exchange (USD/YEN monthly)

After importing data, this software extracts single row csv data (Figure 5) where user wants to place it.

103.95000
100.95000
102.20000
101.55000
101.24000
101.20000

Figure 5. Converted csv file

At the same time, MIDI data is also generated. Composer can choose a tonality from the list before conversion (Figure 5). These tonalities are resampled from random data of csv file. The workflow of the conversion is following (Figure 6).

Figure 6. Screenshots of each tonality

About conversion, we use csv time-series data and resample its values. This system requires at least time data, and value of data set (Figure 7).

$$\text{Midi} = f(\mathcal{D}, P1, P2, P3, P4)\ \{$$

$\mathcal{D}$: csv

P1 = minimum csv parametr

P2 = max csv parameter

P3 = minimum frequency value

P4 = max frequency value

$\}$

Figure 7. Processing Algorithm

After finishing conversion of data, composers can use the converted MIDI file in DAW. As a sample case, we have used this data in a DAW software name Ableton Live (Figure 8). In this part, composer can change each MIDI note length as wish.

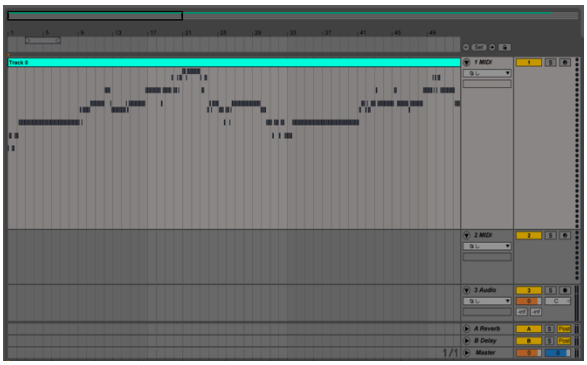

Figure 8. Converted MIDI file in DAW

We have created a work using converted MIDI data (Figure 8).

IV. Experiments

In this part, we show the feasibility of our system and create MIDI data using time series data. As we mentioned in section III-A, we have used the currency data. Using the currency change data as input, the system outputs the data as MIDI data and combines them to create music. Each MIDI data has been already resampled as a tonality of Aeolian scale. And the range of data is mapped as lowest price 10Hz, highest price to 4000Hz. After setting up the scale, the system converts the csv files to MIDI data.

This software aims every kinds of time series data that user want to use. For the example, we suggest some data in table (Table 1).

Experiment 1. USD/JPY

Before (Currency csv data)

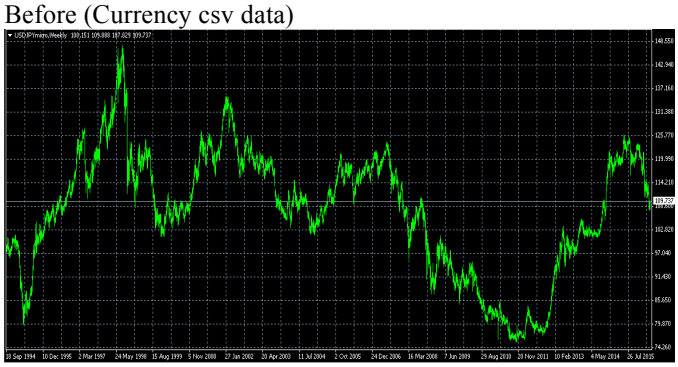

Figure 9. USD/JPY currency data

Result (MIDI as Aeolian scale)

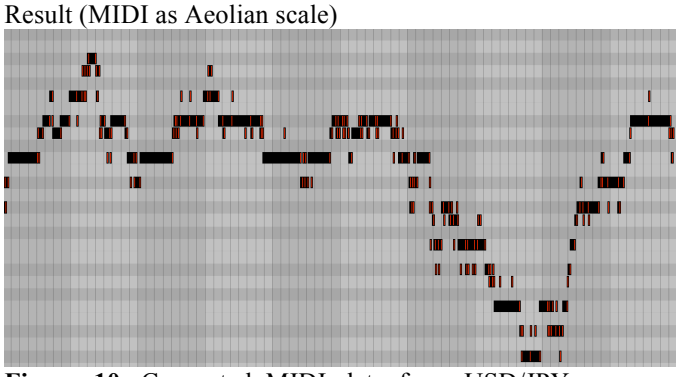

Figure 10. Converted MIDI data from USD/JPY currency data in Aeolian scale

Experiment 2. EUR/YEN

Before (Currency csv data)

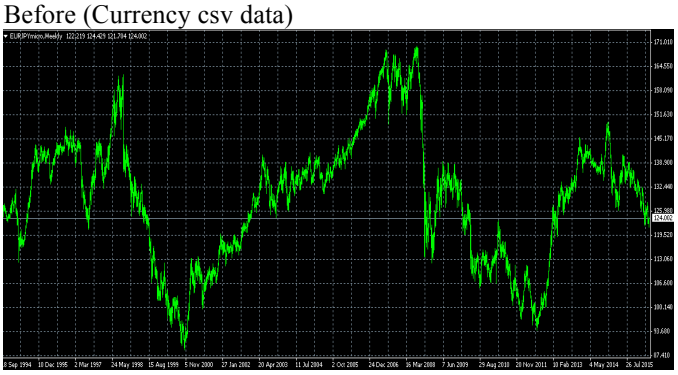

Figure 10. EUR/JPY currency data

Result (MIDI)

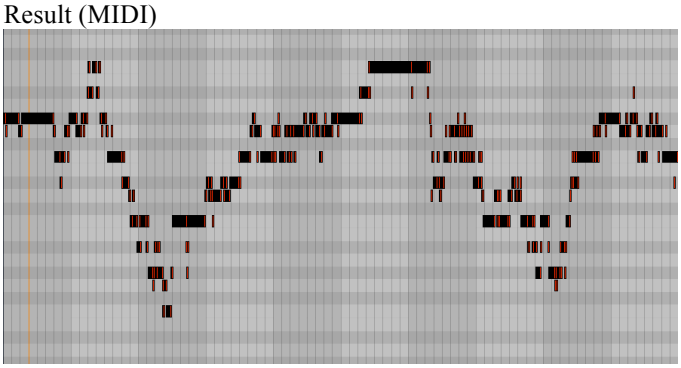

Figure 11. Converted MIDI data from EUR/JPY currency data in Aeolian scale

Experiment 3. NZD/YEN

Before (Currency csv data)

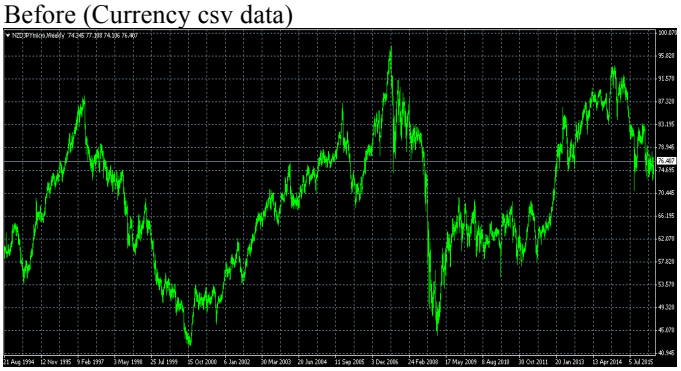

Figure 12. NZD/JPY currency data

Result (MIDI)

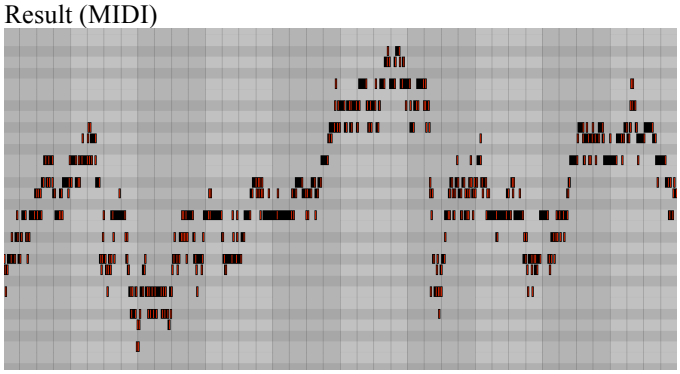

Figure 13. Converted MIDI data from NZD/JPY currency data in Aeolian scale

We have created music to combine these data into one and create image video of this (Figure 14).

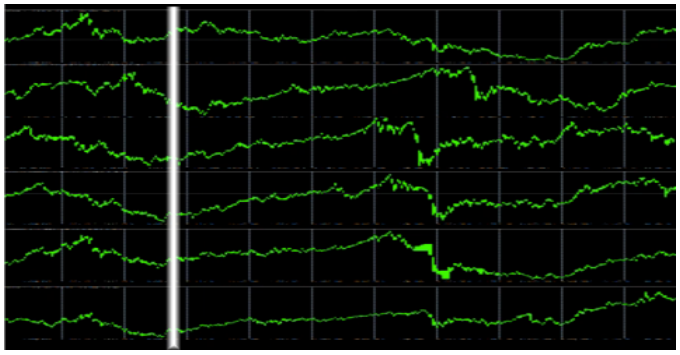

Figure 14. Screenshot of music video of combined currency data

V. CONCLUSION

We have confirmed the software possibility by the experiments. This software will be used for musical expression of time series data more instinctively. This research becomes a start point of new approach for detecting relationships between data that have multi dimensional information. It will become more important to utilize human sense for analysis. The data amount will become larger because the sensing technologies will be advanced more in future. So the conversion process needs to be improved more. Usability of this software is also need to be improved. But simple interface is very important for speedy composition. We should make this as VST plugin for DAW environment for DAW users. And as next step, we will try to use this for virtual reality and environmental sound design solution. Musical composition from data tables is still young research area. In future, every environment of our surrounding become virtual reality, the recognition design of them should be more conventional. This idea should not only lead by researchers but also artists. We aim to create software that enables to communicate smoothly between researchers and artists.

REFERNCES

[1] Thomas Hermann, Andy Hunt, John G. Neuhoff, "The Sonification Handbook", Logos Verlag Berlin GmbH, ISBN 978-3-8325-2819-5, pp.29-52, 2011.

[2] Wu, Zhaohua, and Norden E. Huang. "Ensemble empirical mode decomposition: a noise-assisted data analysis method." *Advances in adaptive data analysis* 1.01 (2009): 1-41.

[3] Janata, Petr, and Edward Childs. "Marketbuzz: Sonification of real-time financial dataa." 2004.

[4] Kramer, Gregory, et al. "Sonification report: Status of the field and research agenda." 2010.

[5] Hermann, Thomas, and Andy Hunt. "An introduction to interactive sonification."*IEEE multimedia* pp20-24, 2005.

[6] Arnold Schoenberg, "Fundamentals of Musical Composition", ISBN978-4276106208, 1998

[7] Krumhansl, Carol L. "The psychological representation of musical pitch in a tonal context." *Cognitive Psychology* 11.3, pp346-374,1979.

[8] Marks, Lawrence E. "On associations of light and sound: The mediation of brightness, pitch, and loudness." *The American journal of psychology* (1974): 173-188.

Table 1. Examples of data type and its table

Source Type Examples	Data Source	Description
Foreign Exchange	• Time and Date • Starting Price • Highest Price • Lowest Price • End Price	In foreign exchange data, composers can 5 kinds of data. If composer want to use only "End Price", the melody of music express it.
Remote Sensing Data	• Temperature • Humidity • Congestion • Brightness • Etc…	By using sensing device, composer imagines the impression of environmental change. These data can use not only for observation of environmental changes, but also for example, notification of people activity.
Environment Databases	• Time • Location • Deforestation Rate • Increase rata of sea level • Etc…	This example is environmental changes in long term. Composer can even use these fundamentals for composition.