

# A VISUAL ANALYSIS SYSTEM FOR COMPOSITIONAL PROCESSES OF COMPOSERS IN SPECTRAL SCHOOL

Yuriko Takakura<sup>†</sup>

Masanori Nakayama<sup>†</sup>

Issei Fujishiro<sup>†</sup>

<sup>†</sup>Graduate School of Science and Technology, Keio University

## ABSTRACT

We propose a visual analysis approach to explore the compositional process of composers in Spectral School, with a particular focus on the sub-processes of sound analysis and synthesis. Spectral music is one of the significant trends in contemporary music since the 1970s. Composers in Spectral School use the acoustic properties of sound spectra as the basis of their compositional materials. One of the representative software systems they use is AudioSculpt, which has been developed by IRCAM. We have developed an accompanying system with AudioSculpt to represent the history of creating sounds with spectral analysis of sound materials and processing of sound spectra using the various filters. The salient feature of the system lies in its stacked spectrogram space whose axes represent the elapsed time of the sound and the progress of composition. On the pixel-oriented spatial substrate, the system makes it possible for users to analyze the compositional processes by dedicated interactive manipulations. As such, the users are allowed to examine the compositional processes of musical pieces, whereas primary targets of most previous studies were only completed pieces. The present system can also be regarded as an initial attempt at managing the provenance of time-series events in music visualization field. Our approach is intended to open a door for the composers to develop and share the compositional methodologies.

## 1. INTRODUCTION

With the advent of computer technologies in the 20th century, composers initiated the use of electronic sounds in their musical pieces. Composition by processing sounds using the computer technologies has been developed in contemporary music. Among many kinds of compositional methodologies having appeared in such situation, Spectral School, which has its primary root in IRCAM (Institut de Recherche et Coordination Acoustique/Musique), is positioned as one of the representative trends in contemporary music. Spectral music is a term of art referring to music composed mainly in Europe since the 1970s, which uses the acoustic properties of sound itself or sound spectra as

the basis of its compositional materials [1].

Since spectral composers have a wide variety of compositional processes, it is difficult to categorize them perfectly. However, their compositional processes are basically organized as follows: firstly spectral composers analyze several sound materials with software, and then they compose their pieces with unique sounds by processing based on their sound spectra. Although each composer has a different style to use computers, most of them use software for their own spectral analysis of sound materials. This means that examining acoustic properties with spectral analysis of sound materials by use of computers is one of the significant processes in their composition.

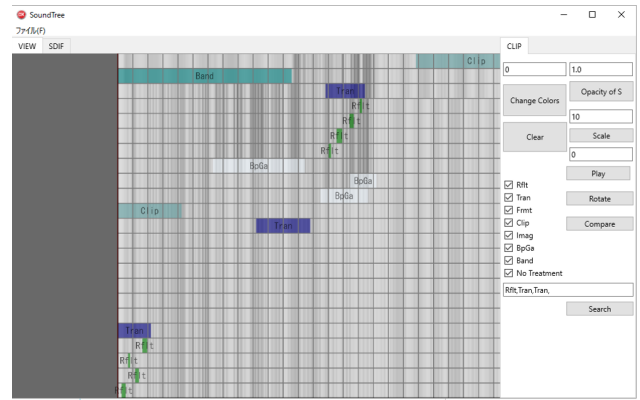
Examples of sound materials used by the composers include abstract harmonic series, natural sounds, and mathematical models of sound materials [2]. Tristan Murail (1947–), who is known as a co-founder of Spectral School, makes a spectral analysis of bell sounds and orchestrates his representative piece *Gondwana* (1980) based on the analysis result. Gérard Grisey (1946–1998) uses the result of analyzing a trombone sound within his representative musical piece, *Les Espaces Acoustiques* (1974–1985). As thus far described, spectral composers use various sound materials encompassing from musical sounds to unpitched ones in their pieces.

In order to explore such compositional process of music, it is necessary to study the acoustic properties of the sound materials. In the field of musicology, resource research, bibliographic survey and musical analysis have been mainly used for studying compositional processes. Because of that, it is difficult to study musical pieces which use some mathematical methods for examining sound properties. The most important contribution of this paper is to make it possible for users to study objective compositional methods from the perspective of computer science. In other words, this study is intended to search for a new possibility of music research and composition.

One of the representative software systems for spectral analysis and synthesis used by spectral composers is AudioSculpt [3], which has been developed by IRCAM. By the use of AudioSculpt, we can “sculpt” a sound by directly editing its spectral contents. As shown in Figure 1(a), the interface of AudioSculpt displays the spectrogram of a sound and this system allows the users to process the sounds visu-



(a) A screenshot of AudioSculpt interface



(b) A screenshot of our system interface

Figure 1: AudioSculpt and our system

ally by means of their spectrogram and returns an *up-to-date* result of spectral analysis of sounds. Our basic idea is to propose the accompanying system with AudioSculpt so that we can visualize the *history* of sound analysis and synthesis as well. Composers may use AudioSculpt in combination with our system because they use our system for reviewing and managing their compositional processes. On the other hand, musicologists may use our system independently for analyzing the compositional processes of the musical pieces which were composed by historical composers.

This system aims at the study on spectral composers' compositional process, however our approach would be applied to other genres of music or the field of sound design because sound processing with spectrograms is not an exclusive approach adopted by spectral composers.

The remaining part of this paper is organized as follows. In Section 2, we review the related works. In Section 3, we describe the design of our system. In Section 4, we explain about the current implementation and results. We conclude the paper in Section 5, with a few remarks on future directions.

## 2. RELATED WORK

AudioSculpt is one of the software systems to provide a spectral analysis and sound synthesis. Spectral analysis and synthesis itself is a general approach in the sound processing field as mentioned above. Among many software systems which enable spectral analysis and synthesis [4][5], AudioSculpt is positioned as software that targets for composers in Spectral School for creating new sounds by sound processing. Indeed, compared with the other software systems, AudioSculpt has much more functions, including Transposition, which allows to transpose a sound without changing its length and without losing sound quality, Formant Filter, which creates a series of second order resonant

band filters, and the like.

In the field of music visualization, previous works focus mainly on visualizing and analyzing the structure of musical pieces or exploring some similarities among the pieces. The examples include the system named "Arc Diagrams" proposed by Wittenberg [6], where some repeated patterns used in the musical piece are visualized with some arcs. Chan et al. [7] proposed a system using some colored lines to visualize the roles of each orchestral instrument in a symphony. This system represents how instruments are used in the musical piece from a cursory inspection. There are some known works which focus on the progress of harmonies, as demonstrated by Bergstrom et al. [8]. In this system, a coordination system called "Tonnetz," which is represented by paved triangles, is used to visualize harmonies.

Provenance visualization can also be regarded as another key aspect because our research also concentrates on the history of sound processing. Examples of comprehensive provenance visualization systems include VisTrails [9] and VIDELICET [10]. Both systems are intended to visualize the modular structure of a visualization application and support how to design effective visualization workflows for a given goal. There exist other systems to support designs. For example, Kurlander et al. [11] introduced an editable graphical history. Recently, Doboš et al. [12] proposed an approach for visualizing the history of constructing 3D models with time-lines. Other studies introduce several types of designs to visualize specific provenances. The system by Chen et al. [13] visualizes provenances by use of networks and its case studies involve provenance of a satellite imagery processing pipeline and provenance in a large-scale computer network testbed. The work by Borkin et al. [14] is one of the cases where provenances are visualized with tree diagram and the effectiveness of this system is demonstrated by some user studies. Yoon et al. [15] proposes a system which visualizes the history of code changes

by use of time-lines.

With reference to these related works, we propose a system to visualize the progress of sound processing. We concentrate on the compositional processes of musical pieces, whereas primary targets of most previous works were only completed pieces. In contrast, our study is focusing on visualizing a specific provenance—the compositional process of composers in Spectral School—and can also be regarded as an initial attempt at managing the provenance of *time-series events* in music visualization field.

### 3. VISUALIZATION DESIGN

While time-lines is often utilized for provenance visualization, we propose a pixel-oriented spatial substrate whose axes represent the elapsed time of sounds and the progress of composition. The horizontal axis of this system represents a time progression of the sound while the vertical axis shows the progress of sound processing. The vertical axis represents it from bottom up. In order to deal with every sound regardless of its durations, the time scale in this system can be changed according to the length of sound materials. Furthermore, since the number of treatments (the word “treatment” is used in the user manual and the interface of AudioSculpt in the sense of the method of sound processing) may change according to the length of sound files, all treatments can be scrolled if there are too many treatments in a fixed-size window.

The objective of this system is to perform a visual analysis of compositional processes. There are two purposes for studying on compositional processes. The first objective is to clarify how the musical piece was composed. The second one is to analyze the composers’ intentions or their unique compositional techniques. This will be useful for explaining the uniqueness of the composer and for discussing his/her position in the musical history.

To satisfy these objectives for studying compositional processes, we have defined three requirements for our system: firstly, to comprehend the order of sound processing, secondly to clarify the treatment which makes the sound change drastically, and thirdly to make users understand the unique processing patterns of the composer.

The proposed system provides multiple functions on the spatial substrate according to the objectives of studying compositional process and the requirements of visualization advocated in Shneiderman’s TTT (Type-by-Task Taxonomy) [16]. The system takes as input, an SDIF (Sound Description Interchange Format) [17] file, which is an intermediate product of AudioSculpt. This data format was co-developed by IRCAM and University of California, Berkeley and includes data of sound processing in the sequence of the sound. An SDIF file also includes data which shows the order of sound processing, by which we can see how

the sound was processed. From this kind of file, we utilize the data on orders, types and durations of treatments. Figure 1(b) shows the interface design of our system, where each of the treatments is represented by a colored block and we call them “treatment blocks” in this paper. The color of a treatment block represents the type of the treatment such as Transposition and Bandpass Filter. The left side of each block corresponds to the start time of the treatment of the sound material and the width of a block means the duration of the treatment. In our system, a history of creating sounds is represented in a vertical sequence of treatment blocks. In addition, spectrograms may be superimposed on the back of these treatment blocks.

In the information visualization field, horizontal axis is normally used for elapsed time. In this system, users can interchange these two axes depending on which axes the user is focusing on.

As described in Section 1, primary targeted users include spectral composers and musicologists. Objectives to use our system are different between them; composers target creating new unique sounds with spectral analysis whereas musicologists aim to analyze a compositional process. We will explain the difference with expositions of six functions according to the classification proposed by Shneiderman.

1) *Overview* : Users can overview the history of sound processing of the composer. This view makes it possible for both composers and researchers to comprehend a complete picture of the sound processing history. The steps with no treatment blocks imply that the treatments were deleted by the composer. In the overview mode, for the sake of avoiding visual clutters, spectrograms are averaged and gray-scaled.

2) *Zoom* : The zoom mode provides the details of spectrograms by widening the spectrograms. The spectrograms are depicted with full colors. The yellow color shows the loudest sound and the sound will be weaker if the colors of spectrograms turn to red or blue. Since the spectrograms are adopted to visualize stereo audio files, the upper half of each spectrogram corresponds to the right channel and the lower half to the left channel. The system also has a function to locate a particular timing of the sound to extract some treatments which are provided at the timing. Both composers and researchers can understand the effects of some treatments at the specified timings.

3) *Filter* : Our system provides a function to filter some particular treatment blocks. Users can use this function by manipulating the corresponding check boxes. This function makes it possible for composers to consider their tendency of sound processing while musicologists can understand the unique treatments of the composer and comprehend the history of sound processing in more depth.

4) *Extract* : The system enables to extract some processing patterns which the composer uses frequently. The

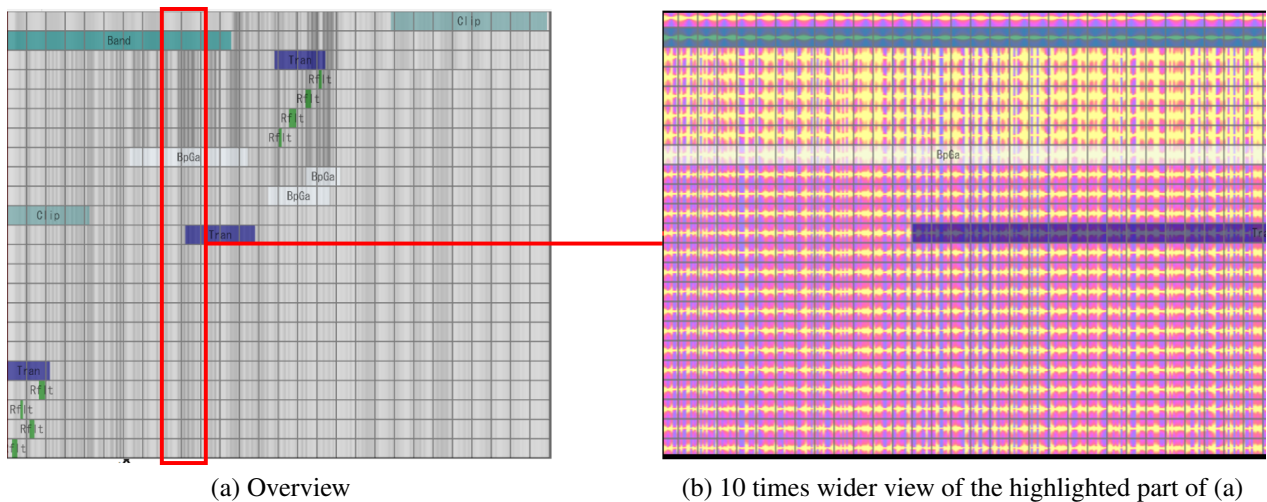


Figure 2: Overview and zoom

function makes it possible for both musicologists and composers to understand the feature history of sound processing. By this function, both composers and musicologists can understand the relationships of treatments with great circumstance.

5) *View Relations* : Our system also provides a function to observe the changes of sonorities by calculating the feature quantity, MFCC (Mel-Frequency Cepstrum Coefficiens) of each sound created by sound processing, and plotting the results on a graph. The horizontal axis of this graph means the progress of sound processing, and the vertical axis the differences of MFCC from the selected sound as basis. This graph is shown as the second window. If users click the vertices of the graph, the corresponding treatment block in the first window will be highlighted.

We provide another function to show mutual relationships of treatments, for example whether a pattern of treatments shown in one place can also be observed in another. If users input the data created by a different composer, users will understand the history of sound processing of other composers and compare their processes.

6) *Details on Demand* : We have some more functions to enable users to understand a transformation of the sound. Users can check the effects of each treatment on the spectrogram. In addition, users can listen to an actual sound which reflects some effects provided by the treatments. While the sound is playing, the color of the spectrogram corresponding to the playing sound turns to full color.

#### 4. IMPLEMENTATION AND RESULTS

The current prototype system has been developed with Delphi and runs on Microsoft Windows 10, a 64-bit operating system. The hardware running the software is a desktop

PC consisting of an Intel Core i7 2.40GHz CPU, 8.00GB of main memory, and an Intel HD Graphics 5500 GPU.

Figure 2 (a) depicts the history of processing the first 2.788 seconds of a recorded temple bell sound with a total of 23 treatments. Some blanks from 6th to 11th steps from the bottom mean that these treatments were deleted by the composer. Furthermore, we can see the sound is changed drastically in the latter part of this sound processing because the colors of the spectrograms become darker.

Figure 2 (b) illustrates 10 times wider view of the highlighted part of Figure 2 (a). Users can take a closer look at the transformation of spectrogram reflecting the effect of treatments. This result shows the high pitched harmonies are deleted by the Bandpass Filter.

Figure 3 represents that the user extracts the portion where the Gain Filters were applied. The Gain Filter has an effect to strengthen the sound. It turns out that the Gain Filters are used intensively in the middle of the sound, which implies that the composer would like to emphasize the sound there.

Figure 4 shows that the user extracts Rectangular Surface Filters and Transposition by using the “Extract” function to choose particular treatment patterns. Rectangular Surface Filter is a distinguishing filter of AudioSculpt while Transposition is one of the most effective treatments by which the pitch of the sound can be changed. With the “Extract” function, we can notice that a pattern of treatment—using Transposition after utilizing of several Rectangular Surface Filters—is repeated in the first and the latter parts of the processing. Users can visually understand that this treatment pattern is a unique feature of this sound processing.

Figure 5 shows the changes of sonority as the sound was processed. The data on the vertical axis represents the differences of MFCC from the original sound of temple bell.

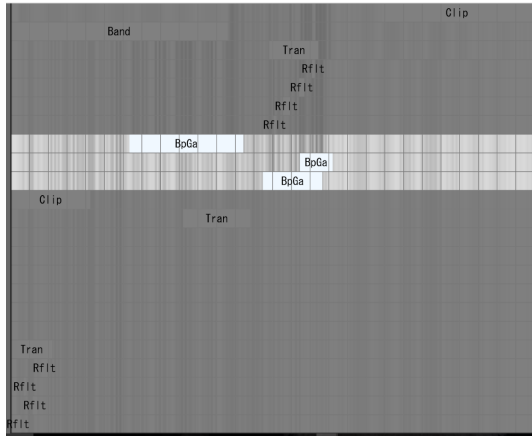


Figure 3: Extracting Gain filters

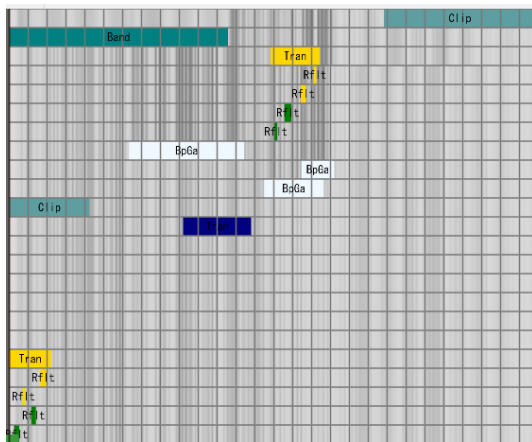


Figure 4: Extracting patterns of Rectangular Surface Filter and Transposition

The slope of this graph becomes steeper between the 20th and 21st treatments. This means that the sound was changed drastically by the 21st treatment.

These results show that users can comprehend the history of sound processing and extract unique treatment patterns. They also understand the treatment which changes the sound drastically.

We interviewed a composer who studied under Tristan Murail—a representative composer of spectral music as mentioned above—about this system. The composer said that the approach that visualizes the compositional process of spectral music is effective for spectral composers. However, the composer mentioned that analyzing data from AudioSculpt is not enough to show the entire compositional process of spectral music since those composers also use papers and/or other software for their composition.

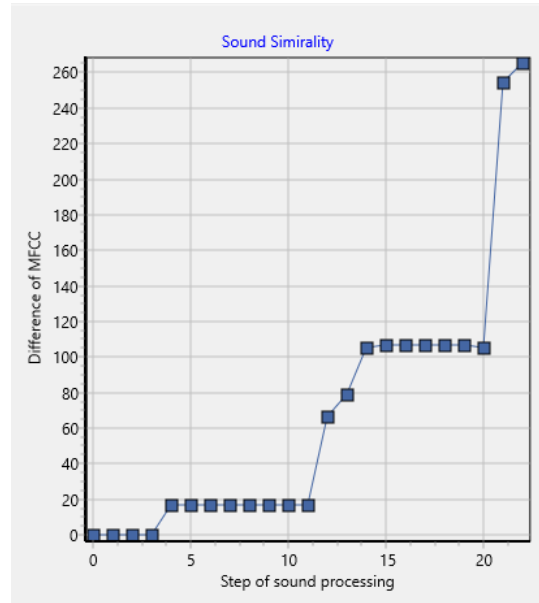


Figure 5: Changes of sonorities in the compositional process calculated with MFCC

### 5. CONCLUDING REMARKS

We have proposed a visual analysis approach to explore spectral composers' compositional processes. We introduced an accompanying system with AudioSculpt to trace the process of creating sounds. On the pixel-oriented spatial substrate, the system makes it possible to visually analyze the compositional processes by dedicated interactive manipulations. This system allows the users to examine the compositional processes of musical pieces and can also be regarded as an initial attempt at managing the provenance of time-series events in music visualization field.

The results of this study provide an overview of sound processing history with transformations of spectrograms and extract a unique treatment patterns in the process. They also show that the treatment which makes the sound change drastically. It is suggested that by using the present software, composers can understand their own compositional processes in an objective way and musicologists can comprehend and analyze the history of sound processing visually.

As future works, we will conduct more thorough user studies with several composers and musicologists. Furthermore, we take advantage of the system to analyze historical musical pieces by spectral composers.

For more detailed studies, we have to improve our system so as to apply more functions on AudioSculpt since our system does not cover all of functions provided by AudioSculpt. For example, one of the main functions of AudioSculpt, "partial synthesis" is not treated in the current system.

Furthermore, as pointed out by the composer who we interviewed, our system must also be applied to other software such as OpenMusic [18], which is one of the well-known software systems used by spectral composers. In addition to that, the composers also use papers to develop their ideas of musical pieces. We have to discuss how to incorporate such real situations.

### ACKNOWLEDGMENTS

This research presentation is supported in part by a research assistantship of a Grant-in-Aid to the Program for Leading Graduate School for “Science for Development of Super Mature Society” from the Ministry of Education, Culture, Sport, Science, and Technology in Japan.

### REFERENCES

- [1] J. Anderson: “Spectral Music,” Grove Music Online, Oxford Music Online, <http://www.oxfordmusiconline.com/subscriber/article/grove/music/50982> (2016).
- [2] J. Fineberg: “Guide to the Basic Concepts and Techniques of Spectral Music,” *Contemporary Music Review*, Vol. 19, No. 2, pp. 81–113 (2000).
- [3] AudioSculpt Ircam Anasynth, <http://anasynth.ircam.fr/home/english/software/audiosculpt> (2016).
- [4] Audacity, <http://www.audacityteam.org/> (2016).
- [5] Adobe Audition CC, <http://www.adobe.com/jp/products/audition.html> (2016).
- [6] M. Wittenberg: “Arc Diagrams: Visualizing Structure In Strings,” in *Proceedings of the IEEE Symposium on Information Visualization*, pp. 110–116 (2002).
- [7] W. Y. Chan, H. Qu, W. H. Mak: “Visualizing The Semantic Structure in Classical Music Works,” *IEEE Transactions on Visualization and Computer Graphics*, Vol. 16, No. 1, pp. 161–173 (2010).
- [8] T. Bergstom, K. Karahalios, J. C. Hart: “Isochords: Visualizing Structure in Music,” in *Proceedings of the Graphics Interface*, pp. 297–304 (2007).
- [9] C. T. Silva, J. Freire, S. P. Callahan: “Provenance for Visualizations: Reproducibility and Beyond,” *IEEE Computing in Science Engineering*, Vol. 9, No. 5, pp. 82–89 (2007).
- [10] I. Fujishiro: “Visualization Design and Lifecycle Management,” *Dagstuhl Seminar on Scientific Visualization* (2007).
- [11] D. Kurlander, S. Feiner: “Editable Graphical Histories,” in *Proceedings of the IEEE Workshop on Visual Languages*, pp. 127–134 (1988).
- [12] J. Doboš, N. J. Mitra, A. Steed: “3D Timeline: Reverse Engineering of A Part-based Provenance from Consecutive 3D Models,” *Computer Graphics Forum*, Vol. 33, No. 2, pp. 133–144 (2014).
- [13] P. Chen, B. Plale, Y. W. Cheah, D. Ghoshal, S. Jensen, Y. Luo: “Visualization of Network Data Provenance,” in *Proceedings of the 19th International Conference on High Performance Computing*, pp. 1–9 (2012).
- [14] M. A. Borkin, C. S. Yeh, M. Boyd, P. Macko, K. Z. Gajos, M. Seltzer, H. Pfister: “Evaluation of Filesystem Provenance Visualization Tools,” *IEEE Transactions on Visualization and Computer Graphics*, Vol. 19, No. 12, pp. 2476–2485 (2013).
- [15] Y.-S. Yoon, B. A. Myers, S. Koo: “Visualization of Fine-Grained Code Change History,” in *Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing*, pp. 119–126 (2013).
- [16] B. Shneiderman: “The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations,” in *Proceedings of the IEEE Symposium on Visual Languages*, pp. 336–343 (1996).
- [17] SDIF Sound Description Interchange Format, <http://sdif.sourceforge.net/> (2016).
- [18] IRCAM Forumnet OpenMusic, <http://forumnet.ircam.fr/product/openmusic-en/> (2016).