Enhancement of liveness

Master thesis

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Abstract

This thesis deals with the enhancement of liveness in musical composition. The emergence of reproductive devices and broadcasting have altered the quality of one's listening experience from a social activity, in which a listener shares their musical experience with other community members, to a personal activity, which is not shared by anyone else. In hopes of creating a more communicable society, the author suggests a strategy of "Dynamic Structure" for composing a piece of music. This strategy derives compositions whose structures aren't fixed before a performance starts, but generated according to unique elements in the specific space at the specific time where a performance is ongoing such as room acoustics and quality of performer. This thesis introduces five different approaches that the author has worked on in the enhancement of uniqueness in a live setting: Sensor instrumental performance, Open Interaction, Pseudo-Agent, Constrained Interaction and Game Piece. As a creation practice, design of my sensor instrument, my sound installation (*Candle Organ*), my mixed music compositions (*Beyond the eternal chaos*, *Audible Playground* and *Tongue-Twister Competition*) are used.

Abstract

Diese Arbeit beschäftigt sich mit der Verstärkung der Einzigartigkeit der Live Situation in der musikalischen Komposition. Die Entstehung von Wiedergabegeräten und Rundfunk veränderte die Qualität des Hörerlebnisses. Aus einer sozialen Aktivität, in der ein Zuhörer seine musikalische Erfahrung mit anderen Mitgliedern der Gemeinschaft teilt, wurde eine persönliche Tätigkeit, die von niemandem geteilt wird. In der Hoffnung, eine kommunikativere Gesellschaft zu schaffen, schlägt der Autor eine Strategie der "Dynamischen Struktur" für die Komposition eines Musikstückes vor. Diese Strategie verlangt Kompositionen, deren Strukturen nicht vor Beginn einer Performance festgelegt sind sondern von singulär auftretenden Elementen in einem spezifischen Raum zu einem spezifischen Zeitpunkt wo deren Aufführung stattfindet, wie z. B. der Raumakustik und dem Können des Performers, erzeugt werden. In dieser Arbeit werden fünf verschiedene Ansätze vorgestellt, in denen der Autor an der Erhöhung der Einzigartigkeit in einem Live-Setting gearbeitet hat: Sensor instrumentale Performance, Open Interaction, Pseudo-Agent, Constrained Interaction und Game Piece. Als praktische Beispiele werden folgende Arbeiten herangezogen: Sensor-Instrumente, meine Klanginstallationen (*Candle Organ*) und verschiedeneKompositionen (*Beyond the eternal chaos*, *Audible Playground* und *Tongue-Twister Competition*).

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Chapter 1

The role of contemporary music today

After the emergence of recorded media and broadcasting of music, liveness in a musical performance became an essential reason to distinguish between a concert setting and audio playback by using a playback device.

Looking back into history, concert halls have been where music was exchanged in a specific social setting and architectural environment. As classical music has been conventionally performed at concert halls, listening to music meant not simply appreciating a performance and a composition, but acquiring a common experience among the other community members by sharing the same moment in the same space. Such common experiences can bring out a basis of communication, which causes solidarity in a society. This led me to the vision that music can create a community which shares an intellectual curiosity to experience something new.

However, listening to music today does not mean acquiring a common experience any longer as the development of technology has drastically changed ones' listening experiences. First, our listening experience was personalized. The emergence of broadcasting made it possible to listen to music regardless of where and with whom the listener was, whereas the traditional listening experience was made with other listeners in a concert hall. As a result, the listener can be alone while listening to a performance. This robs an individual of the chance to share the same listening experiences with other people. Thus, the listening experience is not shared, but personalized. The emergence of portable playing devices such as Walkman and iPod intensified this personalization even more, as they required each listener to use earphones, which interrupt audible signs from other people in front of the listener. This results in making audible signs imperceptible from other people around the audience. Consequently, the listening experience has changed from a social activity to a personal activity just as its quality. Second, our listening experience was fragmentized. The development of recording media such as tape and CD, and of playback devices such as home audio systems enabled listeners to arbitrarily stop and restart a rendition of a piece whenever they wanted due to their own circumstances regardless of a composer's, performer's and other listeners' will. This demonstrates that the course of a listening experience can be easily fragmentized without regard to the creator's intention about the sequence of a rendition. This is contrasted by the fact that the audiences had to let the sequential rendition of a piece run from the beginning to the end in a concert regardless of their own will, because it was shared with other community members at the same time in the same space.

These two tendencies - personalization and fragmentation - demonstrate that the appreciation of music has changed from a social activity, which fosters the sharing of cultural knowledge, to an individual activity, with which people pursue their limited tastes. Hence, although I am aware that the reproductive media allowed many positive changes, I think that these two tendencies caused by the development of technology robbed opportunities to share a common experience, which could be a basis of communication, and as a result, the audience is today isolated from the wider society by listening to music. I call this tendency a negative use of technology. From the perspective of a composer, what is a positive use of technology?

My answer is that liveness in a concert situation can be enhanced by the use of computational technology. Since this underscores the uniqueness of live events in contrast to the listening experience by using recording media, this can stimulate the audience to come back to the concert hall, and enjoy music in a shared situation. For this reason, this master's thesis deals with five different approaches to the enhancement of liveness - uniqueness in a live situation in contrast to a listening experience by using a reproductive device: Sensor-instrument performance, Open Interaction, Pseudo-Agent, Constrained Interaction and Game Piece.

Liveness in a concert situation

What is liveness in this context more precisely? Liveness means something unique in a live situation compared to a listening experience made with playback devises. Concrete examples of such uniqueness are, for example, the presence of the performer, room acoustics, lighting, and presence of other audience members.

The presence of a performer is one of the essential factors that underscore the specialty of a live situation in contrast to the listening experience from a personal playback device, as the performer is to interpret a piece of music in a different way in every performance, whereas playback devices reproduce the same interpretation for every performance. Comparing between a solo and duo performance, slightly different kinds of liveness can be observed: whereas the solo performance draws listeners' attention to how and what kind of sound the player produces with the instrument. The duo performance additionally makes the audience focus on how these two players interact organically with each other. This difference can be seen in different kinds of compositional approaches to computer music. For example, the idea of Hyperinstruments depends on the performative model of solo performance, as it is designed to "to give extra power and finesse to virtuosic performers"[1]. In such cases, the computer's role is typically not conflictive nor contrastive to the embodiment. Instead, it tends to be consistent with the embodiment in a certain manner. I call this model the subject-to-object model. In contrast to this model, the duo performance consists of an interaction between the two players in addition to the expansion of the performer's embodiment. In the field of computer music, this interactive relationship is simulated, for instance, as an ensemble between a player and an autonomous computer system. I call this model the subject-vs-subject model.

Apart from the presence of a performer, environmental factors such as room acoustics, lighting, and presence of other listeners are also the specialties of the space and time where a performance is ongoing as these elements are uniquely different in every venue. These elements conjure up a peculiar atmosphere at a concert hall compared to the listener's daily listening environment such as with an iPod. Therefore, these factors enhance the specialty of live settings.

Consistence

In the subject-to-object model, consistence between sonic motion and a performer's bodily gesture is an essential aspect, which underlines the specialty of a live situation: the presence of the performer. This consistence conjures up a sense that an instrument is performed by a player (I call it a sense of "performance".), so that the listening experience can be easily differentiated from that of reproductive devices. An example of consistence in between is performance of a violin. A performer's actions such as bow-speed, pressure and where a finger presses on a string, deeply affects the sonic character of a violin sound. Therefore, the congruence between the performer's motion and the resultant sound is in essence to make the subject-to-object model special. For this reason, I worked on a project to build a sensor instrument, which translates a performer's bodily motion to sound. This project will be introduced as my example attempt to enhance liveness in Chapter 2 entitled subject-to-object model.

Interactivity

Compared to a subject-to-object model, subject-vs-subject model has an extra specialty: interactivity between two subjects. This is an essential aspect to distinguish between the subject-to-object model and the subject-vs-subject model. Whereas performative settings categorized to subject-to-object model consist only of one performer, settings belonging to subject-vs-object model constitute more than one. This difference brings the subject-vs-subject model an advantage that the two performers can interact with each other during performance. A primitive example of such interaction in musical performance is eye contact between instrumentalists for alignment in a chamber ensemble. In a jazz improvisation, instrumentalists send and receive cues to each other by both making eye contact and producing a specific gesture of sound, which is commonly understood as a signal to other players in the context of jazz performance. These ways of interaction are unique to the subject-vs-subject model compared to subject-to-object model.

Interactive settings can be sub-divided into two types, which I call Constrained Interaction and Open Interaction. Constrained Interaction means that two subjects interact with each other under a certain ruleset, which restricts how each may „pre-act" and react to one another. For example, the card game so-called „Concentration or Match" belongs to this model. In this game, players are required to turn two cards face up alternately in order to find a pair of cards, which are the same rank and color, from the standard deck of 52 cards. The player who finds the most identical pairs wins.

Open interaction means that two subjects interact with each other without specific rules about how they have to interact with each other. For example, a daily conversation belongs to this category. In a daily conversation, speakers act and react to each other in the course of a conversation, instead of consciously following a strict ruleset, like a game. In this case, such relevance is achieved by their pre-acquired knowledge and intelligence.

As exemplified, interaction is seen not only in a performance, but also in any kind of relationship between two agents. Therefore, the idea of interaction can be applied not only to musical performance, but also to a sound installation. As an example piece focusing on Open Interaction, I introduce my sound installation, *Candle Organ*, which will be discussed in Chapter 3.

Incorporation of liveness into a composition

From a composer's point of view, an approach for the enhancement of liveness could be how a composition can incorporate the live factors into its structure, rather than how much a musical performance can involve these live factors. This question highlights the importance of structuring a composition in real-time, as real-time structuring enables a composition to foster its time and pitch structure under the influence of live factors. These characteristics are contrastive to the fact that conventional compositions are supposed to reproduce their courses of music as notated on a musical score prior to their rendition without regard to the state of the factors. An example of real-time structuration is *Imaginary Landscape No. 1*(1939) composed by John Cage. This piece uses sound from a live radio broadcast as part of a piece. Consequently, although a performer has to manipulate the radio in the piece in every performance, the resultant sonic event varies in every performance. The remarkable potential of real-time structuration makes it possible to form a composition, taking into account the property of the live factors, so that the composition can be uniquely differentiated in every performance. I call this real-time structuring approach Dynamic Structure.

In addition to the real-time structuration, interactivity between two performative subjects is also an essential feature to achieve Dynamic Structure, as an antiphonal reciprocation in between a sequence of sonic events according to their performative manners. The real-time structuration is not an unprecedented approach. A conventional example is a structured improvisatory performance seen often in a jazz performance. This approach forms a piece of music in real-time dependent upon a live factor: performer's ability. Another type of approach is a free improvisatory piece, in which a human instrumentalist and an autonomous computer system interact with each other. An example piece is *Voyager*(1993) composed by George Lewis.

An important fact here is that what significantly determines a course of the composition is the design of performative subjects such as the autonomous computer system. Thus, for achieving Dynamic Structure, a composers' mission is not simply to write musical notes on a piece of paper, but to design performative subjects, which derive certain sonic results taking into account properties of live factors in space and time where the performance is ongoing. I call this mission Design of Performative Subject.

Design of Performative Subject is an important mission for performative settings belonging to the subject-vs-subject model, In Chapter 4, I will explain my project belonging to this model, not only from an aspect of what kind of events happen in my compositions, but also how the system, which makes the events happen, is designed.

Chapter 2

Subject-To-Object Model

Sense of “performance” in computer music

The subject-to-object model highlights the specialty of a live situation in such a way of how competent a player handles an instrument to produce sonic allures. In a conventional musical performance, it has been called, for example, virtuosity. This model of appreciation led me to the vision to establish a sensor instrumental performance. Therefore, this chapter deals with my DIY sensor instrument used for performance of my improvisatory compositions.

As I stated in the previous chapter, the main question of this subject-to-object model is how a musical rendition using electronics can evoke the sense of “performance”. There are several approaches which use a performative embodiment in the domain of electroacoustic music such as a real-time diffusion with Acousmonium, mixed music, in which instruments and live electronics are combined, and sensor instrumental performance. All of them have a performative aspect in some ways. For example, in the case of the real-time diffusion with Acousmonium, an interpretation by an operator manipulating the mixing console alters spatialization and loudness of (typically) a stereo sound source from a fixed medium. In mixed music, both an instrumentalist and a computer are often treated as two performers who interact with each other. These settings make it possible to differentiate sonic outcomes depending on the operator’s or performers’ personality.

Although these two approaches still enhance liveness in such a way that the performer’s interpretation influences the sonic outcome, I especially focus on the sensor instrumental performance in order to avoid the following two disadvantages of these approaches.

First, the real-time diffusion of a stereo sound source does not allow the performer’s interpretation to influence the time structure of a composition. This is because the piece is, in most cases, fixed on a recording media, and the interpreter can manipulate only the volume of the audio signals to be streamed from the fixed medium. This means that the interpreter cannot influence the course of the piece in a musical rendition. Therefore, the performative aspect in real-time diffusion is lowest. This fact is similar in mixed music. Most of mixed pieces have a fixed time structure notated typically on a score, with which the performer has to sequentially play from the beginning to the end. Even though a computer uses real-time signal processing, which is varied dynamically and is not a sequence of sonic events, but a motion of sound in each sonic event. This lack of the performer's commitment to the time structure of a piece is caused by the fact that the real-time signal processing is also for processing an incoming sound stream from an instrument, which reproduces the order of all the sonic events sequentially as fixed on a score, similar to Acousmonium.

Second, the mixed music mostly does not demonstrate a relevance between a computer's behavior and a sonic gesture from the loudspeakers. While an acoustic instrument produces a sound by a performer's bodily motion, a computer generates a sonic event only with a tiny vibration of speaker cones, with which people can only difficultly perceive a mechanism of the sound production. This lack of congruence between physicality and sonority in a computer's performance decreases a sense of "performance".

In contrast to these two approaches, the sensor instrumental performance has two advantages. First, the performer's physical motion is easily associated with sonic outcomes from the loudspeakers. This possibility is caused by the fact that the sensor instrument is typically designed to generate sounds according to how the performer changes the condition of the instrument such as its tilt and acceleration. This fact brings an audience an illusion that the performer is creating the sound rather than the loudspeakers are doing so. Second, the possibility described above gives a performer the ability to improvise music. The fact that the sensor instrument allows a performer to abruptly produce sounds enables him/her to be attentively committed to the time structure of a composition.

For these reasons, I focus on improvisatory performance using a sensor instrument for the enhancement of performative aspects.

Rethinking the "instrument"

When we think about the design of an instrument, a first question should be "what is an instrument?". This question is not a metaphysical question, but rather an introverted question, which inquires what makes us think that a device which we perceive as an instrument. As a description, which explains the properties of an acoustic instrument most accurately, I would like to cite the following statement.

> *In an acoustic instrument, the playing interface is inherently bound up with the sound source. A violin's string is both part of the control mechanism and the sound generator. Since they are inseparable, the connections between the two are complex, subtle and determined by physical laws.(Andy Hunt , Marcelo M. Wanderley & Matthew Paradis, 2003)[2]*

In my opinion, this property of an acoustic instrument highlights an important point, which makes the listener identify the device as an instrument: the physical law serves as an action and reaction of a physical sounding object, as exemplified by the fact that the longer a string is, the lower a pitch becomes. Since these physical laws are observed in the audience's daily experiences, they can easily guess the relationship between the player's manipulation and the sonic result in association with their experiences, which produce sound by any acoustic means. This relationship caused by physical laws is an essential property of an acoustic instrument.

Instrument by means of computational technologies

In the case of a sensor instrument, the relationship between an input to its interface and a sonic output from loudspeakers is not connected by the physical laws unlike an acoustic instrument, but should be designed artificially. Therefore, the mapping between the input and the output is an essential issue to create a relevant relationship in between. Since the input and the output means typically a sensor and synthetic parameters respectively in the case of instrumental design, the main issue can be restated as the design of mapping between a sensor and synthetic parameters.

Throughout the preceding research about mapping between (a) sensor(s) and synthetic parameters, the following three types of mapping[3] are widely recognized;

- One-To-One Mapping: An independent gestural output is assigned to a single musical parameter.
- Divergent Mapping: One gestural output is employed to control multiple synthetic parameters. This is called one-to-many mapping[4] as well.

- Convergent Mapping: Multiple gestural outputs are coupled to control a single musical parameter. This is also called many-to-one mapping[4].

In analogy to the relationship caused by physical laws, these types of mappings are often implemented as a static system. This means that the assigns between an input and an output are not dynamic, but fixed. This invariability of mapping gives the audience a heuristic opportunity, where the listener can learn a causality between a certain bodily gesture and a sonic outcome through observing reactions of the instrument. I call this approach virtual imitation of a behavior of an acoustic instrument.

However, from a composer's point of view, what is valuable is not to simulate how an acoustic instrument behaves by means of computational technologies, but to extend the possibilities of the instrument, taking advantage of the use of a computer. Since the specialty of a sensor instrument is actually liberation from physical laws, it is a worthwhile attempt to design a mapping system, which dynamically changes its mapping between a physical gesture and a sonic outcome in response to some other kind of input. I call this mapping strategy Dynamic Mapping. This Dynamic Mapping can be combined with the above-mentioned three types of mappings: One-to-one Mapping, Divergent Mapping, Convergent Mapping. I call these types of mappings with the feature of Dynamic Mapping as follows;

- Dynamic One-to-one Mapping: This system changes its mapping between a single bodily gesture and a single synthetic parameter. Although, the assignment changes from a single synthetic parameter to another, no more than one synthetic parameters are linked simultaneously.
- Dynamic Divergent Mapping: This is a mapping system, which flexibly changes its assignment between a physical gesture and more than one synthetic parameter.
- Dynamic Convergent Mapping: This type of mapping alters its mapping between more than one physical gesture and one synthetic parameter.

The following chapter deals with how some of these mappings are implemented in my sensor instrument.

Ground design of my instrument

My instrument(figure 1) features two types of mapping: Dynamic One-to-one Mapping and Dynamic Divergent Mapping. Dynamic Divergent Mapping is used for connecting the tilt of the instrument and the synthetic parameters of a granular synthesizer. Dynamic One-to-one Mapping is employed for mapping between an accelerometer and the parameters for samplers. The Dynamic Mapping is achieved by selecting a preset parameter setting from the storage of preset parameter settings saved timely prior to a performance. In order to explain the details of these Dynamic Mapping systems, the following part of this chapter will elucidate the fundamental structure of this instrument, which consists of two parts: a hardware part and a software part. These are complementary, and they work together as a unified single system.

figure 1. my sensor instrument

Hardware part

This instrument is designed to easily be handled by a performer. Therefore, the size of the instrument is approximately 45cm(width)*25cm(depth)*5cm(height). This size enables the player to convey certain types of player's gestures to the instrument easily. At same time, this size restricts the player's motion in certain ways: this instrument allows the player to change its tilt easily and to shake itself abruptly, while it slightly motivates the manipulator to rotate. As a result, the player's motion is confined within a certain extent.

The pieces of wood are used as a main material, which forms the body of the instrument. The use of wooden pieces made it possible to make the weight of this instrument lighter compared to some other materials such as metal and steel. The choice of light material is to motivate a performer to lift the instrument up for fluid performance. The body of the instrument has an inner space, in order to place several electronic parts.

The electronic part of this instrument is made out of the combination of two types of sensors and two buttons connected to an Arduino Uno(figure 2). The two types of sensors consist of a gyro sensor and an accelerometer, which detect how steep a performer tilts the instrument and how fast the performer shakes the instrument, respectively. These sensors are implemented on a chip, MPU-6050, which is implemented inside the body of the instrument. The two buttons underneath the instrument allow the user to quickly change, for instance, from a preset parameter setting to another. Arduino Uno is used as a mother board of this electronic circuit. Once the data are detected by the sensors and the buttons, these are immediately streamed to a computer through the Arduino Uno and a USB-cable connecting the Arduino Uno and computer.

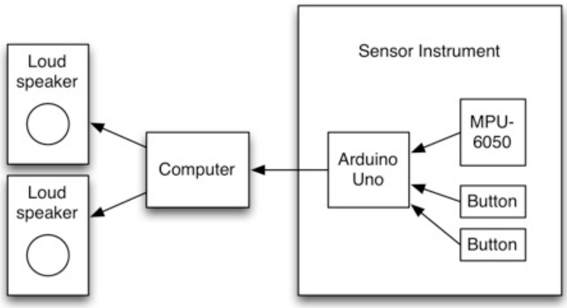

figure 2: The configuration of the instrument

Software part

The software part is programmed on Arduino IDE and Max.

Arduino IDE is used to program the behavior of the Arduino. With this program, the Arduino converts the incoming raw data stream from the sensors and the buttons to appropriate data formats which can be easily used for sound processing in Max. Additionally, the Arduino sends the converted data stream to a Max patch through a serial port. The program for the sensors is based on the one released on the following website;

https://github.com/jrowberg/i2cdevlib/tree/master/Arduino/MPU6050

Since the original code is not programmed to make the two buttons run, few lines are added in order to let the two buttons work by the author. The revised program is downloadable from the following link;

https://drive.google.com/drive/folders/0B_-OTLKwZgq6cC03RUFzcnloYjQ?usp=sharing

The programs in the link above should be placed in a library folder in an Arduino folder in a computer.

Max is in charge of the sound synthesis using the incoming data streams from Arduino. The software part of Max consists of one granular synthesizer, three samplers, a device setting function, an incoming data monitor, and a preset function. For all of these functions, a graphical user interface functions as illustrated in figure 3. The

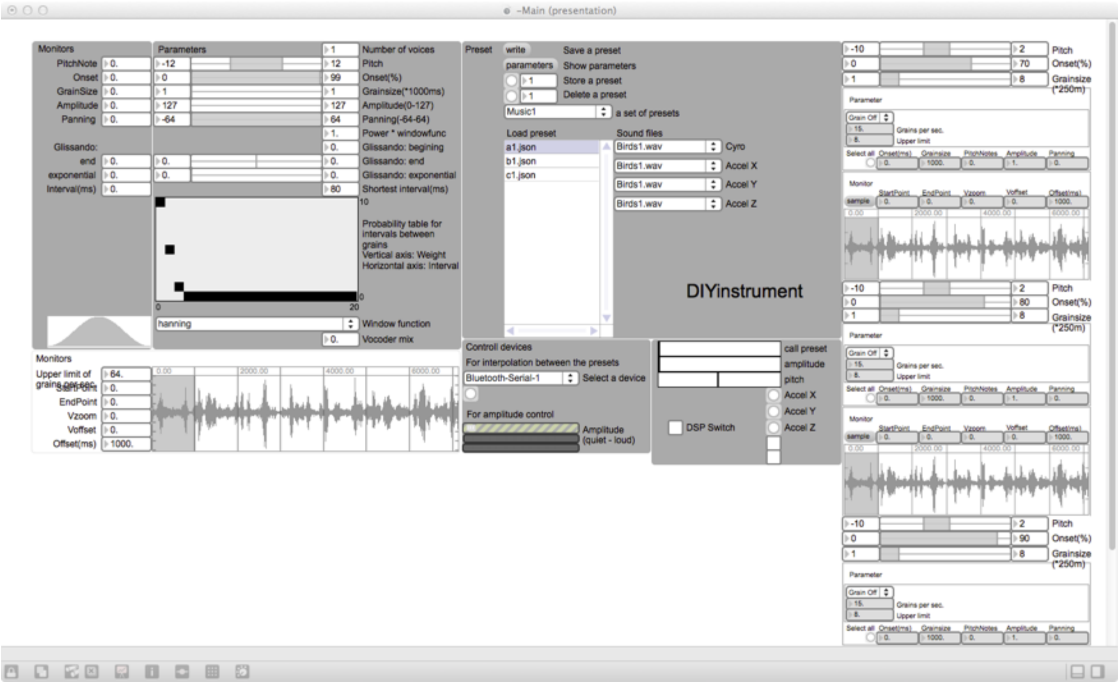

figure 3. Software part

granular synthesizer is mapped to the gyro sensor on the hardware part. The GUI for this is shown on the left side of the figure. The three samplers are assigned with acceleration values on the three dimensions detected by the accelerometer. These are shown on the right side in the figure. The device settings function lists all the devices connected with the user’s computer when the Max patch is opened, so that the user can easily choose a hardware device to be mapped manually. This is shown in the left lower intermediate part of the GUI. The incoming data monitor graphically displays the current value of the incoming data stream. This is stated in the right lower intermediate part of the GUI. The preset menu is assigned with the buttons. This feature offers the user to select an appropriate preset setting from a collection of presets. This preset menu additionally provides the user with the possibility to save and load preset settings as much as the user wants. This function is shown in the upper intermediate part in the GUI.

An example patch of this Max program used for my improvisatory piece "Evolution" is uploaded to the following link;

https://drive.google.com/file/d/0B_-OTLKwZgq6WTJSelFRNHhnRTA/view?usp=sharing

A user has to import all the files in the folder and sub-folders in the package, then double click the Patch named "-EvolutionalTheory.maxpat" to open the Patch. Although this works only with the hardware part of the instrument, the patch can be observed by disabling its presentation mode on Max.

Details of the Max patch

The assignment of the sensors and the synthetic parameters are listed below;

- X axis of the gyro sensor - amplitude of the granular generator
- Y axis of the gyro sensor - pitch
- Z axis of the gyro sensor - preset number

The preset number determines the interpolation value, which recalls stored settings in a pattrstorage object. This object saves and loads the following parameter settings of a granular generator;

- Range of the randomization to determine the number of grains which are played simultaneously.
- Range of the randomization to determine the onset position of a sound file imported into the granular synthesizer.
- Range of the randomization, which affects to the amplitude. This parameter setting is multiplied by the amplitude determined by the X axis of the gyro sensor. Therefore, this parameter is exceptionally a Convergent Mapping.
- Sharpness of the window function.
- Transposition of the pitch at the beginning of each grain.
- Range of the transposition of the pitch in the end of each grain.

- Exponential value for the transposition of the pitch of each grain.
- Probability, which determines duration of intervals between grains.
- Type of the window function.

The pattrstorage object holds two presets, which are matched as two extremes on a Z axis. By changing the angle of the instrument, the system interpolates these presets in order to generate intermediate settings between these presets. This generative process occurs in real-time. Therefore, the system can produce a smooth transition between a preset and another preset.

Each of the three axes on which the accelerometer detects its motion are assigned with a sampler. The sound file imported in the sampler is triggered, when the value of the acceleration receives a value over the threshold. There are three variable parameters for these samplers as stated below;

- Range of the randomization for the transposition
- Range of the randomization for the onset value of the imported sound file
- Range of the randomization, which determines how long the imported sound file should be played, when the sound file is triggered.

In addition to these generators assigned with the sensors, there are three functions which accommodate the use of the instrument in practice as follows;

- Save and load function of presets: This function enables a user to import and export a stored parameter settings as a .json file. Once this file is saved in a folder named “Music1Presets”, the file becomes available to be loaded in the patch. When loading, the file is selected by pressing the physical buttons underneath the body of the instrument.
- Store and delete function of presets: This function allows a user to store and recall a user’s original parameter settings.
- Incoming data monitor: This monitor shows the incoming value from the sensors and the two buttons.
- Control device selector: This functions asks which hardware the user wants to use together with this Max patch. The user needs to select an appropriate device.

- Switch off DSP: This switch turns on and off the real-time signal processing. This turns on and off the communication between the Max patch and the hardware part, when an appropriate device is chosen.

How dynamic is this system?

This system is dynamic in such a way that it allows the user to change the mapping between sound files imported to the granular synthesizer and the samplers. This change occurs when the user pushes the button to call the preset, since the selection of the imported sound file for them is determined by the preset function.

Expectations and results

1.Visual-sonic congruence

In order to imitate the general behaviors of acoustic instruments, the congruence between visual and sound was considered as an essential aspect of the sensor instrumental design. I supposed that the design of a real-time data stream from the sensors to the generators via the mapping system would enhance the congruence between visual and sound, as this design enables a sound to react to the specific types of gestures in real-time. This real-time reactive system was expected to bring out two important aspects to achieve the congruence. First, there is no perceivable time-delay between a gesture and a sound triggered by the gesture. A motion detected by the system is immediately analyzed, then, reflected to the synthetic parameters. Therefore, an audience perceives that a sonic event is triggered by the physical motion. Second, qualities of a motion are reflected to sound. For example, the size of a gesture is reflected to the loudness of a sound. This synchrony enhances the quantitative aspect of the congruence. By these two means, this real-time reactive system of this instrument strived to accomplish an intimate synchronization between gesture and sound.

The result of this system was successful for the reason that the congruence between physical gesture and sound was perceivably demonstrated from both aspects of time and quality. The immediate response of the instrument made it possible to play diverse sonic events within short interval durations. The qualitative synchrony enabled me to introduce theatrical aspects during performance. For these reasons, I think that the result of this system was successful from an aspect of visual-sonic congruence.

2.Variability of reaction

In addition to the congruence between visual and sound, from a composer's point of view, the possibility to vary reactions of the instrument was also an important aspect to extend a design of the instrument beyond acoustic instruments. The implementation of Dynamic Divergent Mapping was expected to vary the instrument's reaction even on a single type of gesture. This feature was supposed to be used in order to create a transition of musical atmosphere from one section to another.

The result of this feature was even more fruitful than my original expectation. Because this feature made it possible to adapt the software not only to a single composition, but also to more than one composition, as Dynamic Mapping was able to switch an atmosphere of music from one to another extremely drastically. For this reason, the software part of the instrument was able to be adapted to various pieces by only changing presets, which affect mapping between the parameters from the sensors and the synthetic parameters. Therefore, it is possible to state that the variability of reaction achieved a possibility to standardize the software part of the instrument.

Conclusion

My sensor instrument was built for the aim of the enhancement of liveness. The entity of the performer is regarded as an essential factor of a live situation. Thus, the congruence between what an audience observes and what they listen to could be the central issue to highlight the specialty of a live situation. As an approach, I proposed Dynamic Divergent Mapping. This means a system, in which the mapping between a sensor and synthetic parameters changes dynamically. This mapping strategy is beneficial to enhance the liveness for two reasons. First, the sonic-visual congruence is easily achieved. The Divergent Mapping enabled the instrument to react to the player's gesture in real-time. This fact results in the intimate synchronicity between a gesture and a sound. Second, the course of a performance can be handled by the performer's decision. This property enabled the instrument to be adapted not only to a single section, but also more than one section, or even other compositions. This flexibility enabled the performer to make a decision about how long a performance of a composition should be. The hardware part of the instrument was built mainly by a gyro sensor, accelerometer, two buttons and an Arduino Uno, which works as a mother board, receiving data from the sensors and buttons. The software part was programmed on Arduino IDE for the code for Arduino Uno, and Max for sound analysis and synthesis. The Dynamic Divergent Mapping was implemented on Max. This Map patch allows users to flexibly alter the mapping according to presets, which are stored by a user and loaded by pressing the buttons. By these features, my sensor instrument achieved strong congruence between visual and sound, and brought out the possibility to introduce a theatrical aspect in my compositions for this instrument.

Chapter 3

Subject-Vs-Subject Model

Subject-vs-subject model remarks the specialty of a live situation from the aspect of how these two performative embodiments interact with each other. This model is not a contradictory model to the subject-to-object model. Instead, it is a model, which stands on the subject-to-object model, since the subject-vs-subject model also includes performative embodiments, who induce an audience to appreciate a performance from an aspect of how competent each player handles an instrument to produce sonic allures, which is a specialty in a live situation whose setting is subject-vs-subject model. In addition to the sense of performance in the subject-to-object model, the subject-vs-subject model conjures up an extra property in performance: interaction between performative embodiments.

Candle Organ

Concept

Candle Organ is a sound-visual installation, which explores an Open Interaction between visitors and a system of the installation. The Open Interaction occurs in such a way that the visitors freely place each candle around in an arbitrary position on a table, thereby, the system differentiates a chord dependent on the candles' position, brightness and number. Since this differentiation of the harmony motivates the visitors to further changes of a state of the candles, this installation creates a recursive interaction between the visitor and the system.

Realization

The required set-up is illustrated in figure 4. The system consists of the following equipment;

- candles
- a table, on which the candles are placed
- a webcam, which captures the candles on the table
- a computer, which translates the image captured by the webcam to sound
- an audio interface, which transmits sound from the computer to a loudspeaker

- the loudspeaker, which produces sound streamed from the computer.

In addition to this hardware, the computer requires a software, MaxMSP, for visual and sound processing. The equipment is set up as illustrated in figure 4.

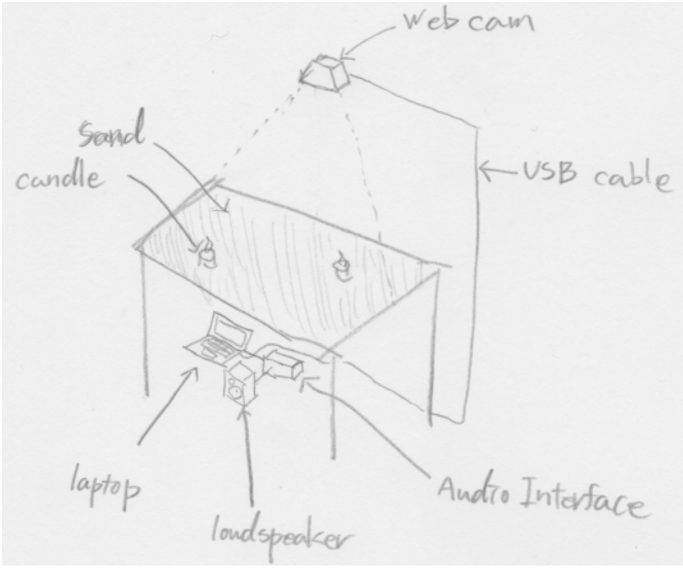

figure 4. set-up of Candle Organ

The system works in the following workflow. First, a visitor places a lit candle onto a table. Then, the webcam constantly sends the computer a video stream capturing the state of the surface of a table, on which the candles are placed. Once, the captured video stream is transmitted to the computer, the computer translates it into sound in such a way that a program for visual processing in Max analyzes the video stream in real-time. The translated sound is sent to the loudspeaker via the audio interface under the table.

The program in Max divides the incoming video stream into 768 cells on 32 columns by 24 rows, and results in the brightness of each cell. The brightness of cells in a single column is summed up, and the total brightness is assigned to a volume of a sine oscillator in such a way that the darkness results in complete silence and the brighter a state of the column is, the louder the sine oscillator produces sound. The address of each cell is mapped to the pitch of the sine oscillator in such a way that 32 subdivided columns from left to right in the video stream are mapped with the three octaves of a diatonic scale from the one octave above the middle C to the 2nd octave above that. In combination with the mapping between the brightness of each column and volume, and that between the address of each column, the system produces a sound according to the position and brightness of the candle. This system is capable of producing a proper sine tone regardless of the number of candles. Therefore, this provides the possibility to create a unique chord progression by changing positions and brightness of multiple candles.

Presentation

This piece was exhibited on 12 and 13 December, 2015 at St.Andra Church in Graz, Austria at an event organized by Some Designer, an artist collective, to which I belong as a co-founding member. We received several visitors, who came up to the church by chance as well as the ones, who visited for the artistic event. Both types of visitors spent certain amounts of time with this installation in order to enjoy playing unique chords by using the candles with their own hands. They wanted to understand the design of the installation and to talk about what impressed them with us.

How did this installation enhanced uniquenesses of the church?

This installation enhanced the value of the church by introducing interactivity into two symbolic specialties of this religious venue: the candles and the chordal harmony. Letting the visitors play the chordal harmony through repositioning the tea-lights, the Open Interaction succeeded in grabbing the visitors' intellectual curiosity for a long time, as they tended to spend, at least, more than three minutes for this installation, and some of them have repeatedly come back to the church in order to play with this installation.

The video recording of the exhibition is uploaded onto the following link;

https://www.youtube.com/watch?v=ZOAfmoB9WAY

Beyond the eternal chaos

Concept

After the emergence of recorded media and broadcasting of music, liveness in a musical rendition became an essential aspect to distinguish between a concert setting and audio playback by using a playback device. In the realm of computer music, this distinction increased the significance of the performative settings such as sensor instrumental performances and mixed music, in which acoustic instruments and electronics are combined. However, such settings brought out a new issue - how to fill a gap between electronics and instruments.

My piece, *Beyond the eternal chaos for a solo flute and electronics*(2014), is dedicated to resolving this problem by achieving a relevant interaction between the instrumental and electroacoustic part. An organic interaction needs certain rational responses. For example, a conversation "Why is the train delayed?" "No, I haven't had a breakfast." is not usually regarded as a relevant dialogue, since they are not sharing a context. Similar to verbal communication, a musical interaction also needs, first, to share a context with the preceding and the following sonic events, and, second, that each entity has an identity, which makes it possible to make its decision by itself for achieving relevance.

A major approach to achieve relevant interaction is the use of real-time signal processing in mixed music, in which an instrument and electronics are combined. This approach makes it possible to produce electronic sound in such a way that an instrumental sound produced in performance is amplified, processed or transformed in real-time, so that, the listener can understand the electronic part in association with the instrumental part, so that, the instrumental and electroacoustic part are contextualized. However, this setting brings out the following two problems in achieving interactivity in mixed music.

First, real-time signal processing is likely a passive system. Real-time signal processing is mostly not designed to produce a musical event timed prior to the performer's action during the course of a piece, since the real-time signal processing systematically needs an incoming signal stream from a sounding body to produce a sound. This means that the electronic part cannot act on the instrumental part before the instrument produces a sound. As a result, sonic events in an electronic part are generated always after the sonic event by instruments during the course of music. This is contrastive to the fact that the instrument can act on the electronic part both before and after a sound in the electronic part is produced. I call this problem Reciprocity.

Second, this passive system reacts to the instrumental part often in an irrelevant musical language. For example, the use of a recursive feedback effect produces occasionally an atmospheric soundscape, whose role is musically a backdrop, even though the instrumental part is playing simultaneously, for example, a melody, which prominently grabs listeners' attention. This difference of the musical languages causes a lack of relevance between the instrumental and electroacoustic part. I call this problem Relevance.

These problems made me envisage two ambitions: the implementation of an active computer system, which can be committed to the instrumental part in a musically relevant manner, and the use of a common musical language between the instrumental and electroacoustic part.

Pseudo-Agent

In order to clarify the requirements of the active computer system, the concept of Agent[5] was referred to. Agent is a concept established in the field of artificial intelligence in response to the question, how to build an autonomous computer system, which can make a decision as if it were a living human. An Agent can be defined as a subject, which has the following four properties;

- *autonomy*: an Agent operates without the direct intervention of humans or others, and has some kind of control over their actions and internal state;
- *social ability*: an Agent interacts with the instrumental part via some kind of communicable language;
- *reactivity*: an Agent perceives the action by the instrumental part through some kind of tracking device such as a combination of a microphone and a pitch detector, and responds in a timely fashion to changes that occur in it;
- *pro-activeness*: an Agent does not simply act in response to their environment,but they are able to exhibit goal-directed behavior by taking initiative.

I found that these four properties of an Agent are what the active computer system should acquire in order to solve the problems of Reciprocity and Relevance.Autonomy and social ability are for solving the problem of Relevance, reactivity and pro-activeness are for Reciprocity.

Agent is not an unprecedented approach to an active computer system. A typical example of the use of Agent is again Voyager, since a human instrumentalist and an autonomous computer system interact with each other in real-time in performance of the piece[6].

However, although this project resulted in a relevant interaction in an improvisatory performance, there is a problem in terms of demonstrability of its Dynamic Structure: its real-time deterministic process is imperceptible for listeners, since a computer is a blackbox, which can both live-generate a sonic event in response to what it perceived and to reproduce a pre-composed sonic event without regard to what it perceives. For this reason, the truth about the real-time deterministic process relies on the listener's belief, instead of what the computer apparently demonstrates. In other words, the computer can cheat as if it is making a decision in real-time.

This problem can be avoided if the piece is exhibited in a form of interactive installation, since listeners can observe reciprocity between the active computer system and themselves. Another solution would be to perform the composition more than once in a concert, so that the listener can perceive how the reactions from the system are differentiated by the live factors in each performance. However, a piece only rarely gets a chance to be performed twice in concert. Thus, the concept of Agent can be easily imperceptible in musical rendition.

In addition to the problem of imperceptibility, there is another problem: although the electronic part can be dynamically structured in every performance by using the active computer system, the instrumental part of a mixed music composition is fixed as long as it is notated on a conventional score. This constrain results in narrowing down the extent, where the active computer system can display its self-made decision during a musical rendition.

My solution for these problems is to focus only on a sonic aspect, disregarding a procedural aspect, meaning whether or not a computer is making a decision in real-time. This leads me to a vision to compose a fixed electronic part, which sounds as if fulfilling Reciprocity and Relevance, instead of building a self-deterministic system. I call this approach Pseudo-Agent.

With the concept of Pseudo-Agent, the structure of a composition should no longer be dynamic. Instead, it should be well-planned in order to conjure up an illusion as if the notated instrumental part is organically interacting with the fixed electronic part. For this reason, some kind of taxonomy about the relationship between an instrument and electronics is needed for my compositional practice.

Taxonomy about relationship between instrument and electronics

John Craft's publication "Thesis on liveness"[7] proposed a referential taxonomy, which comprehensively classifies types of relevance between an instrument and live electronics from an aspect of how close or remote the relationship between a performative effort and an electroacoustic sound is. According to this taxonomy, the modes of relationship in between are classified into the following five categories;

- *Backdrop*: This is the most remote category. This category means a musical situation, in which an instrumental contour is played in front of an atmospheric sound cloud. For example, a sound of flute in a rainforest. In this type of combination, there could be some contacts between these two. However, these two do not play an identical musical role;
- *Accompanimental*: This is the same as the conventional relationship between a singer and the piano in a song: while the singer plays a solo part, the piano accompanies to support and/or illuminate the contour;
- *Responsorial/proliferating*: This category is for an antiphonal relationship between the performative effort and electronic sound. In response to a sonic event by an instrument, a computer reacts with some sounds and vice-verse;
- *Environmental*: This is an emulation of an acoustic environment by using an electronic techniques such as resonators, reverberation, and filters. In this category, the electronic sounds are typically triggered by the instrumental action. An example would be a reflection of a percussive attack played by a timpani in a cave;
- *Instrumental*: This means to create an electronic instrument. The relationship between the player and an instrumentalist is extended by means of electronic technologies.

Although this classification was proposed in order to explain the relationship between an instrument and live electronics, which do not typically have the two properties of Agent, *autonomy* and *pro-activeness*, I found that these five categories about remoteness between an instrumental and electronic part could be a basis for planning Reciprocity and Relevance in an interaction.

Modes of interaction

This paragraph reveals modes of interaction in each section of this composition. The recording and score of this piece is available below;

https://www.dropbox.com/s/5th7i805xmm5qy2/BeyondTheEternalChaosST.mp3?dl=0

https://www.dropbox.com/s/6ba0l7r11d6nbku/Score5.pdf?dl=0

This piece consists of three sections, which are performed without a rest. Each of these three sections shows a different kind of mode of interaction between its instrumental and electronic part. Figure 5 illustrates a transition of remoteness over time.

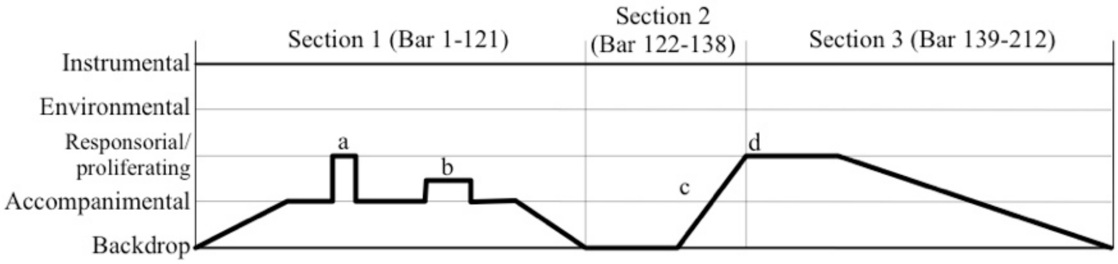

figure 5. Transition of remoteness between instrument and electronics

Section 1 starts from Backdrop - a relationship, in which both the instrumental and electronic part are rather unrelated to each other in a sense that, whereas the flute repeats percussive key noises, the electronics perform a continuous drone sound. After this introduction, the following part in this section (bar 5-51, 54-83 and 91-121) shows an accompanimental relationship in between. The flute continues to mainly play the percussive sounds, which are accompanied and ornamented by electronic sounds. The part “a” in the graph (from bar 51-54) is, where the line indicating the remoteness jumps up. This means that there is an electronic solo, which takes over the role of prominent

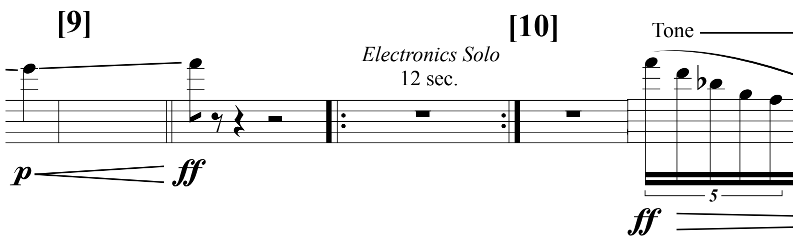

figure 6. An alternation of prominency between the flute and electronic part

player from the flutist in the preceding and following part(figure 6). This alternation of the prominent musical role sounds as if an antiphonal relationship, which may be called *Responsorial.* The part "b" (from bar 83 to 90) is where the remoteness is in between *Accompanimental* and *Responsorial/proliferating*. This is because contours played by the flute are granulated by means of real-time signal processing in order to produce a sound cloud, which is categorized into *Proliferating*. In the end of the first section, a massive noisy succession fades-in gradually in the electronic part. This successive sound fills up the entire spectral range, making the flute sound almost inaudible. Therefore, the relationship is the remotest.

Section 2 starts from bar 122 as a continuation of section 1. After the massive noisy succession disappears, the remoteness shifts gradually from *Backdrop* to *Proliferating* in the part "c" (bar 134-137), since the processing gradually starts to duplicate the instrumental sound.

Section 3 begins with antiphonal handovers of a single contour between the flute part and electronic part as exemplified in figure 7. The flute and electronics co-render a single contour by crossfading a part of the contour. Gradually, the contour becomes not handed over, but overlapped with each other toward the end of the piece, and so, the relationship in between changes from *Responsorial* to *Proliferating* (not distinctively represented in the graph, since these are regarded as the same category) and finally to *Backdrop* because of an extreme granulation, which blurs a sonic character of the original flute sound.

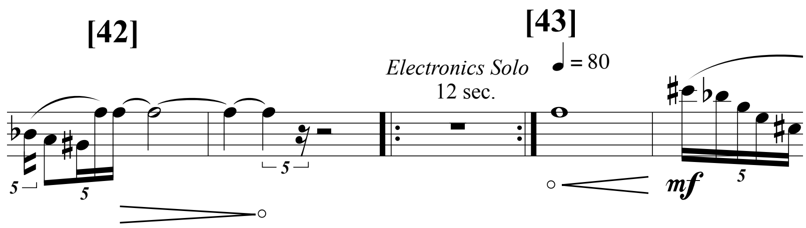

figure 7. An example of antiphonal handovers of a single contour

Conclusion

This piece aimed to achieve Dynamic Structure by means of Open Interaction in subject-vs-subject modeling. Looking into the problems to use real-time signal processing as an approach to create organic interactions with a living human, which seems an essential precondition to bring about liveness, I pointed out the two insufficient properties to make a computer capable of organic interactions: Reciprocity and Relevance. In order to achieve these properties, the concept of Agent - an autonomous computer system, which can make a decision by itself - was referred to. Although the four properties of Agent are required for achieving Reciprocity and Relevance in interactions, the fact that a composition is generally performed only once in a concert makes its real-time self-deterministic process imperceptible. For this reason, it makes sense to focus only on the sonic aspect of Agent, instead of the procedural aspect of it. Therefore, a question was not how to implement an Agent, which can recognize and react on another performer, but what is the relationship between the instrument and electronics, which sounds as if they are communicating with each other. As a possible answer, I propose a concept, Pseudo-Agent: a computer, whose behaviors are predetermined, and so, not recognizing the intension of other performative subjects, but still simulating pretense interactions with others. As a possible approach to achieve a social ability, I referred to John Craft's taxonomy, which classifies several modes of relationships between a performative gesture and live electronics into four categories dependent on their remoteness: *Backdrop, Accompanimental, Responsorial/proliferating, Environmental* and *Instrumental*. Applying these modes to my composition practice, this piece features several modes of interactions, and their transitions.

Audible Playground

Concept

Audible Playground(2016) was composed to explore Constrained Interaction between a soprano saxophone and environmental factors enhanced by the use of live electronics, in which real-time signal processing and a feedback loop between a microphone and loudspeakers are combined. The resultant sound in this piece is differentiated independent of the environmental factors such as room acoustics, distance between the microphone and loudspeakers, angle of the microphone against the loudspeakers, frequency response of the loudspeakers and that of the microphone. The saxophonist is required to react and „pre-act" on the responses from the feedback system, following a ruleset given by the composer in each section.

Design of Performative Subject

In addition to the environmental factors, the feedback system applies some of the real-time signal processing to the sound stream from the microphone such as a overdrive, granulator and limiter. The overdrive is used to enhance the volume of sound from the microphone, so that the system can capture even subtle sound. The granulator is employed for spatialization and transformation of sound from the microphone. The limiter equalizes the volume over time so that the feedback system can stably sustain a feedback loop without unintentional bursts and die out of feedback sound. The parameter settings of these effectors change section by section throughout the piece.

In terms of the configuration, the loudspeakers are placed at diagonal positions in a room, facing each other. The microphone is attached to the bell of the soprano saxophone. Throughout the piece, the saxophonist moves around the space between the loudspeakers in order to elicit a change of the feedback sound as illustrated in figure 8. This configuration is, together with the real-time signal processing, an essential mechanism to characterize the resultant sound such as its pitch, spectrum and volume.

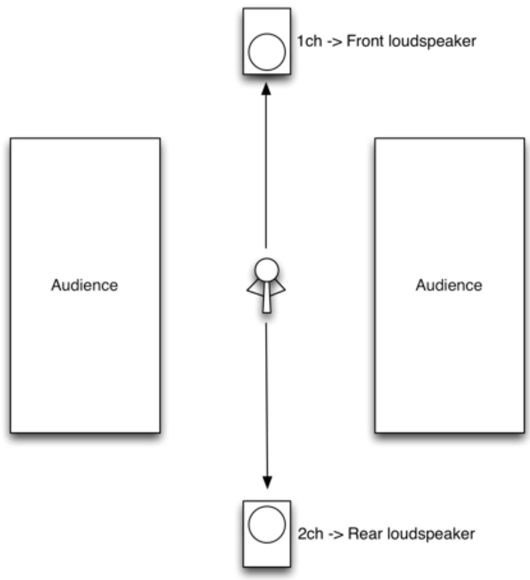

figure 8. configuration of the Performative Subjects

Time structure

The time structure of the piece is roughly predetermined, and its details are improvised by the saxophonist and the feedback system. The piece consists of seven sections.

Demonstrability of Dynamic Structure

The use of the feedback loop contributes to demonstrate Dynamic Structure of the piece in such a way that the mechanism of feedback clearly shows the relationship between a causal action by the saxophonist and resultant reaction from the feedback system. For example, in section 1, a change of the resultant sound is triggered by a change of the physical and spatial states of the saxophone, as well as the acoustic property of sound produced by the saxophone. More precisely, the saxophonist is required to play a slap tongue after every move in combination with repositioning back and forth between the two loudspeakers, twisting left and right and leaning forward and backward. These types of motions and the sound quality of the slap tongue affect the pitch, timbre and amplitude of the resultant sound from the feedback system. A change of the distance between the loudspeakers and microphone and the angle of the microphone differentiates how the sound of slap tongues are processed over the feedback loop. Therefore, listeners can understand relevance between the saxophone's part and electroacoustic part.

Reciprocity

The reciprocity is assured by the predetermined design of the interaction between the saxophonist and the feedback system. The previous paragraph already explained how the electronic part reacts to the instrumentalist's „pre-actions“ in section 1. As well as the feedback system, the saxophonist also reacts on sound from the feedback system under certain rules sometimes in the piece. An example is section 4, in which the performer is required to produce a specific pitch of long sustained sound in response to the prominent pitch generated as a result of feedback loop. The pitches, which should be randomly chosen, however, must relate to the feedback tone in one of the following ways; sounding in unison, sounding a major second higher or lower, sounding a perfect fourth higher or lower, or sounding a perfect fifth higher or lower. This means that the saxophonist has to carefully listen to the reactions from the electroacoustic part in order to decide his/her following reaction to the electroacoustic part. Therefore, as a consequent, the relationship between the saxophone and the electronics becomes reciprocal.

Notation

Conventional notation has evolved to fix the structure of a composition on both the time and pitch axes. This evolution contributed to the reproduction of the same musical rendition in every performance. However, this reciprocal interaction between the saxophonist and the environmental factors does not require a detailed sequence of events in the piece, but to improvise to produce the detailed sonic events in relationship with reactions from the feedback loop. Therefore, the conventional aesthetics of a score are incompatible in making the piece reproducible.

In response to the problem of this real-time deterministic process, the piece is notated in a way that combines both graphical and text form. The graphical score indicates the rough sketch of each event during the course of the piece, whereas the text score instructs how the saxophonist has to behave and react to the feedback system in each section. In other words, the fixed part of the piece - sequence of the sections - is notated on the graphical score, and the dynamic part of the piece - real-time deterministic process - is notated on the text score. The combination of both formats fulfills the requirement to notate this piece: the entire time structure is fixed, and the details are improvised under certain rules.

Conclusion

This piece explored Constrained Interaction between the saxophone's part and electroacoustic part. By using the feedback system, which incorporates the physical and spatial states of the performer and the loudspeakers, the piece made the reaction from the electroacoustic part perceivable, as the change of the sound is according to physical law. Additionally, the saxophonist reacts in response to sound from the feedback system under certain rules, so that the reciprocity between the instrumental part and the electroacoustic part is fulfilled. Since this reciprocal interaction is a real-time process, the conventional notation is abandoned. Instead, a combination of graphical and textual notation is used. Through these explorations, this piece contributes to the compositional practice to make Dynamic Structure reproducible without losing the incorporation of the live factors.

Chapter 4

Future work

Game Piece

Game Piece is a compositional approach of constructing a sequence of events as a result of a real-time interaction between performers according to a specific ruleset, much like a sporting event. A specialty of this approach is the capability for Dynamic Structure to be used, as this can reflect performers' actions in a real-time generative process of its compositional structure such as a sequence of sonic events and a combination of instruments. This could be my further research topic.

Game Piece belongs to Constrained Interaction, since the ruleset tends to restrict modes of interaction between performative subjects. For example, a Game Piece, *Duel*(1959) for two conductors and two orchestras, composed by Iannis Xenakis has a strict ruleset[9]. A combination of conductor and an orchestra is grouped as a team and they compete with another team. A single course of this piece has several rounds. Each conductor choses instantaneously an event out of the 6 different musical events in every round. The combination of two events played simultaneously by the two orchestras is evaluated in the light of a few subjective criteria, which have been prepared by the composer. After playing several rounds, the team who has acquired the higher score is regarded as the winner of the game. By this strategy, the piece acquires a flexibility to alter its time structure according to the interaction between the two orchestras.

However, this approach has posed several questions in terms of its demonstrability and reproductivity. First, although the ruleset is clearly formulated, this is hardly recognized by listeners, since the listeners cannot communicate with the table of subjective evaluators, which are necessary to win the game. This problem is caused by the fact that the processes of evaluations are not demonstrated in an audible, visible or any perceptible way during performance.

This problem of imperceptibility was mentioned in Chapter 3. In my piece, Beyond the Eternal Chaos, this problem disregarded the concept of Agent, as the imperceptibility basically makes the real-time decision-making process indistinguishable from a prefixed pretense interaction between two performative subjects. In hopes that the perceivable demonstration of the real-time generative process of a game highlights the specialty of a live setting because of the incorporation of the performer's decision into the structure of a piece, it is beneficial to implement some kind of heuristic process through which listeners can glean under what kind of ruleset the players are competing.

My piece *Tongue-Twister Competition*(2016) contributes to this issue of demonstrability.

Tongue-Twister Competition

This piece was composed for Ensemble Intercontemporain without electronics in 2016 for a concert during the Manifeste Academy 2016 at IRCAM in France.

This piece explores Constrained Interaction between performers in an ensemble by applying the concept of Game Piece. A live factor focused on in this piece is performers' competence to play musical phrases as fast as possible. Referring to the general rules of Tongue-Twister - a game, in which players compete with each other to be the fastest player to pronounce a verbal phrase, which is difficult to articulate properly - , this piece is composed as a tournament competition consisting of several rounds, in which each instrumentalist has to play a given musical phrase as fast as possible.

This piece consists of the following four types of sections; Competitive section, Judgement section, Fixed section, and a Grand winner's presentation section.

In the competitive sections, performers are required to play the notated phrase as fast as possible without intended synchronization with other players performing together. In the Judgement section, a conductor has to judge who played the phrase the slowest in the preceding competitive section. The player who are judged as the slowest (in other words, a loser) has to move from the stage to the auditorium. While the player is moving to out of the stage, the player is required to play the following fixed section only when it is feasible. In each of the first 9 rounds, a player is disqualified from participating in the following competitive sections. After that, the game goes into the final rounds. Final rounds consists of a series of competitive sections at which two top candidates compete with each other. The conductor is required to count how many times each player wins throughout the final round, then, needs to determine the ground winner right before the beginning of the grand winner's presentation section.

Fixed sections are played by all instruments including pre-disqualified players. While the winners play this section on the stage, losers play this in the auditorium.

Judgement section is where the conductor judges and points to the loser of the preceding competitive section. Since the players are required to sit down on their seat after playing the competitive section, the conductor can ideally recognize who was the loser at the competition. If the loser was ambiguous, the conductor has the right to decide the loser imperatively. Judgement sections must be played as short as possible. At the beginning of the last fixed section, the conductor has to indicate who is the grand winner.

Grand winner's presentation section is where the ground winner plays the notated phrase as perfectly as possible.

Its demonstrability is investigated in such a visual way that the performer has to stand up during each Competition section, and has to sit down as fast as possible right after finishing a given phrase in the Competition section so that the slowest instrumentalist sits down at the latest section which should be easily visible for listeners. Additionally, although this process to determine a loser is not listener's intrinsic knowledge, they have several chances to glean this process by attentively listening and watching the course of the events on the stage, since this process is repetitively displayed in every competition section. Gradually, the listener can recognize a principle that one player is dismissed from the following competition sections after finishing a given phrase last.

For the future

From the example above, it is possible to point out two approaches to the clear demonstration of the ruleset of a game: repetition and multimedia. In terms of repetition, this works as a heuristic process, through which a listener can come to understand the ruleset of a game piece. Through observing similar kinds of action, the listener can comprehend a principle of the ruleset applied to the players in a piece. Regarding the use of multimedia, some principles can be explicitly demonstrated not by sonic actions, but by spatial or physical actions. In the case of my composition, the fact that a player is the slowest is represented by his/her spatial motion from the stage to the auditorium. Thus, the rule of disqualification was not only audibly, but also visibly explained. At this point, the use of computational technologies might facilitate the development of the idea of multimedia representation of the ruleset of a game. Since, the computer is capable of mapping visual elements to sound in real-time. A system for a future composition might posses more communicable demonstrability for the listeners.

Another problem that this piece revealed was the problem of notation. Conventional notation has evolved to fix the structure of a composition on both the time and pitch axes. This evolution contributed to the reproduction of the same musical rendition during every performance. However, Dynamic Structure and a possible approach, Game Piece, requires a real-time generative process for organizing a sequence of events, which is fairly incompatible with the conventional aesthetics of notation. In the case of Tongue-Twister Competition, the dynamic part was only a combination of instruments in each competition section. Therefore, a solution was to notate a phrase for all of the instruments, who will potentially play it in the competition section. However, once the idea of Dynamic Structure is applied not to the combination of instruments, but to something which influences the order of the sections, the conventional score is not capable of representing what the piece wants the player to do. Therefore, as a further development of Game Piece, an animated score might be a relevant approach.

For the problem of demonstrability and notation, the use of a computer seems an eloquent approach. In my following projects, I would like to work on these problems with the use of a computer.

Chapter 5

Conclusion

This thesis dealt with several approaches to the enhancement of liveness by using computational technologies. The first chapter clarified what liveness means, and pointed out the importance of the Dynamic Structure. Two models of Dynamic Structure are proposed: subject-to-object model and subject-vs-subject model. For subject-to-object model, a sensor instrumental performance is explored as a practical approach as explained in Chapter 2.

For subject-vs-subject model, the author pointed out the importance of interaction between Performative Subjects for achieving Dynamic Structure incorporating unique live factors at a performance venue. As practical approaches, three projects are elucidated: *Candle Organ*, *Beyond the eternal chaos* and *Audible Playground*. Each piece explored interactivity in a different way.

The sound installation, *Candle Organ*, explored Open Interaction, in which the visitor is naturally motivated to reposition the table-light placed on a table in response to the sonic reaction affected by the repositioning the table light.

The mixed music piece, *Beyond the eternal chaos for a solo flute and electronics*, explored an organic relationship between a flute and electronics by using the combination of prerecorded sound files and real-time signal processing. Pointing out the impossibility to demonstrate the real-time deterministic process in musical format, and the importance of audible relevance between instrumental sound and electroacoustic sound, the piece includes several modes of pretense interactions during its course. I call the computer playing such pretense interactions Pseudo-Agent.

The mixed music piece, *Audible Playground for a soprano saxophone and electronics*, investigates the reciprocal interaction and a possible notation method of Dynamic Structure. The use of a feedback loop makes it possible to demonstrate how the feedback system reacts to the performer's action in a perceivable way. Together with the rules of how the saxophonist has to react to sound from the feedback system, this piece renders the reciprocal interaction between them. Since this piece predetermines the sequence of sonic events only roughly, and the details of the events are structured through the improvisation between the saxophonist and the feedback system in real-time, a combination of graphical and text style score was used for its notation, instead of the conventional notation.

As an additional possibility, the thesis mentions the concept of Game Piece. Since Game Piece can produce a sequence of events through Constrained Interaction, this is a possible approach to Dynamic Structure. Combining some computational technologies, Game Piece might be able to obtain an even clearer demonstrability of Dynamic Structure by using multimedia, and the liberation from the restriction of design of ruleset. This is caused by the restrictions of conventional notation which was originally developed to fix the sequence of events in a composition by using an animated notation system.

Throughout these attempts, this thesis presents several approaches to Dynamic Structure. These approaches will hopefully enhance the value of concert venues, and consequently, will serve as a unique listening experience by using a listener's playback device. It is my wish that the aesthetics of enhanced liveness will reinforce social communication.

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