Transition of Instruments in The SINE WAVE ORCHESTRA

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The SINE WAVE ORCHESTRA (SWO)

This article discusses the transition of instruments in The SINE WAVE ORCHESTRA (SWO), which is a participatory sound performance project. Its basic concept is that each participant plays a sine wave, to collectively create a sound representation. Although all SWO works use the same sound source (i.e., sine waves), each SWO work employs different instruments. The employment of various instruments results in different styles of collective sound representation. This article examines five of the instruments utilized in SWO works. In The SINE WAVE ORCHESTRA The Stairway, the participants played sine waves with light-sensitive instruments as well as other instruments. In The SINE WAVE ORCHESTRA stay, participants accumulated sine waves in an echoless chamber. In The SINE WAVE ORCHESTRA nomadic, each participants played and exhibitied a sine wave with a Linux-installed Pod. At The SINE WAVE ORCHESTRA at ZeroOne San Jose/ISEA 2006, each participant played a sine wave with a hand-held plastic egg instrument; in The SINE WAVE ORCHESTRA mediate, participants extended the recursion of sine waves with eight sets of boards. In this article we discuss which elements of the instrument affect how people create collective sound representations and describe the participants' experience with the instruments.

Categories and Subject Descriptors: J.5 [**Computer Applications**]: Arts and Humanities—*Performing arts (e.g., dance, music)*

General Terms: Design, Experimentation

Additional Key Words and Phrases: The SINE WAVE ORCHESTRA, participatory sound performance, collective sound representation, participant, instrument

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1. INTRODUCTION

The SINE WAVE ORCHESTRA (SWO) is a participatory sound performance project that has been performing at various exhibitions, for both long and short periods of time since 2002 [http://swo.jp/]. The authors have served as

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the core organizers of the project. Under the basic concept that each participant plays a sine wave by changing its frequency, volume, position, and/or duration, people are invited to create a sea of sine waves as a collective sound representation.

Barthes [1977] divided music into two categories: music for performing and music for listening. Music for performing occurs when people subjectively engage in the creation of sound, while listening has only a subordinate role. Music for listening occurs when people engage passively to the sound representation by listening. Barthes argues that from the arrival of bourgeois democracy, those who relate with these two musics came to be distinguished as the performer and the listner. In SWO works, the boundary between the performer and the listener is blurred. Each participant is a performer to other participants, and is also a listener to other participants. The instruments in SWO works enable the creation of the sound representations (i.e. sine waves) that are not only for performing but also for listening.

Although all SWO works use the same sound source (i.e. sine waves), each SWO work employs different instruments with different temporal, physical, environmental, and procedural settings [Jo et al. 2005, 2006, 2007]. The different instruments result in different styles of collective sound representation. This article examines five of the instruments in SWO works and discusses which elements of the instrument affect how people create collective sound representations. Our initial explorations reveal a number of considerations for the design of instruments for collective sound representation.

2. BACKGROUND

Tanaka [2006] makes a distinction between “tool” and “instrument”: A tool is an apparatus for a specific task that should be easy to use, and should get better as it attains perfection at realizing its tasks. But an instrument is not meant to carry out a single well-defined task. It is not necessary that an instrument be perfect as it is for it to display distinguishing characteristics, or “personality” [Tanaka 2006]. Even when the instruments in works by SWO only produce the same sound source, each instrument has its own character, with different controllers, display environments, number of participants, and styles of participation, and the resulting collective sound representation is distincti for each SWO work.

The instrument for producing sound is a unity of sound source and interface [Bongers 2007]. In an acoustic instrument, the playing interface is tightly coupled to the sound source. But in electronic and computer instruments, the interface is usually completely separated from the sound source, and the relationship between them has to be defined. How we choose the interface and the relationship affects the perception and the playability of the instrument [Hunt 2002]. Examining five of the instruments with different interfaces and relationships in works by SWO will allow us to focus on those elements in the instruments that affect how people create collective sound representations through the same sound source.

Fig. 1. (From left to right): The Stairway of The SINE WAVE ORCHESTRA; The SINE WAVE ORCHESTRA stay; The SINE WAVE ORCHESTRA nomadic; The SINE WAVE ORCHESTRA at ZeroOne San Jose/ISEA 2006; The SINE WAVE ORCHESTRA mediate.

Fig. 2. The Stairway: The SINE WAVE ORCHESTRA.

3. INSTRUMENTS IN THE SINE WAVE ORCHESTRA

Figure 1 shows snapshots of the five instruments used in works by SWO, which we will describe in detail below.

3.1 The Stairway of The SINE WAVE ORCHESTRA

The Stairway of The SINE WAVE ORCHESTRA (SWO-stairway) took place at the NTT InterCommunication Center on19th June 2004 as a part of the n_ext exhibition (see Figure 2 and SWOstairway.mov).

The instrument consists of an oscillator, a CDS photocell, a speaker, and a battery within a hand-held plastic sphere. The frequency and volume of the sine wave changes depending on the amount of light the instrument receives (see Figure 3).

The public were invited to participate via website and mailing list announcements; passers-by at the site were invited as well. The organizers provided the participants with 50 instruments, and some people brought their own as well (e.g., laptop PCs and synthesizers) to play sine waves at varying frequencies and volumes.

About 200 participants came to the performance, and played sine waves on the instruments for about two hours around sunset in the large hallway by the stairs of the ICC building. As they played, they moved around the hallway and produced varieties of sine wave frequencies.

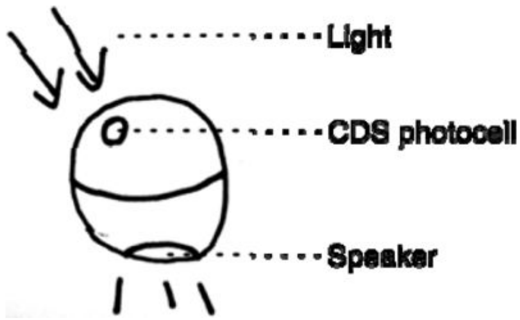

Fig. 3. The instrument for The Stairway of The SINE WAVE ORCHESTRA.

Fig. 4. The SINE WAVE ORCHESTRA stay.

The Oscillator, CDS Photocell, and Battery. The oscillator consists of an analog circuit. The CDS photocell mounted on the top of the sphere is connected to the part that controls the frequency and volume of a sine wave. Depending on the amount of light received by the CDS photocell, the oscillator changes the frequency and the volume of the sine wave. The range of frequency was set at about 420Hz to 480Hz, and the range of volume at about that of a whisper, at zero. If the CDS photocell receives no light, the sine wave will have no volume. The battery is used for the oscillator and lasts about a day.

The Speaker. The sine wave from the oscillator is output through a speaker mounted on the bottom of the sphere. There are holes at the bottom of the sphere, and if people cover the holes, the volume of the sine wave decreases.

3.2 The SINE WAVE ORCHESTRA Stay

The SINE WAVE ORCHESTRA stay (SWO-stay) was premiered at an open nature exhibition at NTT InterCommunication Center from 29th April to 3rd July 2005 (see Figure 4 and SWO-stay.mov).

About 8,000 people participated in this work during the exhibition period. The instrument was a set of controllers, the control engine, light, sound synthesis engine, and multiple speakers. The set of controllers is connected to the control engine. The control engine controls the light and the sound synthesis engine. The sound synthesis engine, connected to multiple speakers, synthesizes sine waves in real time. The multiple speakers are mounted on the wall

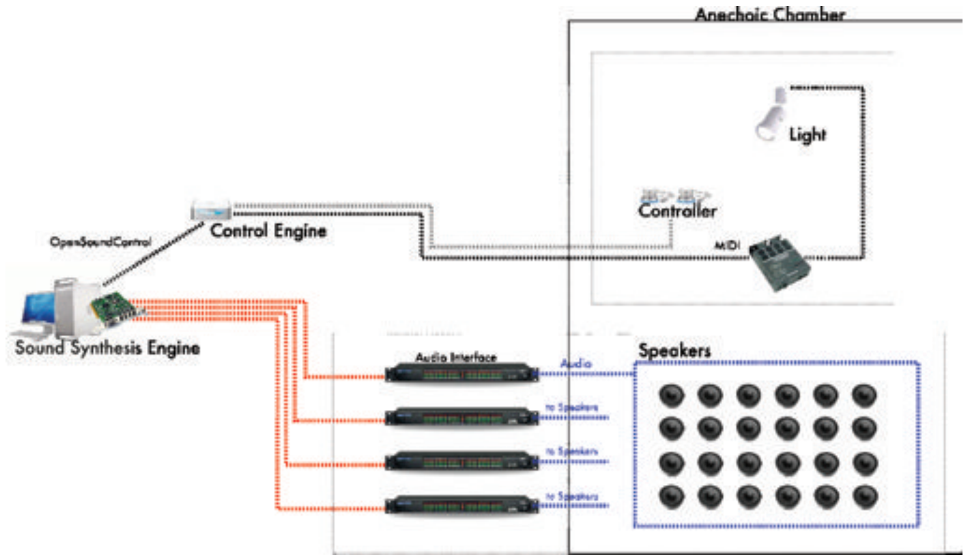

Fig. 5. The instrument for The SINE WAVE ORCHESTRA stay.

horizontally to encircle the participant. The controller, the light, and the multiple speakers are set in an 4m x 4m echoless chamber (see Figure 5).

When entering the room, each participant was exposed to a collective sound representation consisting of sine waves produced by the previous participants. When a participant touches the controllers, a new sine wave starts to play at a higher volume than the other sine waves. The brightness of the room also increases from the initial level. As a participant rotates the controllers, the frequency and position of the sound source of the sine wave changes. The participant then selects the frequency and the sound source position of his/her sine wave by pushing the controllers. That sine wave is then added to the sound field of the room. Then the volume of the sine wave is gradually decreased until it is equal to the other sine waves and the light in the room is gradually decreased to the initial level. The volume of the sine wave produced by each participant is gradually attenuated over a period of two weeks and disappears after the two-week period. As more participants enter the room and leave sine waves, more sine waves are accumulated. During the exhibition, the collective sound representation changed from a phase where each sine wave was discriminable to a cluster consisting of mutually interfering sine waves like white noise that contains all frequencies.

The Controller. SWO-stay sets two rotational controllers [Griffin Powermate [http://www.griffintechnology.com/products/powermate]] in the center of an echoless chamber. One controller is for changing the frequency of a sine wave from 100Hz to 12000Hz, and the other is for changing the position of a sine wave in an omni-horizontal direction through 116 speakers. To generate a release message for the sine wave after configuring these parameters, the participant presses both controllers. At that moment, the frequency and the position of the corresponding sine wave are fixed, and this control data is sent to the control engine.

The Control Engine. The control engine receives data from the controller and sends it to the light and the sound synthesis engines. It is implemented with MaxMSP [Cycling74]. The frequency and the position-control messages are only used for the sound synthesis engine. The release message of the sine wave is used for both the light and sound synthesis engines. After the release message is received, the control engine is locked in order to restrict multiple releases of sine waves from one participant.

The Light. A light is mounted on the ceiling. When it receives a release message from the control engine through a MIDI-based light controller, the brightness of the light is decreased in corrrespondence with the volume of the sine wave.

The Sound Synthesis Engine. The sound synthesis engine treats all sine waves produced by the participants, and is implemented with SuperCollider [http://www.audiosynth.com/]. The frequency and the position control messages from the control engine are transmitted through the Open Sound Control Protocol [http://cnmat.cnmat.berkeley.edu/OSC/], and used as parameters for real-time sine wave synthesis. The sound synthesis engine controls the frequency and the position of sine waves. The position is managed by changing the audio interface's output channel (116ch) [Motu 24. http://www.motu.com/]. Each audio interface's output is connected to one of the multiple speakers. When it receives a release message from the control engine, the frequency and the position of the sine wave are fixed, and the volume of the sine wave is decreased to a level equal to the other sine waves. The volume of each sine wave gradually attenuates over two weeks and then disappears.

Multiple Speakers. All the sine waves from the sound synthesis engine are output through multiple speakers mounted on the wall of the echoless chamber. In total, 116 speakers encircle the participant from an omni-horizontal direction.

The Echoless Chamber. The controller and the multiple speakers are set in an echoless chamber. In order to listen to the sine waves which are transmitted directly from multiple speakers, and to prevent any noise entering from the outside, the door of the room is kept shut while people are inside.

3.3 The SINE WAVE ORCHESTRA Nomadic

The SINE WAVE ORCHESTRA nomadic (SWO-nomadic) is a work exhibited as a part of the International Triennale at Yokohama, which took place between 28th September and 18th December 2005 (see Figure 6 and SWO-nomadic.mov).

About 190,000 people visited the work during the exhibition period; the instrument was a Linux-installed-iPod and a speaker. The iPod's wheel and center button are for changing the frequency; the forward and rewind buttons are for changing the volume of a sine wave. The screen shows the current frequency and the volume of a sine wave. The output port is connected to a speaker attached to the back of the iPod (see Figure 7).

Fig. 6. The SINE WAVE ORCHESTRA nomadic.

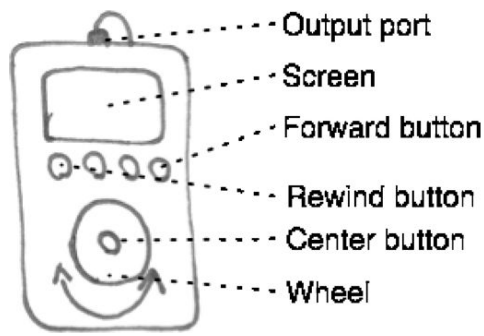

Fig. 7. The instrument for The SINE WAVE ORCHESTRA nomadic.

SWO-nomadic was made up of two parts (see Figure 8). During the first part, five small-scale, one-hour collaborative sound performances took place every other week in different outdoor places in Yokohama. In each performance, about 20 preregistered participants played sine waves with the instruments provided by the organizers. After each performance, the participants moved to the exhibition site. Each participant set the frequency and the volume of a sine wave by using his or her instrument, and exhibited the instrument at the site by attaching it to a string hanging from the high ceiling from a power cable. Each participant was also asked to leave a message on a small tile and to place it on the floor beneath their instruments, which continued to produce sine waves during the exhibition.

Each of the five performances at the exibition added 20 sine waves produced by 20 instruments. Thus, the collective sound representation at the exhibition site grew after every performance. In the end, the site had a collective sound representation of 100 sine waves produced by 100 instruments that visitors to the exhibition could listen to, and they could also see the accompanying 100 tiles showing the messages left by the participants.

During the second part, the participants of the five performances were all invited to join a large-scale performance, which took place at the end of the exhibition period. They removed the instruments from the exhibition site and walked to a nearby park where they played sine waves with their instruments.

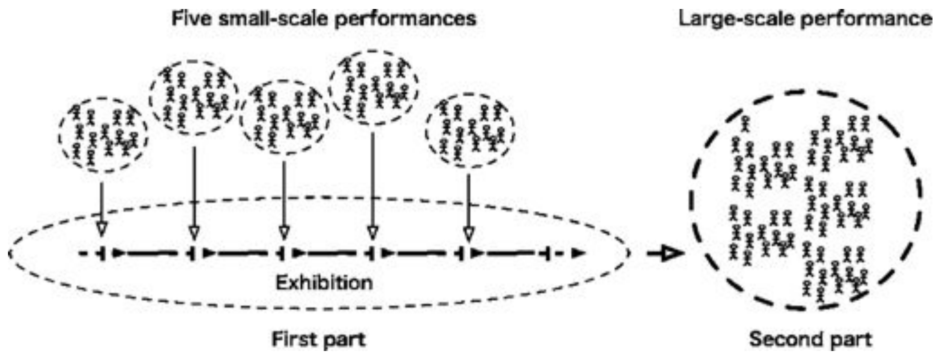

Fig. 8. The two parts of The SINE WAVE ORCHESTRA nomadic.

Fig. 9. The SINE WAVE ORCHESTRA at ZeroOne San Jose/ISEA 2006.

Passersby were invited to join in and play the instruments of those original participants who were not present. The performance lasted for a few hours until all the batteries of the instruments wore out.

The Linux-Installed-iPod. iPodLinux, Podzilla, and a customized version of an audio generator application [iPodLinux. http://ipodlinux.org/] are installed on an Apple iPod 3rd-generation model. The wheel changes the frequency of the sine wave, and the center button changes the interval of the frequency (1Hz, 10Hz, 100Hz). The forward and rewind buttons change the volume of the sine wave (up and down). The screen shows the current frequency and volume of the sine wave. The frequency range of the sine wave is set from 400Hz to 8000Hz; and the volume range of the sine wave is set to zero, at the level of people's normal voices. The battery of the iPod lasts about three hours.

The Speaker. The speaker is connected to the output port of the iPod and is attached to the back of the iPod with glue. When people cover the speaker, the volume of the sine wave goes down.

3.4 The SINE WAVE ORCHESTRA at ZeroOne San Jose/ISEA 2006

The SINE WAVE ORCHESTRA at ZeroOne San Jose/ISEA 2006 (SWO-isea) took place at SOFA Area, San Jose on 12th August 2006, as a part of ZeroOne San Jose/ISEA 2006 (see Figure 9 and SWO-isea.mov).

The instrument consists of an oscillator, a knob, a switch, a speaker, and a battery inside a hand-held plastic egg. The angle of the knob changes the

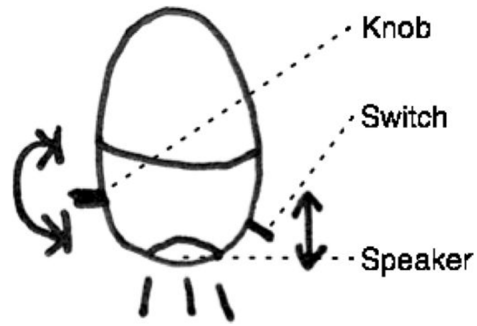

Fig. 10. The Instrument for The SINE WAVE ORCHESTRA at ZerOne San Jose/ISEA 2006.

frequency of the sine wave and the switch turns the sound on and off (see Figure 10).

The public was invited to partiipate via website and mailing list announcements; passers-by at the site were also invited to participate. The organizers provided 50 instruments for the participants; in addition, some people brought their own instruments (e.g., laptop PCs and synthesizers) to produce sine waves with varying frequencies and volumes, in the same way as for SWO-stairway.

About 100 participants came, one after another, to the performance. They played sine waves with the instruments for about one hour in an open outdoor space in downtown San Jose. Participants moved around the space and produced varieties of sine wave frequencies.

The Oscillator, Knob, Switch, and Battery. The oscillator consists of an analog circuit. A variable resistor with a knob is mounted on the bottom of an egg. It is connected to the frequency control part of the circuit; the oscillator changes the frequency of a sine wave depending on the angle of the knob. The range of the frequency is set to around 1200Hz to 2400Hz. The volume is fixed at about the level of people's loud voices. The switch mounted on the bottom of the egg turns the volume of the sine wave on and off. The battery is used for the oscillator and lasts about a day.

The Speaker. The speaker is mounted directly on the bottom of the egg. When people cover the speaker, the volume of the sine wave decreases.

3.5 The SINE WAVE ORCHESTRA Mediate

The SINE WAVE ORCHESTRA mediate (SWO-mediate) was premiered at Re: search, Art Collaboration exibition between Australia and Japan at Sendai mediatheque from 26th November to 25th December 2006 (see Figure 11 and SWO-mediate.mov).

A total of about 3,000 people participated in the work during the exhibition period. The instrument was made up of eight sets of boards with a moving fader and a speaker, a control engine, and a sound synthesis engine. The moving faders are connected to the control engine through a converter. The control engine controls the sound synthesis engine, which is connected to eight speakers

Fig. 11. The SINE WAVE ORCHESTRA mediate.

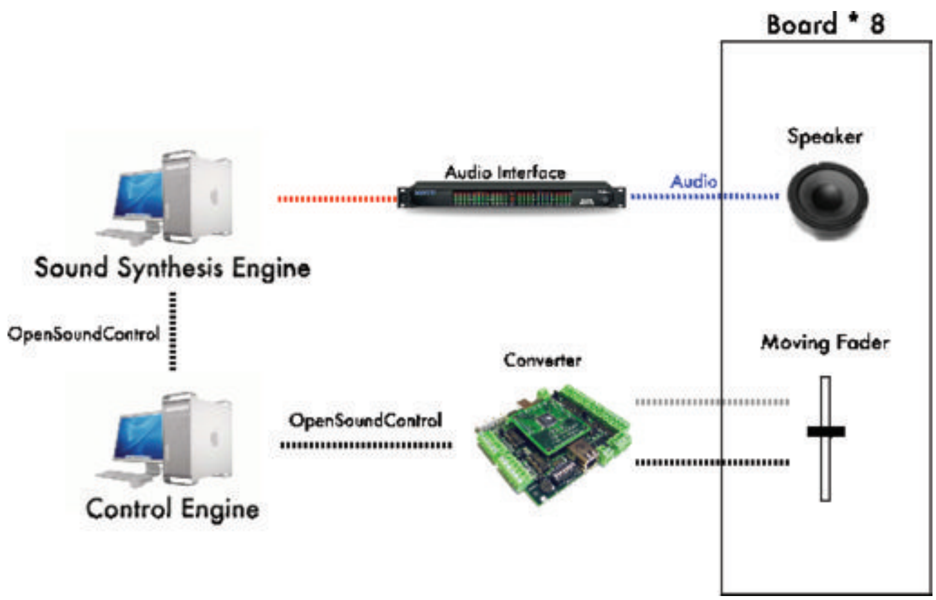

Fig. 12. The instrument for The SINE WAVE ORCHESTRA mediate.

through an audio interface and synthesizes eight sine waves. Each set of the board is hung from the ceiling in the exhibition space (see Figure 12).

There were instructions for the work on the wall of the exhibition space. As each participant touches the moving fader, the fader stops moving. The participant changes the frequency of a sine wave by moving the position of the fader with his or her hand. The sine wave is output from the speaker on the same board. All of his or her performance is recorded.

After the participant releases the fader, the control engine moves the fader recursively, along with the performance record. The sound synthesis engine changes the frequency of the sine wave based on the position of the fader. If another participant touches the fader, the fader stops moving again. After the participant releases the fader, the control engine interposes the participant's perpformance record into the previous performances. Every time a participant touches the instrument, the period of recursion increases. The eight sets of instruments have different periods of recursion, depending on the number of participants and the time of performance.

The Board, Moving Fader, and Speaker. SWO-mediates uses eight sets of wooden boards with a moving fader and a speaker. The size of the board is 3600mm × 450mm × 30mm. The speaker is mounted on the center of the board; the fader is mounted vertically under the speaker. Each speaker outputs a sine wave from the sound synthesis engine through the audio interface. The moving fader consists of a motor, a variable resistor, and a fader with a touch sensor. The motor is connected to the variable resistor with a belt transmission. The fader is directly mounted on the variable resistor. The control engine moves the fader by sending data to the motor through the converter [Make Controller Kit http://www.makezine.com/controller/]. When a participant touches the fader, the touch sensor sends a signal to the control engine and the control engine stops to move the fader. Based on the position of the fader, the variable resistor changes its value. The value is sent to the control engine through the converter to change the frequency of a sine wave from 100Hz to 10000Hz in realtime. The boards are hung from the ceiling facing in the same direction and alternately arranged in an 8 × 8 matrix.

The Control Engine. The control engine is implemented with MaxMSP. It controls and records the movements of the fader, and separately receives data from eight moving faders. The position of the fader is sent directly to the sound synthesis engine for changing the frequency of a sine wave. When a participant touches the fader, the control engine starts to record the position of the fader with the change in the value of the variable resistor. After the participant releases the fader, the engine sends the data recursively to the motor to move the fader. When another participant touches the fader, the engine stops sending data to the motor and starts to record the positional data again. After the release, the engine interposes the recorded data into that part where it stops sending data to the motor. Every time a participant touches the fader, the length of the positional data increases.

The Sound Synthesis Engine. The sound synthesis engine treats eight sine waves for eight speakers. It is implemented with SuperCollider and changes the frequency of each sine wave based on the positional data of the fader from the control engine. Each sine wave is treated as a separate audio signal and is directly output from each speaker through the audio interface [MOTU Traveller. http://www.motu.com/].The range of the frequency is set at about 100Hz to 15000Hz. The volume of each sine wave is fixed at about the level of a talking voice.

4. ELEMENTS OF THE INSTRUMENTS

Though each instrument for an SWO work is unique and gives a more subtle presentation than the specific focus of this article, we will try to discuss those instrument elements that affect how people create collective sound representations. Even if the instruments produce the same sound source (i.e., a sine wave), each instrument has its own distinctive interface and relationship. We classified the instruments according to the following elements: frequency control,

Table I. Elements of the Instruments

Work	Frequency Control/ Range (Hz)	Volume Control/ Level	Display Environment	Number of Participants/ Instruments	Styles of Participation
SWO-stairway	CDS Photocell/ 420–480	Amount of light/ Whisper voice to 0	Speaker	"200"/"50"	Synchronous
SWO-stay	Rotational Controller/ 100–12000	-/Gradually attenuated	Multiple speakers (116)	"8,000"/"1"	Asynchronous (accumulated)
SWO-nomadic	iPod's wheel, Button/ 400–8000	Buttons/ Whisper voice to 0	Speaker, Screen	"100"/"100"	Synchronous, Asynchronous
SWO-isea	Knob/1200–2400	Switch/ Talking voice or 0	Speaker	"100"/"50"	Synchronous
SWO-mediate	Moving Fader/100–15000	-/Talking voice	Speaker	"3000"/"8"	Asynchronous (extended)

volume control, display environment, number of participants and Instruments, and styles of participation (which are summarized in Table I and discussed in the following sections).

4.1 Frequency Control

The instruments utilized different types of physical techniques for frequency control to provide distinctive characteristics for each instrument. Each instrument has a different frequency range, depending on the capacity of the circuit, the application, and/or the speaker.

The instrument for SWO-stairway employs the CDS photocell for frequency control, which changes its frequency depending on the amount of light. The frequency range is approximately from 420Hz to 480Hz, based on the capacity of the circuit.

The instrument for SWO-stay employs the rotational controller for frequency control, which makes it possible to change the frequency continuously from 100Hz to 12000Hz by turning the controller. It has no limits to its rotation, and the frequency range is almost the same as the capability of the speaker and the threshold of hearing. Therefore, when people continuously rotate the controller, the frequency reaches the upper/lower limits of the speaker and goes out of the range of hearing. Every time a participant uses the instrument, one sine wave is added to the collective sound representation. During the exhibition, the collective sound representation changed from a phase where each sine wave was discriminable, to a cluster which consisted of mutually interfering sine waves, like a white noise that contains all frequencies.

The instrument on SWO-nomadic employs the iPod's wheel for frequency control. The center button of the iPod changes the interval of the frequency (1Hz, 10Hz, 100Hz), which makes it possible to change the frequency discontinuously. Although the wheel has no limits to its rotation, as in SWO-stay, it limits its frequency range from 400Hz to 8000Hz due to the capability of application. Therefore, when people continuously rotate the controller, the frequency reaches the upper/lower limits before it reaches the capability of the speaker or the threshold of hearing.

The instrument for SWO-isea employs the knob connected to the variable resistor for frequency control, which allows changing the frequency with the angle of the knob from 1200Hz to 2400Hz. Based on the capability of the circuit, the frequency range is defined by the limit of the resistor's rotation; the resistor turns about 270 degrees.

The instrument for SWO-mediate employs the moving fader for frequency control, which enables changing the frequency continuously from 100Hz to 12000Hz by moving its position. The frequency range is almost the same as the capability of the speaker. So when people move the fader to the upper/lower edge, the frequency reaches the upper/lower limits of the speaker and goes out of the hearing.

4.2 Volume Control

The instruments employ different types of physical techniques for volume control. This provides distinguishing characteristics for each instrument in the same way as frequency control. Depending on the capability of the circuit, the application, and/or the speaker, each instrument has different volume level.

The instrument for SWO-stairway employs the CDS photocell for volume control. Depending on the amount of light, it changes its volume from a whisper to zero. With this instrument, a change in the amount of light produces change in the volume.

The instrument for SWO-stay changes the volume of the sine wave as the work progresses. When a participant touches the controller, the volume increases from the ordinary level so as to distinguish the participant's sine wave from other sine waves. After the participant chooses the frequency and the position, and leaves his or her own sine wave in the work, the volume decreases to the ordinary level. Then the volume gradually attenuates over the period of two weeks and disappears.

The instrument for SWO-nomadic employs the iPod's forward and rewind buttons for volume control. Based on the capability of the speaker, the maximum volume of the sine wave is at about the level of a whisper.

SWO-isea employs the switch for volume control, which enables turning the volume of the sine wave on and off. The volume level of the sine wave is fixed at about the level of a loud voice.

SWO-mediate employs no method for volume control. It fixes the volume of the sine wave aat about the level of a talking voice.

4.3 Display Environment

The instruments employ a variety of speakers and/or visual screens to display sine waves. A sine wave is identified by its frequency and volume. All sine waves are equivalent as long as they have the same frequency and volume, so there is a problem in distinguishing a particular sine wave from other sine waves.

To solve this problem, SWO-stairway, SWO-nomadic, and SWO-isea employ a speaker for each instrument. Since the instruments are equipped with ndividual speakers, the participants are able to identify their own sine wave; such speakers also allow the participants to walk around freely during the performance. If the participant moves to another position while holding the instrument, this not only changes what he or she listens to, but also change the position of the sound source produced by the participant, resulting in changes in the collective sound representation. SWO-nomadic also employs a screen to show the current frequency and volume of the sine wave.

SWO-stay uses 116 speakers for the instrument. When the participant controls the frequency and position, the volume of the sine wave is increased to identify the participant's own sine wave among other sine waves from multiple speakers. Each speaker outputs a cluster that consists of mutually interfering sine waves with different frequencies from different participants. Therefore, depending on where the participant stands in the room relative to the location of the multiple speakers, what a participant listens to changes dynamically.

SWO-mediate employs a speaker for each of eight instruments. Each speaker produces a sine wave. Based on the movement of the fader, the frequency each speaker produces changes over time. Some sine waves occasionally interfere with each other.

4.4 Number of Participants and Instruments

The number of participants and the instruments greatly influence the resulting collective sound representation. Each instrument for an SWO work is suitable for varying numbers of participants, under the basic concept that each participant will play a sine wave by changing its frequency, volume, position, and/or duration.

SWO-stairway, SWO-nomadic, and SWO-isea provided an instrument for each participant. SWO-nomadic provided instruments for only 100 preregistered participants. For SWO-stairway and SWO-isea, passers-by at the site were also invited to participate. Hundreds of participants came one after another, shared the instruments and played sine waves for several hours. In addition to those who were provided with instruments, some participants in SWO-stairway and SWO-isea brought their own instruments (e.g., laptop PCs and synthesizers).

SWO-stay provided an instrument for 8,000 participants. Each participant, one by one, produced a sine wave at different times. Every time a participant used an instrument, one sine wave was added to the collective sound representation.

SWO-mediate provided eight instruments to 3,000 of participants. Each participant played a sine wave with one of eight instruments. Each instrument recursively changed the frequency of the sine wave. Every time a participant played an instrument, the duration of the recursion increased. The eight instruments had different periods of recursion and a dynamically changing collective sound representation.

4.5 Styles of Participation

The instruments provided different styles of participation to the participants in different temporal and spatial settings. How participants shared the time and space resulted in different types of collective sound representation.

SWO-stairway and SWO-isea were colocated synchronous performances, in which each participant played a sine wave while sharing both time and space. The collective sound representation was created through the interactions among the participants.

SWO-stay and SWO-mediate were colocated asynchronous events, in which each participant, one by one, played the sine wave at different times while sharing the space. The collective sound representation changed during the period of the exhibition through the involvement of other participants. However, the approaches to the creation of the collective sound were crucially different in the two works.

In SWO-stay, the number of sine waves depends on the number of participants. Each participant fixes the frequency and position of a sine wave, which are added one by one to the collective sound representation. Every time a participant took part in the work, the number of the sine waves increased. The sine waves were accumulated and the collective sound representation changed from a phase where each sine wave was discriminable, to a cluster that consists of mutually interfering sine waves.

In SWO-mediate, the number of sine waves was fixed. Each participant played one of the sine waves by moving the fader. The performance of each participant was interposed in previous performances. The sine wave changed its frequency recursively along with the recorded data of the performance. Every time a participant took part in the work, the period of recursion increased. The sine wave were extended and the collective sound representation changed from a phase where each recursion of a sine wave was detectable as a drone, consisting of continuously changing sine waves with the different periods of recursion.

SWO-nomadic involves different styles of collective sound performance. Each of the five small-scale performances of the first part demonstrated synchronous, colocated, collective sound performances. The results were accumulated one by one at the exhibition site by hanging the instruments from the ceiling. The five synchronous collaborative sound representations synthesized a single persistent sound at the site. Visitors to the exhibition site could listen to the asynchronous collected sound representations at the site. The large-scale performance in the second part invited the participants of the previous five performances to participate again in the face-to-face synchronous collective sound performance at the end of the exhibition.

5. THE PARTICIPANTS' EXPERIENCE

Through informal observations of the participants' during performances of SWO-stairway, SWO-nomadic, and SWO-isea, we saw the following behviors.

In SWO-stairway, the instrument could not produce sound with the small amount of light at sunset, and observed that participants with their instruments were gathered around the the fixed light. The amount of light that defines the frequency almost matches the available light, so mutually interfering sine waves were produced by the instruments. We also observed that some participants dynamically changed the volume by illuminating the instrument with a flashlight. In the performance, some people brought their own instruments to produce sine waves (e.g., laptop PCs and synthesizers). We also saw that some of the participants seemed to understand sine waves, shared their knowledge, and showed others how to play, on the instruments provided, and negotiated the way to play on them. Some passersby asked the participants what they were doing and took part in the performance.

In SWO-nomadic, the instrument limited its frequency range from 400Hz to 8000Hz; these limits are under the threshold of hearing. During the performance, we observed that some participants complained about the upper/lower limits of the frequency; the maximum volume of the instrument is at about the level of a whisper. In a performance in an outdoor space, with noise from other sources (e.g., waterfall, public address system), we saw a number of participants leaniing closer to each other and turning their ears toward the speakers of the other participants. The instruments show the current frequency and the volume of the sine wave on the screen. During a moment after each performance, we saw that some participants set the frequency to a number that was meaningful to them (e.g., a birthday, etc.).

In SWO-isea, the instrument has a knob and a switch in a hand-held plastic egg. During the performance, we observed that some participants did not hold the body but held he knob instead and dynamically turned the body up and down. We also observed that some participants dynamically changed the volume: some turned the switch on and off, some put their hands on the speaker, and others covered their instruments with their mouths. Some participants shared, negotiated, and imitated in the same manner as SWO-stairway participants.

Due to the absence of observers (i.e., ourselves), we could not manage observations for SWO-stay and SWO-mediate. Even when the instruments produce the same sound (i.e., a sine wave), each instrument, due to its individual characteristics (e.g. light sensitive, display equipped, knob and switch equipped) provides a different experience for each participant. Such characteristics not only define the relationship between the instrument and a participant, but also change how participants interact with each other during a performance. Our initial observations indicate a number of considerations for how we should design the relationships among sound, instrument, and participant in a collective sound performance.

6. CONCLUSIONS

In a traditional classical music performance, the composer prescribes the collective sound representation in the form of a score for the instruments. The skilled performers produce the collective sound representation by playing instruments on which they have practiced for long periods of time. The participants in works by The SINE WAVE ORCHESTRA create the collective sound representation by playig on instruments unfamiliar to them. As a result, even when the organizers provide instruments with a highly restricted sound source (i.e., a sine wave), the evolution of the collective sound representation is unpredictable and depends on the total involvement of the participants [Ascott 1966].

This raises a question about the outcomes for the instruments. In each work of SWO, the collective sound representation actively changes its state through the involvement of the participants. The instruments act as dynamic-interactive systems to include output from the participants [Cornock 1973]. In SWO works, the instrument is an unfamiliar device to the participant; it takes time to learn to play it. By restricting the sound source and the interface of the instrument, each participant in an SWO work creates a part of the collective sound representation, which changes continuously throughout the entire period of the exhibition. The instruments retain consistency for the overall sound representation.

The five instruments in this article were developed for the participants in the work of SWO, enabling people to create collective sound representations with their own sine waves. The instruments for collective sound representation began to emerge as a field for research. The field of collaborative musical interfaces for novices explores the design of the interface for musical collaboration; it facilitates exploration of a sound space for participants with low entry-level skills [Blaine 2003]. People gather to play together and to produce sound, but the resulting sound representations of such collaborative musical interfaces seem instant and ad-hoc; they cannot maintain consistency as a composition. The field of interconnected music networks investigates live performance systems for creating dynamic and evolving musical compositions [Weinberg 2002]. In the field, the social organization of performers is analyzed, and several network architectures and topologies for live performance are proposed. However, the boundary between performer and listener (i.e., participant) has not yet been fully discussed. We are in the early stages of understanding the complexity of the elements of the instrument that affect how people create collective sound representations. We anticipate that our initial explorations will reveal a number of ways in whch we could design an instrument for collective sound representation.

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REFERENCES

ASCOTT, R. 1966. Behaviourist art and cybernetic vision. *Cybernetica 9*, 4, 247–264.

BARTHES, R. 1977. Musica pratica. In *Image – Music – Text*, Hill and Wang, New York, 149–154.

BLAINE, T. AND FELS, S. 2003. Collaborative musical experiences for novices. *J. New Music Research 32*, 4, 411–428.

BONGERS, B. 2007. Electronic musical Instruments: Experiences of a new Luthier. *Leonardo Music J*. 17(Dec.), 9–16.

CORNOCK, S. AND EDMONDS, E. 1973. The creative process where the artist is amplified or superseded by the computer. *Leonardo 6*, 1, 11–16.

CYCLING74. MaxMSP. http://www.cycling74.com/products/maxmsp.

GRIFFIN. Griffin Technology, Powermate. http://www.griffintechnology.com/products/powermate.

HUNT, A., WANDERLEY, M. M., AND PARADIS, M. 2002. The importance of parameter mapping in electronic instrument design. In *Proceedings of the Conference on New Interfaces for Musical Expression* (NIME-02), 149–154.

IPODLINUX. iPodLinux Podzzila, and audio generator. http://ipodlinux.org/.

JO, K., FURUDATE, K. ISHIDA, D., AND NOGUCHI, M. 2007. Two approaches to collective sound creation in different temporal settings: The SINE WAVE ORCHESTRA stay and The SINE WAVE ORCHESTRA mediate. *Leonardo Electronic Almanac 15*, 5–6. http://leoalmanac.org/journal/vol_15/lea_v15_n05-06/jkazuhiro.asp.

JO, K., YAMAMOTO, Y., AND NAKAKOJI, K. 2006. *Styles of Participation and Engagement In Collective Sound Performance Projects, Engage: Interaction, Art and Audience Experience*. E. Edmonds et al. (eds.), Creativity and Cognition Studios Press, Sydney, Australia, 110–119.

JO, K., FURUDATE, K. ISHIDA, D., AND NOGUCHI, M. 2005. The SINE WAVE ORCHESTRA stay. In *Proceedings of the 13th Annual ACM International Conference on Multimedia* (Singapore), 571–573.

MAKE. MAKE controller kit. http://www.makezine.com/controller/.

MOTU. 24 i/o, traveller. http://www.motu.com/.

OSC open sound control. http://cnmat.cnmat.berkeley.edu/OSC/.

SC. SuperCollider. http://www.audiosynth.com/.

SWO. The SINE WAVE ORCHESTRA. http://swo.jp/.

TANAKA, A. 2006. Interaction, experience, and the future of music. In *Consuming Music Together,* vol. 35, Springer, The Netherlands, 267–288.

WEINGERG, G. 2005. Interconnected musical networks towards a theoretical framework. *Computer Music J. 29*, 2, 23–39.

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