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Two Fragments on Water and Light explores a communal ensemble paradigm made possible through the implementation of customized technologies. The work is for solo voice and two additional performers who use controllers built, and in some cases designed, by the composer. These controllers operate either synthesis or effects processing algorithms which generate sound, modify existing sounds, or both. The arbitrary mapping between controller data and synthesis algorithm and the way that some of the synthesis algorithms function as both sound generators and sound processors allow multiple performers to create or modify the same sound. This permits the possibility of a communal performance environment in which the sonic identity of each performer, or the way in which the performer's physical actions directly translate into sonic result, blur into a common, ensemble sonic identity.

This document shows how technology enables this communal ensemble paradigm. It first discusses the operation of the physical models and controllers. It illustrates specifically how the use of technology allows for the dissolution of the sonic identity of each performer. This document then explains how technology and the performance environment it facilitates are used to highlight themes seen in the medieval texts set in these songs. After a few remarks evaluating the effectiveness of the songs, I present a performance score.

CUSTOM CONTROLLERS AND PHYSICAL MODELS AS

ENABLERS OF COMMUNAL PERFORMANCE

IN *TWO FRAGMENTS ON*

WATER AND LIGHT

by

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CHAPTER I

INTRODUCTION

Two Fragments on Water and Light is a set of two songs for mezzo-soprano and two additional performers. These performers use custom electronic controllers which I built, and in some cases designed, to control various synthesis and processing algorithms. *Two Fragments* is a setting of portions of two medieval Latin poems. The texts of these fragments deal with themes of ambiguity, obscurity and of the dissolution of physical boundaries. To highlight these themes, a communal ensemble paradigm is realized through the use of custom technology. Physical models are implemented in such a way as to function both as sound producers and sound processors. This allows certain timbres to be processed by sound-producing algorithms to create new, combined sonic identities. Further, because the mechanism of sound production is virtual and not physical, the customer controllers used can be mapped so that multiple controllers affect different aspects of the same sound.

At various points in the piece, the sonic identity of each performer, or the way in which the performer's physical actions directly translate into sonic result, is blurred into a common ensemble identity. At these places, each performer's gestures translate into sound indirectly. Here, physical gestures of individual performers affect the sonic result only in relationship to other performers. The level of integration of each performer's sonic identity into the ensemble identity shifts throughout the piece, contributing to the piece's overall form. Most importantly, the way in which the shifting levels of integration correspond to points in the text which deal with ambiguity and the blurring of physical boundaries serves to highlight these themes.

This document explains how this communal paradigm is implemented. First, there is a discussion of the physical models used in the piece and the way in which they can be used as both sound producers and sound processors. Next, there is an explanation of the design and function of the controllers used. This explanation highlights the controllers' symbolic qualities as well as their formal design. This document finally shows specifically how the technologically-enabled communal performance environment highlights themes seen in the text. Following this document, a performance score is presented.

CHAPTER II

THE IMPLEMENTATION OF PHYSICAL MODELS

Two Fragments on Water and Light uses physical modeling as its primary synthesis method. Physical modeling attempts to reproduce the sound of acoustic instruments through computer implementations of the various mathematical equations that describe the acoustic phenomena at work in the production of sound for acoustic instruments. This contrasts to other methods of synthesis which attempt to mimic musical instruments though the use of pre-recorded samples of those instruments or through filtering or combining synthetic waveforms. While the use of physical modeling for studying and imitating instruments is possible, physical modeling can also be used creatively to produce novel timbres that conform to the laws of physics in a virtual manner. For example, physical models can be used to conceptually alter the physical dimensions of an instrument to scales that are impossible to implement in reality (a 300 foot guitar, for example.)

Much of the sonic material of this piece is produced using the waveguide physical modeling method.[1] Waveguides produce implementations of the wave equation through the use of delays with feedback and filtering. A delay, which sonically reproduces a sound that is sent to it after a specified time, is most often used as the basis of sound processing algorithms, not as the basis of sound generating algorithms. However, delay

[1] For a discussion of waveguides, see Julius O. Smith, III, “Physical Modeling Using Digital Waveguides,” *Computer Music Journal* 16, no. 4 (Winter 1992): 74-91.

times used in waveguides are short enough to create pitches when data are sent to the delay line and the output of the delay line is fed back into the input of the delay line. Before the signal from the delay is fed back, filtering, the removal of certain frequency components from a sound, is applied to imitate friction and other dampening forces that occur in musical instrument's physical makeup and function.

Two types of waveguide physical models are used in this piece. One is a physical model of a slide flute designed by Perry Cook.[2] This model imitates flutes of various types using 1) two delay lines; 2) two points of feedback; 3) a filter; 4) an equation to emulate the non-linear response of the instrument; 5) a steady signal that is fed into a delay line to imitate breath pressure; and 6) white noise to imitate the air turbulence created by blowing the instrument. The way that the above generators and processors are routed is illustrated in Figure 1. Rather than using a preexisting implementation of this model, I created a custom implementation in the software program Max/MSP. There were a few reasons that I constructed a custom implementation. First, I wanted to remove limitations to the delay lines' length. The second movement of *Two Fragments* uses delay times whose oscillations create pitches close to the sub-audio range. Second, using a previously compiled implementation would not have allowed me to feed other sounds into the delay line of the model.

[2] Perry Cook, "A Meta-Wind-Instrument Physical Model, and a Meta-Controller for Real Time Performance Control," *Proceedings of the ICMC (1992.)* Referenced by Hind, Nicky, "Physical Modelling Synthesis," http://ccrma.stanford.edu/software/clm/compmus/clm-tutorials/pm.html, (accessed December 4, 2007).

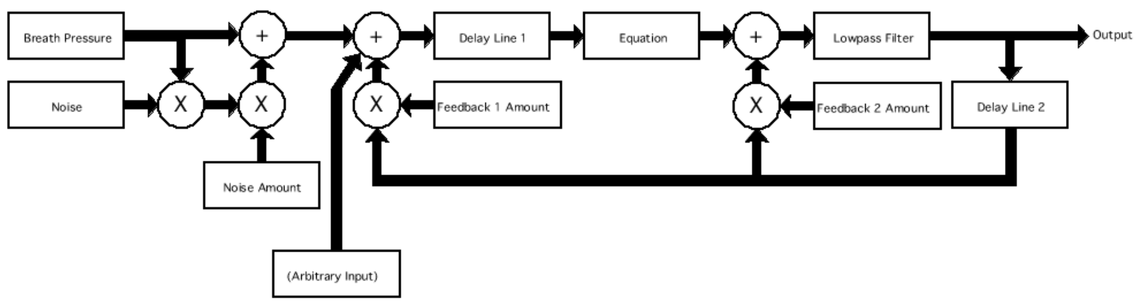

Figure 1. A diagram of the physical model of Perry Cook's Slide Flute. Circles represent points where signals are added or multiplied. Diagram adapted from source.[3]

One advantage of using physical modeling using waveguides is that arbitrary sounds can be fed into the delay line as a way of using the model to process sounds. For example, Cem Duruoz's *Flutar* presents an interaction between an acoustic guitar and a physical model of a flute. In this interaction the guitar sound is fed into the delays of the flute model creating a hybridization of a flute sound and a guitar sound – i.e., a "plucked flute."[4] The identities of each instrument, virtual and real, are combined to produce a new identity, that of the "Flutar."

In *Two Fragments*, the voice and the sound from other physical models are frequently fed into the delay line of other physical models. As with the Flutar, the identity of each performing voice is blurred by feeding one sound into the other. This dissolving of each instrumental identity into one collective identity is used to highlight themes of ambiguity and the blurring of boundaries seen in the text. The use of delay lines in waveguide modeling is what facilitates the highlighting of these themes.

[3] *Ibid.*

[4] Stanford University, CCRMA, "Physical Modeling (Past)," Stanford University, http://ccrma.stanford.edu/overview/pastmodeling.html (accessed February 5, 2008).

The other type of waveguide model used in this piece is the banded waveguide. This type of model is generally used to emulate bells, tablas, bar percussion, and other similar percussion instruments that either have harmonics that are not in tune with a fundamental or are completely inharmonic in nature. A banded waveguide filters the feedback from the delay line using one or more bandpass filters.[5] The bandpass filters have two functions. They eliminate undesirable frequencies that are caused by the literal repetition in the delay line. Second, each filter encourages the waveguide to "ring" at the frequency at which the filter is set.

In *Two Fragments*, banded waveguides are used primarily to create imitations of bells. Rather than imitating an existing physical bell, banded waveguides were crafted to create ideal bells with harmonics derived from the pitch material of the piece. One bandpass filter and one delay line is used to create each harmonic of a particular bell model.

One important part of the operation of waveguides is the excitation model. The excitation model algorithmically describes the method in which sound is initiated or maintained for a particular physical model. With waveguides in particular, delay lines that have no information in them will not create an audio signal. Information has to be placed into the delay lines in order for the model to oscillate. This information is created by an excitation model which is fed directly into the delay line. In the example of Cook's

[5] Georg Essl, Stefania Serafin, Perry R. Cook, Julius O. Smith, III, "Theory of banded waveguides," *Computer Music Journal* 28, no. 1 (Spring 2004): 37-50.

Slide Flute, the excitation model consists primarily of a steady signal to emulate breath pressure and noise to emulate turbulence.

Two Fragments implements banded waveguides in an unusual way. Instead of using a computer generated excitation model, as in Essl et. al., audio information gathered by microphones is fed directly into the delay lines of waveguides. This is what allows one of the controllers of the ensemble, the *Bls.*, to operate. The sound from the wooden bowls that are comprise the *Bls.* controller is picked up by the contact microphones and fed into the delay lines of the banded waveguides. The means of excitation is physical rather than virtual. In addition, the sound of the voice is at times fed into the banded waveguide to create a type of tuned reverb.

In addition to waveguides, *Two Fragments* uses a physical modeling method inspired by Perry Cook's Physically Informed Stochastic Event Modeling (PhISEM.)[6] This physical modeling method is designed to emulate percussive sounds that have some element of randomness. PhISEM has been used to synthesize shakers, wind chimes, footsteps, and tambourines. PhISEM models are implemented through an interesting method of dual envelope generation. First, a system energy envelope is used to describe the amount of energy used to initiate the sound of the instrument. The envelope fades exponentially, and its length and initial amplitude are determined by a number representing the amount of force applied to an instrument. Next, a sound envelope is multiplied by the system energy envelope. This sound envelope implements a similar

[6] Perry R. Cook, "Physically Informed Sonic Modelling (PhISM): Synthesis of Percussive Sounds," *Computer Music Journal* 21, no. 3 (Fall 1997): 40-43.

equation to the system energy envelope. The difference is that while the system energy envelope is initiated deliberately, the sound envelope is initiated repeatedly and at random. It is possible to specify scenarios in which the sound envelope is more likely to be triggered quickly to synthesize a denser sound; for example, a maraca with more beads. The two envelopes working together create the random but quickly decaying envelope associated with certain types of percussion instruments.

I use a similar method to generate chime sounds in this piece. My implementation is quite similar to the PhISEM method, but it has one important difference. Instead of having a second sound envelope, I use randomly occurring impulses lasting no more than 10 samples. These impulses are fed into bandpass filters with an extremely high *Q*.[7] A stochastic routing method is used to determine which bandpass filter a particular impulse is fed into. When an impulse is fed into one of the filters, it produces a ringing sound at the frequency at which the filter is set to due to the extremely high *Q*. All of this creates the chime sound. The advantage of using this artificial model, rather than real chimes, is that I am able to tune the chimes according to the pitch materials occurring in the piece.

Later in the piece, I subject phonemes performed live by the vocalist to granular sampling. I feed individual grains into bandpass filters with their *Q* set high in a manner similar to the chime model. The only difference between this sound producing mechanism and the chime model is that in this algorithm the recorded voice, not an

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[7] *Q* describes the bandwidth of the bandpass filter, or the distance between the top and bottom frequencies that are allowed to pass through the filter. Curtis Rhoads describes *Q* as the "degree of 'resonance'" of the filter, implying that filters can resonate when an incoming signal has a frequency that matches the center frequency of the filter. Curtis Rhoads, *Computer Music Tutorial* (Cambridge, MA: MIT Press, 1996), 189-190.

impulse, is used to initiate sound. This creates an illusion that chimes are being rung by the voice. This is another example of the way in which physical modeling facilities the blurring of individual performer sonic identities into a single ensemble identity.

All of the physical models used in this piece use at least one element that is more commonly used to process sound than to create sound. The delay lines of the waveguide models and the filters of the chime models can be used both to create sound and to change sound. These elements allow the virtual instruments used in this piece to be used as both synthesizers and effects processors. The sounds that are fed into these physical models take on some of the sonic characteristics of these models. Thus, the results of one performer's actions take on sonic qualities of the results of other performer's actions. Physical modeling used in this way is one crucial method used to blur the sonic identities of individual performers.

CHAPTER III

THE DESIGN AND USE OF CUSTOM CONTROLLERS

In addition to physical models, the use of custom controllers built, and, in some cases, designed by the composer helps to contribute to the unique ensemble paradigm found in *Two Fragments on Water and Light*.

One problem encountered in the production and performance of electronic and computer music is the temporal and spatial separation between physical input and sound generation. One line of research in computer music is an attempt to discover ways to reincorporate real-time physical control into computer music through the use of custom built controllers and input devices. These devices provide data derived from physical gestures which are interpreted by the computer to create or modify sound electronically.

Physical interfaces for electronic music have varying levels of similarity to traditional instruments. At one end of the spectrum, "augmented instruments" are traditional acoustic instruments with sensors attached. [8] Other types of controllers are modeled on existing instruments. Commercially available wind controllers, for example, are modeled on various types of woodwind instruments. Some physical interfaces have only slight similarities to existing instruments. A controller may require a set of gestures that are similar to those in use for a particular acoustic instrument without explicitly

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[8] Eduardo R. Miranda and Marcelo M. Wanderley. *New Digital Musical Instruments: Control and Interaction Beyond the Keyboard* (Middleton, WI: A-R Editions, Inc., 2006), 20-21.

taking on the form of that instrument. Finally, some controllers are designed to have no similarities at all to traditional instruments.[9]

Designing at either end of the continuum has advantages and disadvantages. For interfaces that are closely modeled on existing instruments, it is much easier to "leverage expert technique."[10] An accomplished pianist could easily learn to perform on a keyboard controller without spending too much additional practice time. The drawback to using controllers closely modeled on existing instruments is that the resulting controllers tend to inherit some of the limitations of those instruments. Further, traditional physical interactions can inspire more traditional music. Because acoustic instruments that make traditional music already exist, it seems inefficient to me to create new physical interactions to perform traditional music.

The opposite of controllers closely modeled on existing instruments are "alternative controllers." [11] The advantage of using alternative controllers is that one is not limited to physical gestures associated with the use of acoustic instruments. There are a greater number of physical gestures available to the designer. One is freer to implement the measurement of physical gesture in creative ways. It is even possible to design a controller that is operated by gestures that have their own independent and symbolic meaning. For example, one controller used in this piece can be operated by blowing on

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[9] Ibid.

[10] Perry Cook, "Principles for Designing Computer Music Controllers," in *New Interfaces for Musical Expression, NIME-01, Proceedings*, (Vancouver, BC: Human Communications Technologies Laboratory, Unversity of British Columbia, 2001), http://hct.ece.ubc.ca/nime/2001/papers/cook.pdf (accessed October 23, 2007).

[11] Miranda and Wanderley, *New Digital Musical Instruments*, 2006.

the surface of water. This physical gesture mimics images describing the wind disturbing the surface of the ocean seen in the text that is set in this piece.

The drawback to using alternative controllers, however, is that one is not able to leverage "expert technique." Expressive alternative controllers can take longer to master unless the designer specifically attends to the abilities of an amateur. Another challenge is that the way in which gesture should be mapped to sound is not inherently obvious. With instrument-like controllers, one can simply copy the ways in which the physical gesture of an acoustic instrument generates sound. This is not possible in the case of alternative controllers that do not use the same gestures as acoustic instruments.

In designing and choosing the input devices used in *Two Fragments*, my approach was neither to use devices that functioned similarly to acoustic instruments, nor was it to use controllers that were completely unlike existing instruments. Rather, I designed the controllers using elements from both of these approaches. The devices can be classified as alternative controllers because their formal characteristics are for the most part unlike any existing instruments. However, metaphors that relate the playing techniques used for these controllers to playing techniques used for acoustic instruments are chosen to implement appropriate mappings between physical gesture and sonic result. This allows performers to use the devices successfully while also allowing the gestures and design of the interfaces to be imbued with symbolic meaning. In this way, I was able to allow the physical gestures of the performers and design of the controllers to correspond at various levels to themes seen in the poetry set in this piece.

The controller with the greatest level of similarity to the form and playing techniques of existing instruments is the *Bls.* This controller consists of four wooden bowls with contact microphones attached. In the first movement of the piece, the audio information from each microphone is sent into the delay line of a custom-tuned banded waveguide. This creates an interaction that is oddly similar to playing some type of gong or tuned bowl. If the performer strikes the bowl with a mallet or other implement the computer produces a sound similar to a bell being struck. Scraping the bowl with a stick produces a sound similar to the sound of a bell being scraped. The interaction is oddly realistic, although it is a bit disconcerting due to the material dissonance between the metallic sounds and the wooden material of the controller.

In the second movement, the raw sound of the wooden bowl is often more audible. This is because audio information from the contact microphones are fed into delay lines with sub-audio delay times, not waveguides. Further, at some points in the piece the delay time is gradually reduced from a sub-audio frequency to a frequency with an audible pitch. This gives the impression that the repeating sound of the wood is morphed into a pitch.

The *Bls.* is not simply a controller in a traditional sense. Rather, it is a mix of musical instrument and controller; an “augmented instrument.” The lines between interface and instrument are blurred in this interaction.

The performer who uses the *Bls.* also uses my implementation of Sebastian Tomcek's *Toriton Plus.*[12] This controller was designed at the Electronic Music Unit, Elder Conservatorium of Music, University of Adelaide. This controller is constructed from a few LED-photoresistor pairs and a bowl or other clear container of water. The light sensors are used to measure disturbances in the surface of the water. In the original implementation, laser LED's are directed from above the surface of the water directly to photoresistors underneath the container of water. When the surface of the water is disturbed, one or more of the laser beams are refracted and the amount of light received by the photoresistor increase or decreases. This is transformed into a stream of information sent to the computer to control synthesis algorithms.

In my implementation, an optical distance sensor, which consists of a photoresistor and an infrared LED placed together in one housing, is placed at the bottom of a clear glass plate of water. Some of the infrared light from the LED, which is shining upward towards the surface of the water, is reflected by the water's surface. Disturbing the surface of the water changes the amount of light received by the photoresistor. Despite these differences, the process of converting the electrical signal into a data stream is quite similar to the original design.

I made these modifications to the design for two reasons. First, the optical sensors were significantly less expensive than the laser modules. Second, the original design had the lasers pointed into the surface of the water from the top. This reduced access to the

[12] Sebastian Tomcek, "Water Music" Little-Scale: Stuff About Things, http://little-scale.blogspot.com/search/label/water%20music (accessed February 5, 2008).

surface of the water. Removing the laser modules allowed more and closer access to the surface of the water. This facilitated freer disturbances of the water with the hand. It even allowed the controller to be played by blowing on the water's surface.

To determine the way in which physical gesture would be mapped to sonic result, I created a metaphor comparing the function of the Toriton Plus to the sound producing mechanisms and playing techniques seen in wind chimes. The rippling of the Toriton Plus's surface is somewhat chaotic and uncontrollable when touched by the performer. The shape of the array of chimes seen in wind chimes also behaves uncontrollably when the performer interacts with it. The performer can continue to react with both surfaces, but the shape is still uncontrollable throughout the interaction. Finally, the surfaces of both instruments continue to move when the performer ceases to interact with them.

I realized the mapping of the chimes in two ways. First, I used PhISEM to generate models of chime sounds. When the surface of the water is displaced by a certain threshold amount, it initiates a system energy envelope whose apex is based on the amount of the water's displacement. This creates a responsive interaction; when the water's surface is displaced by a larger amount, the sound is louder.

Second, I use the surface of the water to control granular synthesis. The triggering of each grain is done at random when the surface of the water is displaced above a certain threshold. The way in which each grain is triggered at random was also inspired by the random excitation of sound seen in wind chimes.

I made the greatest number of design and mapping decisions in the construction of the Lichtflöte and the determination of its mapping. The Lichtflöte in its current implementation consists of a PVC pipe that is approximately one foot long. At either end, there is a super bright LED and photoresistor. These two items are placed closely together and separated by a wooden divider. At one end, the performer can move his mouth around the end of the tube. When the mouth is opened widely, high numbers are sent to the computer to be interpreted by synthesis and processing algorithms. When the mouth is completely closed, zeros are sent to the computer. At the other end of the PVC pipe, the performer generally moves his hand towards and away from the end of the tube. When the hand is closer to the end of the tube, the numbers sent to the computer are higher. Finally, three force sensing resitors (FSR's) are placed close to one of the ends of the Lichtflöte. When force is applied to one of these resistors, a flag indicating that a button is being pressed is sent to the computer. [13]

I selected two metaphors to transform physical gesture into sound for this controller. For the first of the two songs, I chose to map the gestures of the Lichtflöte to the synthesis parameters of the flute physical model. The mouth controls the model's breath pressure. Both of the hands are used to control pitch. The fingers that operate the FSR's select the pitch chromatically in the same manner that a trumpet would. Moving the hand around the Lichtflote's other opening transposes the selected note up or down a fifth or octave.

In the second movement, the mapping is mixed. During much of the movement, the Lichtflöte often controlls a very low flute sound. The way that the mapping is

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[13] Force sensing resistors are thin, plastic, bendable, wafer-like components which affect an electrical signal depending how hard the wafer-like components is pressed.

implemented in this movement is that the mouth controls breath pressure as in the first movement, but only the hand that covers the other end of the flute controls the pitch. The control of pitch here is continuous, like a trombone, and not discrete. Because of this mapping, virtual flute glissandi are featured prominently in the second movement.

In addition to the operation of the flute model, the Lichtflöte is used to control sound processing algorithms in the second movement. In a few locations, the mouth controls the wet mix of a reverberation algorithm. Often, at the same time, the hand controls the delay times for the delay lines that are being used to process the raw sounds coming from the contact microphones of the *Bls.* When used in this way, the Lichtflöte is a catalyst for communal performance. In places in the piece similar to the one seen in Figure 2, each member of the trio is contributing to the sound world in some way. The voice is producing the sound. The voice sound is altered by the Toriton Plus to sound like wind chimes. The voice and the Toriton Plus sounds are fed into the reverb algorithm, which is continuously changed by the performer of the Lichtflöte's mouth. In this circumstance, the way in which the Lichtflöte is mapped to an effects processing routine gives this gesture its communal nature as the shape and direction of this sound is controlled by the reverb mix.

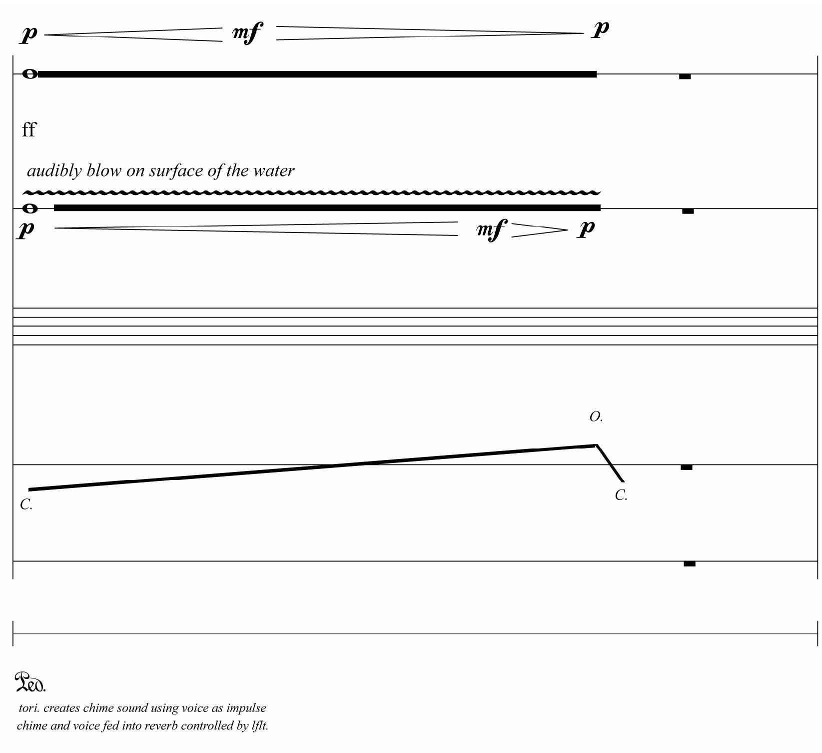

Figure 2. A communal gesture in which the Lichtflöte influences the overall sound through applying the same effect to both sounds.

It should be evident from the preceding discussion that the way in which a controller creates or contributes to a sound varies throughout this piece. This is because there is still a separation between physical gesture and sound producing mechanism. But because the mapping between gesture and sound is not immutable, I am able to use changes in mapping to vary the level of integration of the individual performer's sonic identities into the integral ensemble identity. I am thus able to highlight certain words that the vocalist performs dealing with issues of ambiguity and the blurring of physical boundaries. I do this by implementing mappings that route many controller data to a single sound process.

Finally, the form of the controllers and their playing methods at times mimic the images contained in the text. The water of the Toriton Plus is correlated to images of the sea and melting snow. The way in which it is played by being blown imitates images of wind presented in the text. The light from the LED's of the Lichtflöte parallels images of the sun. Hiding the light of the LED with the hand mimics images of clouds hiding the light of the stars.

While there is definitely an element of novelty associated with the use of these custom controllers, the most important reason for using them is that their form and function can relate to the text. It is rare for the form and playing mechanisms of acoustic instruments to correspond to images projected by a text. For me, the tight integration of ensemble and text is part where the interest in this piece truly lies.

CHAPTER IV

TECHNOLOGY AND THE TEXT

Ultimately, the interesting aspect of *Two Fragments on Water and Light* is the way in which physical models and controllers are used to highlight subjects of ambiguity, obscurity, and the blurring of physical boundaries seen in the text. The value of the piece extends beyond the mere implementation of physical models and controllers to the use of these technologies for artistic and aesthetic ends. Explicating the nature of these songs involves explaining how technology is implemented in conjunction with the way that the text is set. The meanings of each text, the progression of the music, and the concurrent evolution of the controller mappings should be considered in order to fully understand these songs.

The first poem, *Leuis Exsurgit Zephirus,* presents an image of the melting snow at the beginning of spring. *Two Fragments* sets only the first stanza of the poem:

Leuis exsurgit zephirus
Et sol procedit tepidus,
Iam terra sinus aperit,
Dulcore suo difluit. [14]

Lightly rises the west wind
And the sun proceeds tepidly,
Now the earth bares its breast,
Sweetness in its flowing apart.[15]

[14] "Leuis Exsurgit Zephirus," in *The Cambridge Songs (Carmina Cantabrigiensia),* trans. Jan M. Ziolkowski, (New York: Garland Publishing, Inc., 1994), 116-117.
[15] This is a loosely literal translation made by myself.

While later stanzas of the poem describe the onset of spring explicitly, these four lines describe it in a very indirect manner. The tepidness of the proceeding sun implies a warmness that is only very recent. The image of the earth baring its breast implies the snow melting to show the bare earth beneath. Further, the word *difluit* means flowing apart and further suggests the flowing apart of solid snow into water.

The image of snow melting and flowing apart is the central idea of the setting of this poem. The way in which discrete particles of snow melt into one integral mass of water is mirrored by the way that discrete instrumental identities melt into an integral ensemble identity. The progression of the song presents a progression in which each performer's sonic identities are at first discrete. Identities are blurred when parts of the text that point to the melting of the snow are performed. At the end of the song, when the singer whispers the word *difluit,* the individual sonic identities of each performer have been obscured completely. At this point, the physical gestures of the performers contribute to one integral ensemble identity rather than establishing their own sonic identities. This melting of individual identities mimics the melting of snow as seen in the poem.

The first line of the poem, "*Levis exsurgit zephirus,*" introduces to the listener the possibility of the melting of sonic identities. The temporally extended performance of the first "s" sound at the end of the word *Levis* is processed by a bell model that is tuned to the C4 that the singer sang on the previous vowel. Further, this "s" sound is captured by the computer, played back and processed by the chime model when the Toriton Plus is performed in the next gesture.

When the vocalist again performs an extended “s” sound, this time as part of the word “*zephirus,”* the vocal sound is again fed into a tuned bell model. As before, the model is tuned to the note that the vocalist previously sang. In addition, the flute sound is processed by the bell models that performer of the *Bls.* was using previously. At this moment, every performer’s identity is processed by a model of a bell. In effect, the sonic identity of the ensemble becomes that of the *Bls.*

The setting of next line, *“et sol procedit tepidus,”* utilizes none of the processing paradigms used in the previous section. Depicting the idea of progression through the gradual revelation of the melodic line creates much tension and musical interest. It was necessary to avoid the process of obscuring the performers’ sonic identities in order to keep a sense of propulsion to this section. Further, abstaining from the use of these obscuring procedures heightens the effect of these procedures when they are used in conjunction with the next line.

The goal of the section which sets the line “*et sol procedit tepidus”* is the word “*iam*” (now). This word represents an important point in the poem because it makes the first reference to the image of the earth baring its breast and by extension, the melting snow. Further, the urgency that the word imparts through its temporal implications provides a stark contrast to the references to lightness and tepidness in the first two lines. When “*iam*” is sung, the sound of the chimes controlled by the Toriton Plus is processed by the *Bls*. Further, the score calls for the sound of Toriton Plus to be processed by the delay lines of the flute model.[16] This routing appears until the vocalist performs the word "*aperit*" which is roughly equivalent to the English word "bares."

The word "*aperit*" is repeated three times throughout the denouement of the piece. After the third repetition of the word "*aperit*," the individual sonic identities produced by each performer begin to combine, leading to the state of maximum integration at the end of the piece. First, when the vocalist sings "*dulcore*," her voice is processed by the bell models that are being activated simultaneously by the performer of the *Bls.* Next, the flute sound is processed by the same sounds bell models.

Finally, when the word "*difluit*" is whispered, the mapping between sound producing mechanisms and sound processing mechanisms becomes considerably more complex. The vocalist's whispering is processed by the Toriton Plus to sound fragmented. This sound is processed by the bell models that were previously activated by the performer of the *Bls.* Finally, the amount of the processed voice sound that is allowed to seep into the bell models is controlled by mouth of the Lichtflöte, which also controls the breath pressure of the flute model. At this point, it is difficult, if not impossible, for the audience to see how each performer's gestures contribute to the sound world. Each member of the ensemble is contributing to the function of the same virtual instrument, namely, the bell models. The creation of the final sound of this song could not occur

[16] While in theory this should work, in practice the sound of the flute sounded too synthetic when this method of routing was in place. In order to hear the impulses coming from the chimes, the filter that was used to simulate the energy loss present in the actual instrument had to be set rather high. The resulting frequency-rich sound was quite similar to a raw pulse wave or square wave. For the premiere of the piece, which occurred on April 20, 2008, the routing of the chime sound into the flute sound was removed.

without the continuous intervention of each performer. The sonic identity of the ensemble is still present, but the sonic identities of each performer are maximally obscured.

The second poem of this cycle, a setting of a fragment of a song by Boethius, deals primarily with darkness and obscurity:

Nubibus atris
condita nullum
fundere possunt
sidera lumen.
Si mare volvens
turbidus Auster…

Stars hidden
by dark clouds
can shed
no light.
If the south wind
should stir the roiling sea…[17]

This fragment of Boethius' song is somewhat befuddling. It consists of a relatively straightforward statement followed by a sentence fragment without an object. This befuddling nature is mirrored by ideas of darkness discussed in the first sentence of the text. The theme of this entire fragment is hiding and each line deals with this subject in a different way. The first sentence explicitly describes the hiding of the light of the stars. The second sentence hides the predicate of the sentence. At multiple levels, the poem deals with notions of obscurity and ambiguity.

[17] Boethius, "Nubibus Atris," in *The Cambridge Songs (Carmina Cantabrigiensia)*, trans. Jan M. Ziolkowski, (New York: Garland Publishing, Inc., 1994), 132-133. This translation is Ziolkowski's translation.

The second song of *Two Fragments* obscures the sonic identities of the performers to highlight themes of obscurity seen in the text. This song blurs the distinction between each performer's sonic identity more consistently than the first song because the theme of hiding is so pervasive throughout the second text. Less emphasis is placed on highlighting individual words through these techniques and more emphasis is placed on using these techniques to imbue a form to the entire song.

The song begins with the vocalist performing the first few lines of the text with most of the vowels and voiced consonants omitted. First, the vocalist whispers a "b" sound twice to substitute for the word "*nubibus*." This is fed into four delay lines with feedback whose length is controlled by the hand of the Lichtflöte. The unprocessed sound of the *Bls.* being struck is fed into the same delay lines. This sound decays until the Lichtflöte performer's hand completely covers the Lichtflöte's light.

The second part of this first gesture consists of the vocalist performing the "s" sound of "*nubibus.*" This sound is fed into reverberation whose wet mix is controlled by the Lichtflötist's mouth. This sound is also recorded and played back in a fragmented manner by the Toriton Plus. This fragmented playback is fed into the reverberation.

The sounds at the beginning of this song are already the result of collaborative techniques. The first part of the opening gesture is initiated by the vocalist, but it continues because of feedback into the delay lines controlled by the Lichtflöte. The *Bls.* performer ensures that the sound continues despite the slow decay due to feedback. The dissolution of the performer's sonic identities is implemented here by the passing around of responsibility for the maintenance of the sound.

The moment in which sonic identities are most integrated occurs when the vocalist speaks the “f” of *“fundere.”* The Toriton Plus uses the live vocal sounds as a substitute for the impulses of the chime physical model. The chime physical model is fed into the reverberation whose wet mix is controlled by the Lichtflöte. The resulting sound is a mass of gentle noise which grows as the members of the ensemble collaboratively create a crescendo through either altering the wet mix of the reverberation or through increasing the breath pressure applied to the lips or the surface of the Toriton Plus.

As the music progresses, the sonic identity of each performer gradually separates from the collective identity. At the same time, the vocalist begins to use voiced phonemes. At the climactic point in the piece, at the words *“Si mare volvens turbidus auster…”* (if the south wind should disturb the roiling sea), the sonic identity of each performer is clearly audible. As in the previous movement, I chose to maintain the identities of the performers at a point of dramatic tension.

When the opening material is recapitulated, the identities of the performers are not as integrated as in the beginning. The vocal part includes all phonemes, not just unvoiced phonemes. While the first section was dominated by the sound of the *Bls.* being fed into delay lines, in the recapitulation the *Bls.* usually controls a type of bell model which continuously rises in pitch like a Shepard tone.[18] The speed at which the bell model rises in pitch is controlled by the hand of the Lichtflöte. At the end of the piece, the voice is again fed into the reverb controlled by the mouth of the Lichtflöte.

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[18] A Shepard tone is a synthetic illusion of a pitch which continues to rise at a microscopic level, but does not rise at a macroscopic level. The listener hears a rising pitch, but as time goes on, the listener notices that the pitch doesn’t seem particularly that much higher.

The way in which the level of integration of sonic identities migrates throughout the song creates a form in the shape of an arc. The piece begins with the identities of the performers tightly integrated. As the piece progresses, the identities begin to separate until the moment of climax. At the climax, the identities are completely separated. But as the piece progresses from the climax, the sonic identities start to become more integrated until the end where they are again completely integrated.

There are two general observations to be made about the songs. First the subjects of the texts deal mostly with obscurity, fragmentation, hiding, and flowing apart. The appropriateness of this ensemble paradigm in communicating these themes makes the complexities of the technology appropriate. Without these technologies, it would be difficult to express these themes in such a literal way. While it is possible in acoustic music to have dense, complicated textures which obscure the sounds emanating from individual performers, it is impossible to actually have two people control the same sound producing mechanism without creating some sort of spectacle.

Further, the texts contain images of water, wind, the sun and its light. Each of these images is replicated by the form of the instruments or their playing methods, as discussed in Chapter III. It is unusual in acoustic music for the materials that make up the instruments to imitate the subject matter seen in the text. However, the divorce between the physical materials of an instrument and its sound as seen in computer music allows for the flexible mapping between materials and sonic result. This allows physical interactions to fulfill a poetic and symbolic agenda in addition to producing satisfying sonic results.

CHAPTER IV

CONCLUSION

The communal ensemble paradigm utilized in this piece creates interesting challenges for the performer and listener. First, it is not always obvious how physical gestures used to operate the controllers relate to the sounds being produced. This lack of clear cause and effect between gesture and sound is to be expected when the lines between each performer's sonic identity is blurred. However, a listener might object to this effect due to their inability to distinguish clear boundaries.

It is unusually challenging to attempt to successfully practice and perform this piece. The issue is primarily with the way mappings change throughout the piece. One performer might perform the same action several times throughout a passage, but may get completely different results each time the action is performed. Further, despite the score, a performer does not always know when he is affecting the same sound as another performer. In addition, when two performers are affecting the same sound process, it is difficult for one performer to compensate for what the other performer is doing. This performance situation is complex and novel enough to make preparation for a concert difficult.

However, the level of difficulty is unavoidable if the boundaries between performers' sonic identities constantly shift throughout a piece. It is possible to create a stable mapping. However, the boundaries between performers' sonic identities must likewise remain stable throughout the piece. A change in mapping is needed to achieve shifts in sonic identity integration.

There is no easy way to reduce the difficulty associated with two performers controlling the same sound-producing process. This method of performance is rarely, if ever, seen in traditional music. There are few teachers, schools, or precedents for this type of communal performance. People simply have not practiced this method of music making extensively. The only way to reduce this difficulty would be to spend more time creating, practicing, and performing music utilizing this kind of paradigm so that standards and best practices develop over time.

Despite the difficulties associated with utilizing these methods of communal performance, this compositional technique has tremendous musical value. It allows the physical make up of an ensemble to mirror images seen in the text that the ensemble performs. It also creates the possibility of merging individual voices that comprise the ensemble in a way that cannot be accomplished using traditional instruments. Using technology in this way creates a greater number of possibilities for musical expression in that it allows extra-musical elements to be highlighted with greater clarity and richness. In this way, this paradigm creates new possibilities for expression in composition. This is ultimately where the value of implementing this technological-ensemble paradigm lies.

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APPENDIX A. PERFORMANCE SCORE

The score for this piece is in the tabloid format, 11” x 17”. Due to the formatting limitations of this document, the performance score is included as a separate attachment.