SIGNAL TO NOISE: A DISCUSSION ON THE VALUE OF INTERACTIVE TECHNOLOGY IN LIGHTING DESIGN FOR PERFORMING ARTS

by

CRAIG ALFREDSON


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The following individuals certify that they have read, and recommend to the Faculty of Graduate and Postdoctoral Studies for acceptance, the thesis entitled:

Signal to Noise: A Discussion on the Value of Interactive Technology in Lighting Design for Performing Arts

submitted by Craig Alfredson in partial fulfillment of the requirements for the degree of Master of Fine Arts in Theatre

Examining Committee:

Robert Gardiner, Professor – Department of Theatre and Film
Supervisor

Bradley Powers, Associate Professor – Department of Theatre and Film
Supervisory Committee Member
Abstract

The goal of this thesis project was to investigate (within the confines of current technological limitations) some of the advantages and disadvantages of interactive technology in lighting for performing arts and compare it to traditional cue-based systems.

To accomplish this task, the author designed, implemented, and observed interactive lighting for two contemporary dance shows. The first show, with the working title Signal to Noise, was devised with choreographers Arash Khakpour and Kelly McInnes to test various interactive technologies specifically for this thesis project. It was presented in various forms between February and April of 2013. The second show, Karoshi by Shay Kuebler, premiered at the Scotiabank Dance Centre in Vancouver, B.C. Canada on December 6th, 2012 and subsequently toured around British Columbia.

The results were positive but limited. There is notable satisfaction for both the performers and the audience when there is a meaningful correlation between the action on stage and the visual and auditory environment in which it occurs. Automating that correlation using interactive technology can simplify the process for the performers on stage and the artists who create the environment. On the other hand, the complexities of programming computer-controlled interactivity can limit its usefulness. As software improves, interactive technologies will become a more valuable tool for the performing arts.
Lay Summary

This thesis report considers how the use of interactive lighting technology in two contemporary dance performances affected the artistic outcomes, and also examines how the technologies affected the jobs of those involved in creating the performances. The results are positive, but current technology limits the potential.
Preface

This thesis report is based on the original technological research done in preparation for the two aforementioned productions. Though the work was created in artistic collaboration with others, the conclusions drawn in this report are my own. Unless otherwise noted, all photographs and video stills contained in this report were taken by me.
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1. Introduction

Performance is an art form that has existed for thousands of years, and as long as it has been presented in an organized fashion, practitioners have used technology to augment their performances. Theatres in Roman times used devices such as the deus ex machina to simulate acts of the gods, concert halls and opera houses of the 18th and 19th century used candles and gas lighting to create lighting effects, and theatre artists of the 21st century use modern technology and computers to create complex scenography and lighting for the stage. In modern day scripted performances such as theatre, dance and opera, theatre technicians operate the lighting and sound effects as a series of cues. Changes to lighting and sound are programmed as a sequential list of “cues” and then played back during the performance. Though modern technology can allow for very complex sequences of cues, the relationship between performer and technician is reactionary; the performer performs on the stage and the technician advances the cues in reaction to their performance.

In an “interactive” system, the performer would directly trigger the sound and lighting (and other technology), replacing pre-recorded cues with computer systems capable of “reading” and “interpreting” the performer’s speech and/or movements, changing the lighting, sound, and other elements in a more improvisational way (although following pre-determined rules). The current practice of constructing cues as a series of distinct recorded events would be replaced by a continual
interaction between a performer and a computer resulting in changes to the lighting and sound without the need for a human technician.

Though the use of interactive technology in performing arts is still in its infancy, it shows great potential. This thesis project was undertaken to explore some of the advantages and disadvantages of using interactive technology over the best available cue-based technology in scripted performance such as theatre or choreographed dance. To accomplish this, I studied two shows for which I acted as designer and technologist. For each show, I had creative control over some or all of the technological aspects and used interactive technology as much as was possible within the confines of the budget and overall artistic direction.

1.1 Software options

Many different software platforms are currently available to control theatrical technology, and all of them have their strengths and weaknesses. Figure 1 shows a spectrum of software platforms commonly used for projection design (as an example), though most can be used to control other theatrical elements as well, such as lighting or sound. Many have the ability to control interactivity, though some are designed purely as linear or cue-based systems. These various systems have been placed on the graph according to their ease of use and their power and flexibility. “Ease of use” is a very subjective term. For the sake of this graph, I have defined it as referring to the complexity of creating a cue or event, assuming the creator is fluent in the given software. “Power and flexibility” refers to the number of options,
features, and effects that the software might possess. The resulting graph highlights the fact that there is a definite correlation between the two criteria. The more powerful and complex a software platform, the more complicated (and therefore time-consuming) it will be to use. Note again in Figure 1 that the upper right quadrant is mostly blank. The “Holy Grail” software that is both easy to use and highly powerful and flexible does not yet exist.

Figure 1 – A placement of various software platforms used for projection design on a scale of ease of use and power/flexibility. Note that this graph is subjective and intended for illustrative purposes only.
1.2 Isadora

The software platform that I chose to use for my thesis project is Isadora version 1.3 by Troikatronix (the latest release at the time). It is not the most powerful software platform available, nor is it the easiest to use, but it was able to accomplish what I needed without excessive programming time. Isadora is a node-based visual programming environment designed and built by Mark Coniglio for interactive dance performance. It has the ability to control lighting, sound, and projection elements, as well as communicate with other systems via many different protocols, such as MIDI and RS232 (serial). A software development kit is available to extend the current usability, and I have direct communication with the creator to troubleshoot any issues that may occur.

![Isadora Interface](image)

**Figure 2 - A simple scene in Troikatronix Isadora version 1.3**
Isadora allows the user to build complex events using smaller blocks, or nodes in a graphical user interface. Mark Cognilio has given wonderfully descriptive names to these nodes. They are called “actors”, which perform in “scenes” (the canvas on which they are placed and connected) and then are projected in front of an audience on one or multiple “stages” (the outputs to the literal projectors or screens). Each actor has various inputs and outputs and each input or output has a data type – either a media stream (video or audio), or a number (integer, float, binary, etc). Each actor, depending on its purpose, takes the media or value at its input, affects it in some way, and then outputs the affected media or value. With hundreds of different actors with different purposes, which can be connected in thousands of different ways, the resulting outcomes are practically limitless.

A key feature of Isadora is that information from the outside world can be relayed to Isadora as a numerical value and used to control lighting, projections, sound, or any other system. For example, in Signal to Noise I had sensors connected to an Arduino Fio boards communicating to Isadora via an RS-232 serial connection, giving me a value range of 0 to 1023. Within Isadora I am able to connect that value to anything else that inputs a numerical value, such as the intensity of a specific light, or the opacity of a video projection, or the location of the playback head on an audio track. Similarly, I could take an audio input from a microphone and use the magnitude of the sound wave, or the peak frequency, as a numerical input. Or I could take a video input from a camera and isolate the overall brightness, or the brightness of just one colour, or just one pixel, and convert it to a numerical value.
Of equal importance is the ability to output information to the various systems that are used in a theatrical environment. The ability to output audio is straightforward, via either the headphone jack on the computer or any audio interface that may be attached. Likewise, sending video to externally attached monitors or projectors is relatively simple. The ability to output data to the lighting system was initially more problematic. The software included some rudimentary connectivity to allow Isadora to communicate with DMX-512 – the standard protocol used for theatrical lighting – but its scope was quite limited. Control of stage lights was important if Isadora software was to be a viable choice for the projects I wanted to undertake, so prior to embarking on my thesis project I worked with Mark Coniglio to develop a better way for Isadora to communicate with DMX, using standard serial protocol and an open source interface called the Enttec USB DMX Pro.

Figure 3 - Enttec DMX USB Pro device for inputting and outputting DMX 512 protocol via a USB connection. Image courtesy of www.enttec.com.
Though lighting, sound, and video are the main technical elements that I needed to control, other theatre systems, such as stage automation, could also be controlled using similar interfaces and protocols. While Isadora is not the only software platform that can accomplish all of these tasks, it also had an attractive price-point and had the advantage that I was already familiar with it. For all of these reasons, it became clear that it was the best choice of control software for my purposes.

Figure 4 - Example of Isadora code for DMX lighting control via the Enttec USB DMX Pro.
2. Signal to Noise

The first performance piece for this thesis was a contemporary dance piece with the working title *Signal to Noise*. For this project, I invited two emerging choreographers, Arash Khakpour and Kelly McInnes, to dance and choreograph movement that would serve as the vessel for my technological research. Most of the development and initial work-in-progress showings for this piece were done at the Dorothy Somerset Studio at the Point Grey Campus of the University of British Columbia.

Figure 5 - Arash Khakour and Kelly McInnes dancing in a work-in-progress showing of *Signal to Noise*. 
Signal to Noise focused on a single interactive element, that of touch and feel. Though touch and haptic sensors are becoming more and more present in today’s society (for example, touch screens on phones), they have seen little use in performing arts. Touch interaction is a very important tool for dancers to communicate to one another non-verbally. For instance, in the dance form known as touch-improv, dancers move in groups of two or more and create improvised dance based on the way that their bodies touch and interact. Dancers take cues from each other based on the location and force of touch and create complex movement structures without any verbal communication.

It is important to make the distinction that a meaningful touch interaction is more than a simple contact/no contact structure and therefore I required a sensor that was more than a binary on/off switch. In order to collect meaningful data, I elected to use force sensitive resistors (FSR’s).

Figure 6 - Commercially available force sensitive resistor (FSR), approximately 5cm²
photo courtesy of www.adafruit.com
These resistors, which are commercially available in various sizes, have a measurable electrical resistance that changes depending on how much physical pressure (force) is being applied to them. They have many commercial uses, such as electronic scales and musical instruments.

In order to collect locational data, it was necessary to use many of these FSR’s in various locations on the body. For the first iteration of my research, I opted to use four FSR’s located on a dancer’s feet – one on each of the heels and one on each of the balls of the feet.

![Figure 7 - Store bought FSR's attached to a standard insole.](image)

Next, I used Arduino micro-processors to measure the electrical resistance of the FSR’s and convert it to useful data that I could interpret. Arduino is an open-source collection of microprocessors that have multiple inputs and outputs for interfacing real-world devices (such as FSR’s), an easy to use C-based programming language, and serial and USB connections for communication. This proved to be an ideal solution because it could easily translate the resistance of the FSR’s into serial data.
that I could then input into Isadora. Once in Isadora, the data was available for me to monitor and use as needed. Because the dancers needed full freedom of movement, I opted to use a specific Arduino board called a Fio along with an Xbee wireless transmitter. The Fio board uses the same programming language as other Arduino boards and was specifically designed to hold the Xbee transmitter.

![Figure 8 - An XBee Pro Series 1 transmitter.](image)

The Xbee uses 2.4Ghz transmissions to communicate with a receiver that connects to a computer's USB port. This allowed me to collect serial data from the Fio board as if it was physically connected to the computer; there was no discernable latency. The Fio board has 8 analogue (voltage measuring) inputs, meaning I could have up to 8 FSR’s on a dancer and get discreet measurements from each of them. The Fio board and the Xbee transmitter were powered by a small 3.7v lithium polymer battery.
Figure 9 - The Arduino Fio, the XBee transmitter, the voltage divider circuit, and the 3.7v lithium polymer battery all tucked neatly inside a plastic case the size of a deck of cards.

The FSR’s have variable resistance and the Arduino Fio measures variance in voltage, so I used a voltage divider circuit to output a variable voltage based on the ratio of two resistors. One of the resistors was the FSR, so the ratio of the resistance of the FSR to a fixed-value resistor gave a measurable voltage with a proportional relationship to physical pressure applied to the FSR.

We quickly found that the data that was collected from the four FSR’s placed under the dancer’s feet was not particularly interesting or useful. Since contemporary dance is not particularly step-based, and it involves a lot of movement where the dancers are not on their feet, the foot sensors gave a rather incomplete view of the dancing, and any interaction between dancers wasn’t captured. So we took the
same four FSR’s and tape them to various points on the dancers’ bodies. This provided stronger and more interesting data, but the store-bought FSR’s, which came in various sizes from about 1cm diameter to 5cm squares, were either too small or not pliable enough to conform to the dancers’ bodies. I began to research methods of creating my own force sensitive resistors that were both larger and more pliable.

FSR’s are made up of three layers. The top and bottom layer are fully conductive material, and the layer in the middle is the special pressure-sensitive layer. Finding material that was fully conductive, pliable, and came in useful sizes, was fairly straightforward. Finding material that had pressure sensitive resistive properties was more of a challenge, but I discovered a company in California called Eeonyx that made a stretchy spandex-like fabric with this very property. I also found a very common and cheap material used as anti-static packaging for sensitive electronics that also has this property. The Eeonyx fabric was expensive and needed to be shipped from California, but I ordered a sample and also procured a large roll of anti-static sheeting from a local supplier to start building my own sensors.

The first prototypes of my sensors were approximately 12cm squares. The fully conductive layers were nylon fabric purchased from a company called Less EMF. (There is apparently a market for conductive clothing because some believe it protects one from radiation in a manner similar to wearing a tinfoil hat). Between the two layers of conductive nylon, I placed a piece of anti-static sheet. I made this
middle layer slightly larger to avoid the two nylon layers touching directly and causing a short circuit. I then sewed a wire lead onto each of the nylon layers using conductive thread (also from Less EMF), to eventually connect to a voltage divider circuit and the Arduino Fio. Finally, I covered the entire sensor with two iron-on clothing repair patches to protect the sensor and prevent any accidental short-circuiting or electric shock to the dancers.

Figure 10 - Homemade force sensitive resistor attached to Arduin Fio and lithium-polymer battery

At this point some experimentation was required to match the resistance range of the new sensor with the static resistor in the voltage divider circuitry. Figure 9 shows the diagram of how the new homemade sensors worked. For our sensors, the
voltage in was 3.7V, supplied by a small lithium polymer battery. Since it was hard to directly measure the resistance range of the anti-static sheet (R₁), I paired it with many different static resistors (R₂) until the output was a suitable range. I found using a 2000-ohm resistor worked best. If no pressure was being applied to the sensor, the resistance of the anti-static sheet was very close to infinite, resulting in a voltage out that was very close to zero. When medium pressure was applied to the sensor, the resistance ranged between 1000 and 5000 ohms. Using 2000 ohms for easy calculations, the voltage out would be half of the voltage in (1.85V).

Hypothetically, if enough pressure were applied to the sensor, the resistance would reach zero, then the voltage out would equal the voltage in (3.7V). This gave the sensor an overall voltage range of 0V to 3.7V, depending on the pressure applied.

\[ V_{\text{out}} = V_{\text{in}} \left( \frac{R_2}{R_1 + R_2} \right) \]

**Figure 11** – Diagram of the circuitry involved in the homemade sensors as well as the formula for calculating the resulting voltage using a voltage divider circuit.

When the voltage out was connected to one of the analogue inputs on the Arduino board, the Arduino would compare that voltage to its baseline voltage (also 3.7V)
and output a number between 0 and 1023. When no pressure was being applied to the sensor and the voltage out was zero, the Arduino output was also zero. When medium pressure was being applied to the sensor, the Arduino output was between 400 and 600. I could not manually apply enough pressure to get the Arduino to output the full 1023 (equivalent to 3.7V\text{out}), so there was an effective usable range of about 0 to 800.

These homemade FSR pads proved to be quite useful. We were able to tape them to various points on the body to discover which locations provided the most interesting data. The pads themselves were fairly robust and held up well when the dancers were moving, but the wires connecting the pads to the Arduino pack kept breaking. Because the wires had no way to stretch, when the dancers started doing more dynamic movement, the tension on the wires eventually led to failure. There were two skills that I became quite good at – sewing and soldering. I sometimes even did repairs while the sensors and packs were still attached to the dancers, in order to quickly continue experimenting.
Although I had great success with the first prototype of the homemade sensors, it was clear that a new strategy was required. My second (and final) iteration of the homemade sensors was a radical departure from all of my earlier attempts. This was made possible by the arrival of the samples of Eonyx fabric, as well as the fully conductive spandex material (from Less EMF). From our experiments with the previous design, we had found that many sensors dispersed throughout the body gave us the best results. However for simplicity, I decided to concentrate on the
upper body, which allowed us to be conservative with the expensive fabrics. Since
the Arduino sensors allowed for 8 analogue inputs each, I decided to place 8 sensors
on each of the dancers. Kelly had one on each shoulder, one on each arm, one under
each armpit, one on the stomach and one on the lower back. Arash had one on each
shoulder, one under each armpit, two on his stomach and two on his back.

Figure 13 - An intermediate iteration of Arash Khakpour's costume. Note the 6 visible sensor areas and
the “brain” attached via a multi-conductor cable.
For the new design, instead of building stand-alone sensors that attached to the bodies or the costumes, I fully integrated the sensors into the costumes themselves. This design consisted of three shirts worn one on top of the other. The base layer consists of a standard cotton t-shirt, on which were sewn 8 patches of the fully conductive material – one patch at each of the sensor locations. Small “tracks” of the conductive spandex were also sewn from each of the sensors to a central location at the fringe of the t-shirt near the left hip. These spandex strips replaced the copper wires used in the first iteration, and allowed much more freedom of movement without fear of breaking the circuit.

![Figure 14 - The "brain" unit attached to Kelly McInnes' final costume. Above the brain, the rectangular object is a high gain antenna and the small snap is the negative (common) return wire for the electrical circuit.](image-url)
At the end of these “tracks”, I sewed a multi-conductor connector that allowed a quick disconnect. From there, wires ran to the Arduino Fio and battery pack, which were kept in a small plastic case about the size of a deck of cards. This case could be kept in the pants pocket or attached via elastic to the dancer’s leg. The Fio transmitted data wirelessly to the control computer, which was sent into Isadora as RS-232 serial data.

Figure 15 - The base layer of Kelly McInnes’ final costume. Note the seven visible sensor areas.
The second layer of the costume consisted of another full shirt made entirely of the Eeonyx fabric. This shirt covered the first shirt and the 8 sensors completely. The third layer was yet another shirt, this time sewn from the fully conductive spandex material. Again this shirt fully covered the Eeonix layer, with careful attention made so that at no point would this layer touch any of the 8 patches on the under-layer directly. This top layer was connected to the battery pack via a wire and snap connector to complete the circuit.

Figure 16 - The middle (back) and outer (front) layers of Kelly McInnes' final costume. The middle layer is Eeonyx and the outer layer is conductive spandex.
The full circuit worked like this: Positive voltage from the battery passed to the outer layer shirt, which was insulated from the body and sensors by the Eeonyx fabric. However, wherever there was a sensor pad on the under-layer shirt, electricity would pass through the Eeonyx fabric and connect to the sensor pad underneath, with various resistance measurements based on how much pressure was put on the sensor pad. Each of the sensor pads was attached to a different voltage divider circuit that fed an analogue input on the Arduino.

![Diagram of final costume sensors](image)

*Figure 17 - Diagram of final costume sensors. The diagram shows only four sensors, though the actual costumes had 8 sensors each.*
This arrangement allowed for 8 distinct pressure measurements using only one large layer of the Eeonyx fabric. There was no noticeable cross talk between the different circuits in the system.

The other advantage to this system is that the outer layer, though made of a specific fabric, could be styled to match the aesthetics of the piece. All of the sensors and inner-workings of the circuitry were hidden underneath layers of fabric, and because all of the sensors were made of fabric, there was no bulkiness or awkward movement of the fabric. The sensors virtually disappeared. If desired, the inverse could also be fabricated, where the inner layer is the full conductive layer. The patches could then be sewn on the inside of any costume material, hiding the entirety of the sensor array.
Figure 18 - Nearly completed final sensor prototype, worn by dancer Kelly McInnes. Note the outer shiny silver fabric is the fully conductive spandex fabric and the dark grey fabric seen at the sleeves and the neckline is the Eeonyx force sensitive fabric.
2.1 Experimentation

Having made complete and fairly robust costumes with integrated sensors, we were able to experiment with the information we could obtain from the system. To begin, I connected four of the sensors to the brightness of four lights in four quadrants of the stage. The dancers were immediately engaged and fascinated by the way that they could “play” their bodies almost like musical instruments. Direct control over the lighting of their environment was a foreign idea to them. However, controlling the brightness of the lights didn’t really enhance the interaction happening on stage. In effect, it just replaced the operator at the lighting board with the operator who was a dancer on stage. The connections between the locations of the sensors on the body and the location of the quadrants on the stage was arbitrary and didn’t tell a meaningful story.

Figure 19 - Dancers in a square of projector light, the intensity of which was controlled by the fabric sensors.
For the second experiment, I took seven sensors and connected each to one of seven available colours in an array of LED lighting fixtures. This allowed the dancers to give some information about the “intent” of touch. For instance, a touch on the shoulder is cold and impersonal and therefore blue, whereas a touch on the stomach is very intimate, and therefore red. It was still a little arbitrary, but finally we were getting somewhere by suggesting intent through the relationship between touch and colour.

For the third experiment, I connected all the sensors on the male dancer to the brightness of a set of amber top lights, and all the sensors on the female dancer to the brightness of a set of blue top lights. This combination resulted in a very interesting impression of who was dominant at any point in the dance. Typically, when the male dancer was in control or dominating the movement, he was putting pressure on the sensors of the female dancer’s costume, turning the playing space blue. Likewise, when the female dancer was in control, she was pressing the sensors on the male dancer’s costume, turning the space amber. This was very engaging. It was amazing at how subtly and quickly this dominance changed. It didn’t always
work, but by following a few basic choreographic rules, the dancers were able to convey a very telling story.

![Image of dancers in different poses]

**Figure 21 - The contrast between the blue wash when Arash’s shoulders were pressed and amber wash when Kelly’s shoulders were pressed.**

For the final work-in-progress showing, elements of all of these experiments were employed. I maintained the area top washes of blue and amber light, as well as the concept of quadrants. The seven-colour LED fixtures were mounted in a circular array around the stage. I also employed the use of two projectors and an X-Box Kinect sensor. One projector was placed directly over the stage pointing straight down, the other was over the audience, covering the entire stage area and the back wall. The Kinect sensor, which gives the ability to track objects in three-dimensional space, I placed directly over the stage next to the projector. This way I could extrapolate X/Y coordinate data relating to the dancers positions on stage, as well as Z data, which told me how high the dancers were above the stage floor.
2.2 Work-in-progress Showing

The piece, which I gave the working title “Signal to Noise”, started in a sea of TV static (created by the two projectors). The two dancers, unaware of each other’s presence, writhed around on stage. Whenever they moved or lifted themselves off of the floor (as measured by the Kinect sensor), snippets of radio or TV broadcasts would emerge from the static. Eventually they found each other, and working as a team, they were able to find stronger broadcasts to help them to better interpret the “world” in which they existed.

Figure 22 - Kelly McInnes and Arash Khakpour.

Next, the world transitioned into four quadrants. As the dancers connected and separated, they contorted their bodies to try and find each other in the space. As they separated, they found themselves back in the static where they began. Each
time they found each other, their connection grew allowing them to find each other faster and faster.

Figure 23 - The dancers find each other in a field of static.
As their bond grew, they began to explore emotion and the touch that connected them. Each touch connected to a specific emotion and colour of light. The movement became more and more frantic as anger and violent emotions dominated. Eventually, they lost control of their emotions and they were thrown around in a chaos of light and sound. It all came to a peak and then crashed down to a bare stage with no interaction at all.

As they tried to rebuild and reconnect, the stage stayed visually barren. Eventually, they found their emotions again and started dancing as a couple. The connections were intensified by the colours that each of the dancers controlled. The light was also able to hone in and focus on them (via X/Y tracking of the Kinect), further enforcing the fact that they were in control of their environment. Finally, they were left in static, as in the beginning, but now in a place of knowing and accepting, unlike before.

2.3 Summation

Though this piece was never developed beyond its work-in-progress stage, it was still a success in terms of fulfilling the research goals of this thesis project. It managed to show that using interactive technology is a viable method to create artistically valid work, and that sometimes emotional connection can be better expressed using this method rather than using traditional cue-based methods.
3. Karoshi

Figure 24 - Shay Kuebler and the dancers in Karoshi.

The second part of my thesis project was a dance piece choreographed by Shay Kuebler. The piece is titled Karoshi, which translates roughly from Japanese as “death by overwork”. This title was more than apt, given the amount of work myself, Shay, and the dancers put into it. The piece premiered in Vancouver, BC at the Scotiabank Dance Centre in December 2012. My focus for this piece was slightly different than for Signal to Noise. Where for that piece my main purpose was to explore the capabilities of technology, for Karoshi the focus was to create a full-length work with public performances and a subsequent tour. The other significant difference was that I was bound by the constraint of working within Shay’s artistic
vision. Luckily, Shay was eager to explore the technological ideas that I brought forth.

My goal for this project was to program all the technological elements (lighting, sound and projections) using only one software platform – Isadora. Having everything controlled in one place allowed me to easily create interactions between the various elements. For example, at various points in the piece I had recorded sound controlling lighting, live sound influencing lighting, live sound cueing events, projection content influencing lighting, and live movement influencing lighting. The result was very appealing to both myself and Shay, and the interactive elements became a major feature of the piece.

*Karoshi* is very musically driven, with a high-energy pre-recorded sound track and live taiko drumming by percussionist Jason Overy. One of the key design elements was that the lighting should have the same energy and percussiveness as the music. In studio, we spent a lot of time experimenting with the live audio capture capabilities of Isadora, which proved to be quite adequate. Latency, an issue that had been prevalent with older technology, seemed to be negligible when using USB 2.0 audio capture cards. One area with which we did have difficulties was with the reaction time of the lighting instruments themselves. Standard incandescent theatrical luminaires create light by passing electricity through a filament of thin wire, thus heating it up and causing it to glow white (much the same as a household incandescent light bulb). This heating up process, and the subsequent cooling down
when it is turned off, is not instantaneous. This heating and cooling time, usually not perceptible in a household light bulb, is actually quite noticeable in higher wattage theatrical lamps, particularly when the lights are turned on and off in quick succession according to the beat of an accompanying sound track.

The solution to this problem was to replace the incandescent lights with LED fixtures. Unfortunately, not all LEDs are created equally; some cheaper LED lights had their own inherent latency, most likely due to the built-in circuitry. However, the reaction time for higher quality (and more expensive) LEDs was well within the needs of our project. Other commonly cited shortcomings of LED lighting, such as lack of effective low-end dimming and lack of warmth, were not issues in our case (and have more or less become non-issues due to improvements in LED technology in the years between our initial research and the time of writing).

We experimented with a few other types of lighting fixtures in our initial research. We had limited success with fluorescent lighting fixtures. Standard 48” fluorescent tubes with inexpensive ballasts actually proved to be quite responsive, but they lacked the ability to be dimmed and were limited to a single colour. Most compact fluorescent household style light bulbs had the same latency issue as cheaper LED lights, though some labeled “instant-on” proved fairly effective. We also experimented with the LCD projectors that we were already using for content display. They proved quite effective in terms of responsiveness and had other advantages, such as the ability to project different colours, and the ability to use
images or video files as lighting sources. Although replacing all the stage lights with LCD projectors would have been prohibitively expensive, we did use the projectors for interactivity whenever we could.

![Figure 25 - Projector front lighting creating the effect of a moving elevator.](image)

In the final design of the piece, I used 8 Elation ELAR LED par lighting fixtures as side lighting in the wings, and 16 Elation LED Octostrips on booms, visible to the audience. The Octostrips were mounted vertically to create a 7’ high “tube” of light. Aesthetically, these were a symbolic representation of the neon and LED lightscape of urban Japan. They were also used to represent the movement of the subway, a recurring theme in several scenes of the piece.
Figure 26 – Dancers enacting one of the Subway scenes in Karoshi.

A ninth LED par sat on the floor in front of the stage and was used for a strobe light effect. This was later exchanged for a short-throw video projector to give us more content options. In addition, I used a fairly typical contemporary dance lighting
hang of incandescent fixtures and one 7000 lumen LCD projector hung over the audience that covered the full stage area and the back wall. A small 100 lumen pico-projector was embedded into a prop computer monitor and used for one particular scene in the show. It gave the effect of computer light reflecting off of a dancer’s face.

Figure 27 – Shay Kuebler in the opening scene of Karoshi. A 100 lumen projector is embedded into the computer monitor and a second projector illuminates him from the front. The bulb in the lamp is also controlled from the show-control computer.
3.1 Methods of interactivity

Audio track

I used the waveform data from the prerecorded audio track extensively for programming of lighting and video. Because the choreography was so tightly knit with the music, the sound provided valuable information as to how the lighting and imagery should behave. In one section of the piece, the music alternated between an intense rhythmic beat and slower, more melodic sections, and the choreography mirrored these changes. I was able to analyze the frequency and volume of the music to create a threshold that the rhythmic music surpassed but the melodic music did not. When the music switched from melodic to rhythmic, Isadora was programmed to detect that threshold and automatically pulse the side LED fixtures red with the same amplitude as the music. When the melodic music took over again, Isadora automatically stopped the pulsing of red light.

Figure 28 - The pulsing of the red LED to the intensity of the music.
Video track

There were other points in the piece where I used the colour and brightness information from the prerecorded video content to affect the lighting. Using the Isadora ‘color watcher’ actor, I could extract the colour information from one or more pixels of the video stream. In some cases I would follow the average brightness of the overall video image, other times I would extract the red/green/blue information of the video and send it to the red/green/blue LED’s, either as a whole stream average or by sections. This effect was particularly engaging as it really made the video content seem more immersive. The colour of the images on the dancers coming from the front video projector was mirrored by the colour of the LEDs on the sides, giving three-dimensional look to the scene.

Figure 29 - LED side lighting emulating the intensity and colour of the projection overlay.
**Taiko drums**

Another very important interactive element was the live taiko drums, played capably by percussionist Jason Overy. I placed a microphone inside each of the two drums for audio amplification, and also fed this signal into Isadora for interactivity. During one of the drum solos, I connected the amplitude of the sound coming from each of the microphones to the intensity of a spotlight focused tightly on the drum skin of the taiko. The result was that whenever Jason hit the taiko, it shone brightly on an otherwise darkened stage. The effect was simple, yet quite evocative.

![Figure 30 - Jason Overy on the Taiko drums. The light focused on each drum skin was controlled via a microphone inside each drum.](image-url)
At other times we wanted a strike of the taiko drum to initiate a change in the lighting state on stage. In effect, we wanted to turn the drum into a ‘go button’ for the lighting. I initially attempted to do this with the microphones, but I found there were too many false positives – usually caused by ambient sound pickup in the microphone. Instead I mounted a piezo drum trigger inside one of the taiko drums. The drum trigger works similarly to a microphone, except instead of measuring vibrations in the air, it measures the resonant vibrations of the surface to which it is attached. This eliminated all of the false triggers and isolated only the sound from the taiko. The combination of using the microphone to measure variations in sound amplitude and frequency and the drum trigger to isolate specific drum hits proved so effective that the last third of the show (roughly twenty minutes) was entirely controlled by the taiko drummer – he controlled all the lighting changes, and even cued recorded music events. I had backups set on my computer in case of a false trigger, but they proved unnecessary, as the system was very robust.

Figure 31 - A piezo trigger inside the SL Taiko drum was used to advance to the next lighting sequence.
Smash booth

Another unique interactive element of the piece was the “smash telephone booth.” This booth was inspired by a phenomenon that exists in Japan where to relieve stress, people can pay to rent a room, and then smash and break everything inside. Because we could not safely smash things openly on stage, we created a “smash booth.” It resembled a telephone booth that Shay entered and then smashed a stack of china plates rhythmically to the accompanying taiko beats.

![Figure 32 - Shay Kuebler inside the custom made smash booth.](image-url)
To amplify the intensity of this scene, I attached a small microphone to the inside of the booth. We then played with different interactions between the sound of the plates being smashed, the lights inside the booth, and the general lighting of the stage. At the beginning of the scene, the brightness of the lighting inside the booth was set to be the inverse of the volume of the plate smashing, giving the effect that the smashing of plates was somehow affecting or damaging the booth. Gradually the effect reversed, and the booth became brighter with each smash; the effect grew until the entire stage was getting brighter with each smash. This evolved into a rhythmic duet between the taikos and the smashing plates, with both being lit only by their respective spotlights controlled by the live microphones, and no other light on stage.

Figure 33 - The Taiko drums and the smashing of plates created a sonic and visual duet. All the lighting in the scene was controlled by the audio intensity of the three sources.
**Magic Broom**

The final interactive element used in *Karoshi* was a “magical” broom. The idea was that the drummer, who also happened to be a trained martial artist, played the part of the janitor sweeping up after the other dancers. As he was sweeping, he realized that the movement of the broom gave him control over his environment. He used the broom as a bo-stick (a traditional Japanese martial arts weapon) and as he moved it through the air, the lighting changed around him. To create this effect, I borrowed some of the technology I had used in *Signal to Noise*. I carved a small channel on the handle of the broom and placed a small 9-degree-of-freedom inertial movement chip inside.

![Image of 9-degree-of-freedom inertial movement chip](image_courtesy_sparkfun.com)

**Figure 34 - A 9-degree-of-freedom inertial movement chip (image courtesy sparkfun.com)**

I attached this to an Arduino Fio board, which transmitted the movement data back to my computer. With this setup, I had access to acceleration data in three dimensions, rotational data in three dimensions, and magnetic (compass) data in three dimensions. This provided a relatively accurate representation of the broom in three-dimensional space such that I was able to create the effect that he could
control the lighting with the movement of the broom. The effect was not 100% accurate, but it was effective enough to wow the audience.

Figure 35 - Example of Isadora code for communication between the broom and the lighting system.
4. Conclusion

4.1 Stakeholders

In considering the value of interactive control of stage lighting and sound, one can distinguish four categories of people that might benefit from interactivity: technologists, artistic creators (e.g. director, choreographer, designer), performers, and audience. An individual may fall into more than one category. For instance, in both projects I performed the role of technologist and designer. In both projects the choreographers also danced in the piece, making them both performers and artistic creators.

The Technologist

For the technologist, interactive technology does not necessarily make their overall job easier, but it does shift the labour from one aspect of the job to another. To create a scene with great technological complexity using traditional non-interactive software requires hundreds of unique events or cues and several human operators. With interactive technology, the same scene might be created using only a handful of “cue” events, and few or no human operators, but much more time will be needed to create and program the parameters within which the interaction will take place.

I hope that, as technology progresses, it will become simpler for technologists to incorporate interactive elements without excessive programming. A very powerful software platform with a very simple user interface doesn’t currently exist, but
perhaps it will in the future. If that platform is developed, assigning interactive elements will very likely be simplified.

Figure 36 - "Drunk Rag" scene in Karoshi.

Figure 37 - Isadora screen shots of the same "Drunk Rag" scene in Karoshi. Notice when the 'freq 5' surpasses the threshold of 5, the gate is opened and values are sent to the LED lighting fixtures.
The Artistic Creators

For these projects the artistic creators consisted of the choreographers and myself, the designer. In theatre-based pieces, this category would include a director as well as other designers that may or may not have a hand in the interactive technology.

For the artistic creators, the main question is whether interactivity actually adds merit to the work. Lighting and sound that clearly interacts with the performers can be spectacular and evocative, particularly as this idea is still innovative and new. However, spectacle is often superficial. Ultimately, the answers to questions about interactivity are similar to all artistic questions: they are answered according to the judgment of the artists. Like all other theatre technology, interactivity is tool in the artistic toolkit that can be used enhance a particular piece, but whether it is the appropriate tool in any given case is a matter of subjective opinion.

The Performers

For the performer on stage, it seems that using interactive technology will almost certainly be a more gratifying experience. All of the dancers involved in both pieces during this thesis project reported enjoying the process and encountered a sort of symbiosis with their interactive environments that simply does not exist in pieces that are programmed in a conventional way. Working with interactive technology can make the performers’ jobs easier and less structured. For example, in a conventional dance setting, the choreography is usually set first and then the lighting is programmed to follow it. In this format, the onus is on the dancer to get
the choreography exactly correct at every performance in order to stay in their light – the slightest mistake could betray the symmetry of the two elements. Whereas if the technology is set to interactively follow the dancer, small variations in the choreography won’t affect the symmetry, because the technology will automatically and immediately adapt to the movement. Furthermore, the dancer is not bound to the choreography and is able to improvise if desired and the technology will follow.

The Audience

A significant question regarding interactive technology is whether it should be noticeable to the audience. Early works with interactive technology relied heavily on the “wow” factor of the technology and it often became the main theme of the work, or a prop on which the main theme relied. In these circumstances, it is usually the desire of the creators that the audience recognize and appreciate the interactive technology. A more recent trend is to integrate interactivity more seamlessly with the other elements of the show. For instance, in the example used before where there the lighting is closely tracking the dancer, is it important that the audience knows if the lighting is interactively following the dancer or if the dancer has tightly choreographed to the lighting? Is one inherently better than the other? Ultimately – as with all “technical effects” the significant question is whether the technical production elements, interactive or not, enhance the audience’s ability to understand and appreciate the performance.
4.2 Moving forward

It should be noted that a significant period of time elapsed between the initial research for this thesis in early 2012 and the final writing of this report. During this time, Karoshi was remounted as a touring production and I worked as designer and or technologist on at least half a dozen other productions involving interactive technology, some of which have toured nationally and internationally. Inevitably, technology has evolved and improved over time, as have my methodologies.

For the touring version of Karoshi, it was necessary to simplify the show to allow it to be quickly installed in various venues. Though Isadora was running all of the elements effectively, the prototype interface for lighting control was too time-consuming to program for repetitive use. So I separated the lighting control out of Isadora and into a different software-based lighting program called LX Console, designed by Claude Heintz. In order to maintain interactivity between the lighting and other elements, I used Isadora as the hub, and communicated with LX Console via MIDI commands. This allowed me to maintain the same level of interactivity in the production, but with a lighting interface much better suited to the multiple quick setups and tear-downs of a touring show.

The other interactive element that was eliminated for the tour was the magic broom. This was eliminated for artistic reasons, not technical limitations. After the original show had opened, the choreographer and I reflected on the effectiveness and impact of all the technological elements, and we came to the conclusion that the broom,
despite having high “wow” factor, did not really contribute dramaturgically to the piece.

In *Signal to Noise*, the touch-sensitive fabric sensors yielded interesting results, but I don’t see a wide spectrum of use for the technology. A second series of experiments might involve place the sensors on (or under) the floor rather than on the dancers. With very little modification to the underlying technology, it would be fairly easy to create a fabric-thin array of pressure sensitive tiles that could be placed underneath a conventional portable dance floor. This would give both positional (within the space) and pressure (weight) data that could yield some very interesting interpretations. Though pressure sensitive floors already exist, to my knowledge none exist that would be this portable or tourable.

Also, since starting my thesis project, the number of available software platforms has increased and the existing software platforms have improved. The current version of Isadora, for example, is much more powerful in terms of processing, and the user interface is simpler. Many users have moved to a new software platform called Touch Designer, by Derivative Software, which is more powerful in many senses, but the user interface is complex, and the lack of an inherent cueing system makes it cumbersome to use in a traditional theatrical setting. On the other end of the spectrum, Figure 53 software has released a fourth version of their popular software platform Q Lab. This new release has the ability to natively run DMX controlled lighting as well as audio and video media. The simple-to-use graphical
interface positions the software at a groundbreaking point as the first truly all-in-one software package. Unfortunately Q Lab does not have any inherent ability to run interactively. However, it does support all of the common communications protocols (MIDI, OSC, etc), so it can interface with other interactive software and hardware devices.

This thesis project focused on interactive applications in contemporary dance, but there are some fairly obvious ways that interactivity could improve and/or simplify traditional theatre production as well. For instance, motion tracking technology could be used to create automated followspots, or sensors could be embedded in light switches and prop guns to provide faster reaction times. Some of this technology exists and is used at the higher end of the theatre industry, but with the availability of inexpensive sensors, it could easily be used by theatres of all budget levels.

4.3 Final Thoughts

In the end, the argument for interactive technology can be reduced to two questions – are we making things easier and are we making things better? The answer cannot be so simply reduced. Currently it’s still a lot of work to create interactive environments for performance, but software and equipment are improving rapidly. Every new show I work on, I create something that is incrementally better than the previous show. I can then take that advancement to the next show and build upon it some more. On the other hand, there are many very intelligent people working on
these same problems. It seems like every time I think of some improvement I would want, a few months later it has been implemented. Eventually we will reach a threshold where the tools we need will simply exist and it will only be a matter of pressing the appropriate button or checking the appropriate box and systems will link automatically and share information. Sensors will become commonplace and the challenge will be choosing what interaction happens when, and not how to make the interactions happen in the first place.

And are we making things better? I would certainly hope so. In my personal practice, I am happy to be finally moving beyond the question of “Can we do this?” to “Should we do this?” Interactive technology is no longer a complete novelty and so becomes another powerful tool with which to tell a story or explore an idea. Much like modern theatrical lighting or a complex soundscape can help evoke a particular mood, interactive technology can help engage the audience in ways that were formerly impossible.
References


Figure 53 (2018). Q Lab (version 4.3) [computer software]. Retrieved from https://figure53.com/qlab/

Troikatronix (2013). Isadora (version 1.3.1) [computer software]. Retrieved from https://www.troikatronix.com
Appendices

Appendix 1: *Signal to Noise* Lighting Paperwork
Appendix 2: *Signal to Noise* Isadora Scene Examples
Appendix 3: *Karoshi* Lighting Paperwork

**LX Inventory:**
- 16 x 36" ETC S4 575 watts. (10 used - top wash - 1 swapped to 70"
- 2 x 10" ETC S4 675 watts. (2 used - swapped to 66x for booms)
- 8 x 26" ETC S4 575 watts. (8 used - specials - 2 swapped to 50"
- 6 x 50" ETC S4 575 watts. (6 used - booms)
- 4 x ETC Par 750 watts (full lens kit), (not used)
- 12 x PAR 66 NPL 1 kit, (not used)

**Wash Colours:**
- Cool Backs: R81 (froth tip wash)
- Warm Backs: L156 (acrylics)
- Cool Top: R362 (acrylics) + R119
- Warm Top: R112 + R119
- Tops: R304 + R119
- Shirts: R132
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</table>
### Karaoke/drunk

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<thead>
<tr>
<th>Scene</th>
<th>Event</th>
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<tbody>
<tr>
<td>51</td>
<td>all turn to face front, karaoke, karaoke video</td>
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<tr>
<td>52</td>
<td>??</td>
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<tr>
<td>53</td>
<td>Video shifts to back curtain</td>
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<tr>
<td>54</td>
<td>Scott big Karaoke</td>
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<tr>
<td>55</td>
<td>DSL TV</td>
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<tr>
<td>56</td>
<td>Restore</td>
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<tr>
<td>57</td>
<td>MSR TV</td>
</tr>
<tr>
<td>58</td>
<td>Restore</td>
</tr>
<tr>
<td>59</td>
<td>lose big karaoke</td>
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<tr>
<td>62</td>
<td>B/O transition into drunk</td>
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<tr>
<td>65</td>
<td>second drunk look</td>
</tr>
<tr>
<td>66</td>
<td>drunk strobes, SL strobes</td>
</tr>
<tr>
<td>67</td>
<td>B/O, Restore</td>
</tr>
</tbody>
</table>

### Samurai Solo

<table>
<thead>
<tr>
<th>Scene</th>
<th>Event</th>
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<tbody>
<tr>
<td>70</td>
<td>Nick straightens (wind audio), Shins</td>
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<tr>
<td>71</td>
<td>Nick's head hits the floor, Samurai</td>
</tr>
<tr>
<td>72</td>
<td>B/O, Nick ends in Jason's light</td>
</tr>
<tr>
<td>74</td>
<td>Nick stands, Add DSL square, Standby Eric</td>
</tr>
<tr>
<td>75</td>
<td>Nick kneels, Add sword special</td>
</tr>
<tr>
<td>76</td>
<td>First Taiko hit, Tyler enters</td>
</tr>
<tr>
<td>77</td>
<td>Second Taiko hit, B/O, Legs out</td>
</tr>
<tr>
<td>78</td>
<td>ON rim shots, Add booth special, Scrim out</td>
</tr>
</tbody>
</table>

### Booth

<table>
<thead>
<tr>
<th>Scene</th>
<th>Event</th>
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<tbody>
<tr>
<td>80</td>
<td>Shay Enters Booth, Booth, booth back only</td>
</tr>
<tr>
<td>81</td>
<td>Jason Screams, B/O</td>
</tr>
<tr>
<td>82</td>
<td>Shay screams, no interaction</td>
</tr>
<tr>
<td>85</td>
<td>Shay goes at it a secon time, Booth 2, Reverse interaction</td>
</tr>
<tr>
<td>86</td>
<td>Shay Final big yell, B/O</td>
</tr>
<tr>
<td>87</td>
<td>Shay opens door, Brighter exterior</td>
</tr>
<tr>
<td>88</td>
<td>Shay leaves</td>
</tr>
<tr>
<td>89</td>
<td>Sweeper</td>
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<tr>
<td>90</td>
<td>Shay enters Booth, Booth, booth back only</td>
</tr>
</tbody>
</table>

### Second Walking

<table>
<thead>
<tr>
<th>Scene</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>90</td>
<td>As sweepers start to leave, Falls 2, crossfade to falling, Legs in</td>
</tr>
<tr>
<td>91</td>
<td>B/O with falls</td>
</tr>
<tr>
<td>92</td>
<td>B/O, Ending square</td>
</tr>
<tr>
<td>93</td>
<td>darker walking look</td>
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<tr>
<td>94</td>
<td>Brighter with dropouts</td>
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<tr>
<td>99</td>
<td>Oorishi, Oorishi</td>
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</tbody>
</table>

### Mayhem

<table>
<thead>
<tr>
<th>Scene</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>on last hit of Oorishi (auto), B/O, Bright mayhem look</td>
</tr>
<tr>
<td>105</td>
<td>(end of mayhem), Drum rolls, drum rolls into flash/B/O</td>
</tr>
<tr>
<td>108</td>
<td>after 3rd Drum roll, B/O, Stairwell &amp; final audio</td>
</tr>
<tr>
<td>111</td>
<td>(end of audio??), Blackout</td>
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<tr>
<td>112</td>
<td>Curtain call</td>
</tr>
<tr>
<td>113</td>
<td>dip</td>
</tr>
<tr>
<td>114</td>
<td>Post Show</td>
</tr>
</tbody>
</table>
Appendix 4: Karoshi Isadora Scene Examples