Developing Ensemble Works for Acoustic Instruments and Audiovisual Media

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Abstract: This paper describes three recent audiovisual compositions, composed by the author, for small acoustic ensembles, and discusses three key elements of the creative process. The audiovisual works feature notated compositions for acoustic instruments, reactive visuals created in TouchDesigner and reactive electronic sound created in Pure Data. Interactivity between the musicians and audiovisual media is enabled via digital signal processing of the acoustic instruments' sound, as well as a wireless, accelerometer-laden glove on musician hands for gestural control. The three points of discussion include: the managing of roles between ensemble members in an audiovisual set up, sequencing audiovisual elements in small ensemble formats, and incorporating sensor-glove movement instructions in the sheet music.

Introduction

In this paper, I describe the processes and approaches in my creation of three recent works (*Songs of Innocence, Albinauric's Cave and Dreamscape*) for acoustic instruments and audiovisual media. The focus of these three works is in the conventions of audiovisual performance design specifically for small ensembles. Two works are for duo ensemble, and one work is for trio ensemble. These design conventions include the consideration of role assignment between ensemble members, sequencing audiovisual elements with ensemble reactivity in mind, and a consideration for communicating gestural movement to ensemble members who are using a sensor-glove.

Songs of Innocence is for violin, piano, and reactive computer-processed video and sound, and is inspired by William Blake's poem of the same name. *Albinauric's Cave* is for bass clarinet, cello, piano, and reactive

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computer-processed video and sound, and is inspired both in sound and visuals by video game environments. *Dreamscape* is a piece for viola, piano and reactive computer-processed video and sound, and was performed live at the CMT Welcome Concert at the Queensland Conservatorium, Griffith University in March 2024.

Overview of Technologies

The majority of audiovisual work with acoustic instruments only features solo instrumentalists, with ensembles being greatly underrepresented. Some examples of relevant audiovisual work include the *Hyper-hybrid Flute* (Chin et al., 2021), the augmented guitar pick *Magpick* (Morreale et al., 2019), the *Alto.Glove* (Thorn, 2018), the augmented piano performance tool *PiaF* (Zandt-Escobar et al., 2014) and the augmented electric guitar (Lähdeoja, 2008). Despite these works featuring only a solo instrumentalist, they were all of great inspiration due to their applications of reactive electronic sound and/or visuals with acoustic instruments.

Various software and hardware were involved in the creation of the three aforementioned audiovisual works. These include: sensor-gloves for motion tracking, Pure Data software for data processing and performance sequencing, and TouchDesigner software for visual generation. A microphone was also used on select instruments for live sound sampling and digital signal processing in Pure Data. This subsection briefly describes the general use of the above technologies in each of the audiovisual works.

A movement tracking glove was used by the violinist and pianist in *Songs of Innocence* for live control over electronic sound effects and visual effects. The glove was used only by the pianist in *Albinauric's Cave*, for control over electronic sound effects. The glove was used again by both the violist and pianist in *Dreamscape* for control over electronic sound. As seen in Figure 1, the sensor-glove that was used shares a similar design to preexisting examples (Torresen et al, 2010; Lu et al., 2012, and Thorn, 2018), with my iteration involving an XBee wireless module (transmitting on the IEEE 802.15.4/ZigBee standard), Teensy LC and accelerometer, to transmit accelerometer data from the musician's hand movement to the receiving XBee module connected to the computer.

Figure 1. Wireless sensor build.

Figure 2 shows the sensor-glove worn by a violinist. As my sensor-glove design is relatively simple and already well documented by the aforementioned authors, it is not a part of this paper's discussions. While those aforementioned authors describe technologies for building sensor-gloves, the focus of my work is in the compositional methods of audiovisual works, and the situation of technology in an ensemble that foregrounds acoustic instrumentation.

Figure 2. Violinist using the sensor-glove.

Pure Data is a versatile programming environment that is well suited for audiovisual performance creation. Pure Data served as the processing hub of each audiovisual work. The sensor data processing, visual sequencing, and digital signal processing all intersected within Pure Data. Microphones were used to provide sound input into Pure Data for live digital signal processing and sampling effects, although the sound input was also routed into TouchDesigner to facilitate visual manipulations. TouchDesigner is a popular visual design software commonly used in a wide variety of audiovisual installations and performances. TouchDesigner was used to generate all visuals seen in the three audiovisual works, with visual sequencing completed within Pure Data. Some developmental findings regarding Pure Data and TouchDesigner implementation are discussed throughout this paper from section 2 onwards. The first main point of discussion is in the managing of roles between ensemble members in an audiovisual set-up.

Managing Roles Within an Ensemble

When two or more performers are actively involved in the affecting of audiovisual elements, it becomes a design challenge to assign roles of control to each performer. As I am the composer of the music, designer of the audiovisual systems and pianist in each of the three works, I naturally become the leader of the ensemble and need to coordinate the audiovisual sequencing during the performance. Performance sequencing is expanded upon in section 3. Having the audiovisual designer/s themselves actively coordinating a performance amongst an

ensemble has the obvious benefit that they know the work the best, and can take on the responsibility much more easily compared to other less tech-experienced ensemble members. However, it is not always possible for the system designer/s to be present at a performance of their work (e.g. a performance by an established ensemble based in a different country).

A common thread in the three works is that they primarily feature piano and various stringed instruments. This instrumental combination was chosen due to pianists and string players having a considerable range of motion while playing. Each instrumentalist in an ensemble has their own gestural limits, i.e., a saxophonist does not have a notable range of motion in their arm and hands, aside from individual finger movements which can be relatively subtle to an audience. A pianist's hands have a horizontal plane of movement (i.e., playing in a lower or higher register) which can be used for audiovisual control. String players have two axes of movement that can be taken advantage of: horizontal motion across a string, and vertical tilt of the bow as it crosses to higher or lower strings. I found it important to consider the capabilities of each musician, and how their performative movements could be harnessed in a way that is congruent with the desired audiovisual effect control. For future research, it may be an opportunity to investigate how instruments with a restricted range of movement could have meaningful control over audiovisual media.

A solution to the role of the pianist in all three works was that the left hand (equipped with a sensor-glove) can be freed at desired moments of the work to focus on gestural control over audiovisual elements. This allows for a simultaneous gestural control with the left hand while the right hand plays the piano, if so desired. In *Songs of Innocence*, the pianist's left hand controls simple visual effects such as lens distort, brightness and colour effects. As a contrast, in *Albinauric's Cave*, the pianist's glove hand controls digital signal processing effects, including distortion, overdrive and frequency filters. In *Dreamscape*, the pianist's glove was used to record short audio samples of the viola being played, and then manipulate that sample with various digital signal processing effects. The pianist also uses a MIDI keyboard as an additional controller, located on the left side of the piano music stand, which is mapped to control the performance sequencing of the work. I found that the most effective use of the pianist's glove was in *Albinauric's Cave* and *Dreamscape*, where it controlled digital signal processing effects. It proved more convincing than the control over visuals as seen in *Songs of Innocence*, and as the visuals were also partly reactive to the processed sound effects, it created a pleasing chain-reaction of audiovisual interactivity. My approach in chaining audiovisual reactivity was inspired by works such as *Allures* (Jacobs, 1961), which aimed to blend the image and sound together seamlessly so as to forge an inseparable whole.

That is not to say that all tech-related control is assigned to the pianist or 'leader' of the ensemble. In *Songs of Innocence*, the violinist was responsible for all of the electronic sound manipulations, from triggering a

re-record of the acoustic sound sample, as well as reverb, frequency filters and delay effects affected by the tilt of the bow. A custom 'excitement meter' (as seen in Figure 3) was built in Pure Data, which tracks the amount of bow movement every second, and so builds up the 'excitement level' represented by a vertical slider. Continued bow movement over a certain threshold per second will steadily make the meter rise to the maximum value, and if the bow movement is not maintained over the 'excitement' threshold, then the meter will slowly decrease back to the minimum value until the threshold is met again.

Link to performance of *Songs of Innocence*: https://www.youtube.com/watch?v=k8ze0dnQbdk

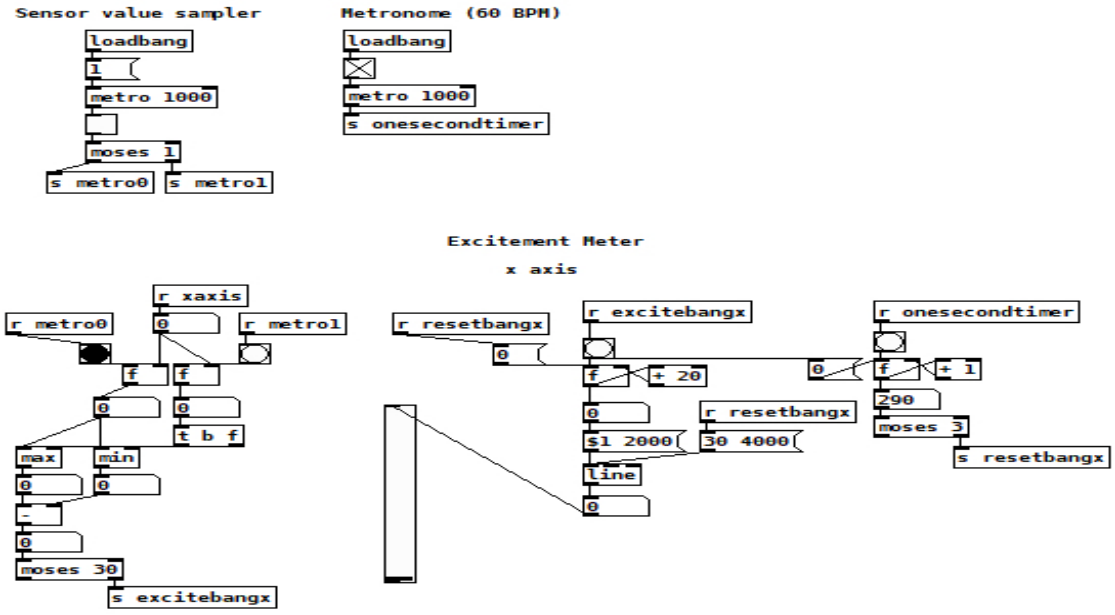

Figure 3. 'Excitement meter' in Pure Data.

The violinist was given an interesting role of electronic sound control over the entire ensemble, not just over its own sound. In sections of solo piano (such as at the start of *Night* at 21:29 of *Songs of Innocence*), the violinist moved her sensor-glove to catch the acoustic piano sound, trigger re-records, and apply audio effects. This co-control of electronic sound over other ensemble members was an interesting interplay that I developed further in *Dreamscape*.

Dreamscape is largely founded in the idea of both ensemble members having an equally weighted interaction with the other ensemble member and the audiovisual media. The musical composition was written as an extended call-and-response, with one member of the duo actively playing their instrument, while the musically non-active member focused on gestural controls to digitally sample and apply effects based on the acoustic sound of the other musician. This relationship was inverted between the duo with the following musical phrase, and so on. Both musicians each wore a sensor-glove, but only one glove's sensor data was active at any one time,

according to when each instrumentalist was required to use switch to the gesture-making. This was an enjoyable function that myself and the viola player liked using and performing with. Further steps would be to experiment with how a similar system could be created for larger ensemble sizes. Overall, the roles of musicians within the ensembles were decided based on each ensemble member's level of insight into the audiovisual systems and the gestural capabilities afforded by the instruments themselves.

Performance Sequencing

With the live performance elements covered, the audio visual elements also required hardcoded sequencing to follow the structure of the music. The audiovisual progression of a work was initially conceptualised as either being set on a timer, with each subsequent event triggered at preset intervals, or alternatively, being manually cycled through by one of the musicians with a MIDI (Musical Instrument Digital Interface) controller. The second option was preferred for being the more flexible in a live scenario, where adhering to strict timings can be a major detriment. This role of 'performance coordinator' naturally lent itself to being the composer/designer of the audiovisual systems, who plays the piano in each work. A MIDI keyboard was placed on the left side of the piano music stand, with its touch pads and potentiometers mapped to parts of the Pure Data patch to control the progression of the audiovisual media, as well as to calibrate audiovisual sensitivities on the fly.

To cycle through visual scenes in TouchDesigner, one touch pad on the MIDI keyboard was mapped to a Trigger object, with the number of button presses, or triggers, counted with a Count object. The Count object value was then mapped back to a Switch object. For rehearsal and performance purposes, another touch pad was mapped to step back one scene in the cycle, and another pad was mapped to reset both the TouchDesigner and Pure Data files back to the 'pre-performance' status. Figure 4 shows how the digital sound processing effects in Dreamscape were changed when cycling forward through the performance sequence. Each sound setting was defined by changes in digital signal processing effects such as an amplitude LFO (low-frequency oscillation), a hard sound gating effect, reverb, filters, and pitch transposition. All that was needed to switch to a new sound setting was to send the desired sound setting number from one to five to the 'soundsetting' send object.

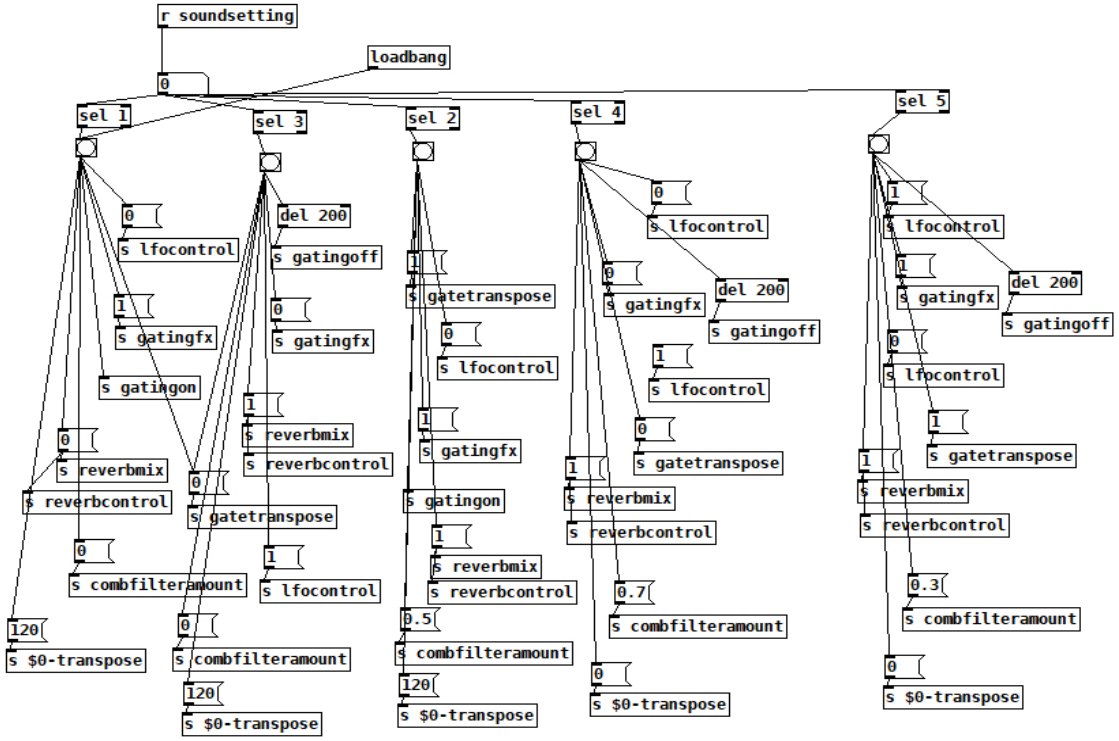

Figure 4. Digital signal processing effect sequencing in Pure Data.

The back-and-forth sensor control featured in *Dreamscape*, as described in section 2, required gating either the pianist's or the violist's sensor data, and sequencing these gating messages according to the needs of the acoustic music. As seen in Figure 5, the flow of sensor data into Pure Data was gated via the spigot object. While the Pure Data patch allows for data from all three accelerometer axes, only one axis was used in this work, in order to simplify the motion controls. When the viola plays the acoustic music part and the pianist is using their sensor-glove, a '0' is sent to the viola's sensor-glove spigot object, and a '1' is sent to the pianist's sensor-glove spigot object. When the roles between the musicians switch, so do the numbers sent to the spigot objects. These 0 and 1 messages were sent from the primary sequencing sub-patch, in a similar manner to the digital signal processing effect changes seen in Figure 4.

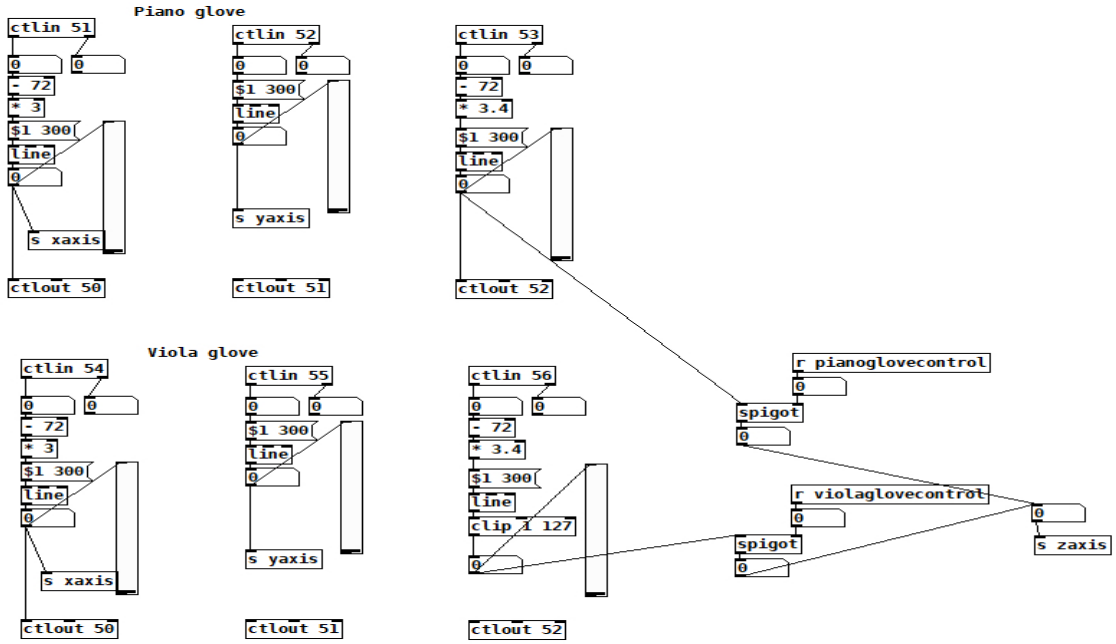

Figure 5. Gated sensor values in Pure Data.

Albinauric's Cave presented a unique opportunity in its performance sequencing as the visuals all take place within a single 3D-modelled environment, and each scene is a unique camera angle within the environment to focus on new visual elements. Once the entire visual environment was constructed within TouchDesigner, the order of scenes would be chosen and then programmed into TouchDesigner via a Switch object. These camera angles were found by adjusting the camera's translate, rotate and pivot values until pleasing results were obtained. Tables were created containing this camera position data, with one such table illustrated in Figure 6. To avoid a static scene, the translate x, y and z values have slight shifts in their movement, with the use of an LFO object and its range remapped to the values as specified in the table.

Scene 1	Translate	Rotate	Scale	Pivot	Uniform Scale
x	-0.84 to -1.5 LFO Frequency: 0.01 LFO Phase: 0	2.3	1	-7.34	1
y	-0.85 to -1.05 LFO Frequency: 0.01 LFO Phase: 0.3	324		-0.79	
z	2.32 to 2.72 LFO Frequency: 0.01 LFO Phase: 0.7	0		-1.5	

Figure 6. TouchDesigner camera control values.

A camera control sub-patch was then created in Pure Data, which sent the above numbers directly to the camera object in TouchDesigner. However, it proved overly complicated and was ultimately abandoned in favour

of sequencing within TouchDesigner. It was found ideal to keep all numbers and math for visual manipulations within TouchDesigner, and not to use Pure Data as the number-processing intermediary. The last key point of discussion relates to the incorporation of gestural symbols in sheet music to instruct sensor-glove movements.

Notating Motion-Tracking Sensor Movement In Sheet Music

As sensor gloves play a key part of the interactivity in each of the three audiovisual works, there have been considerations for how glove movements could be instructed to musicians, with the use of custom-created symbols placed within the acoustic sheet music. My need for gestural symbol implementation originated from my preference for glove movements being more deliberate and specific. Traditional music notation is continually being reinvented within the avant-garde and music technology communities. *Notations 21* (Sauer, 2012) is a compendium of music from around the world with experimental notation, inspired by the work of John Cage. The book contains a plethora of approaches to graphical musical scores, that uses visual elements such as shape, colour and texture in peculiar ways to convey the musical result. Elements of these graphical scores have been adopted for my audiovisual works.

The use of the sensor-glove in *Songs of Innocence* was relatively undefined and more improvisatory, which led to feelings of non-direction. From that experience, I wanted to use the sensor-glove to move and gesture in certain musical moments to produce unique, pleasing audio effects. I also wanted to reliably reproduce those pleasing effects in each performance of a work. As an improvement on the performance outcomes of *Songs of Innocence*, the sheet music for *Albinauric's Cave* featured an array of symbols to instruct the pianist to move their sensor-gloved hand in various ways at defined moments in the music. Figure 7 shows an array of gestural instruction icons which I designed. The eight top-most icons instruct the musician to rotate their glove-equipped hand either left or right, and to an approximate degree of rotation. The icons of a number within an hourglass indicate how many seconds a gestural movement should be completed over and are always paired with a gestural movement icon. The audio speaker icon indicates when digitally processed sound is expected to be heard.

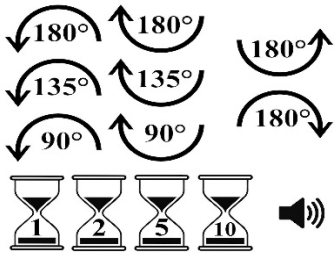

Figure 7. Gesture icons.

The process of adding the gestural symbols to the sheet music occurred towards the end of the development process, after the Pure Data sound generation elements were finalised, and after the TouchDesigner visual file was reasonably close to completion. While the initial sketches of the gesture icons included ideas for 'pitch' rotation icons, these were ultimately scrapped, to keep the movement only on the x axis and simplify these score additions for musicians who may not have much extra bandwidth beyond what they are most experienced in, which is simply playing their instrument.

In preparation for the performance and recording of each work, a studio session was spent running through the work (which was done myself, without other ensemble members) and experimenting with sensor movements and timings at key moments of the composition, to find pleasing effects that complement the music. Symbols to describe the sensor's turn directions, angles, and durations at all the desired times were inserted into the sheet music above the stave. It can be seen in Figure 8 how these symbols were inserted into the first two lines of *Albinauric's Cave.*

Link to performance of *Albinauric's Cave*: https://www.youtube.com/watch?v=eUHD7p7XkF4

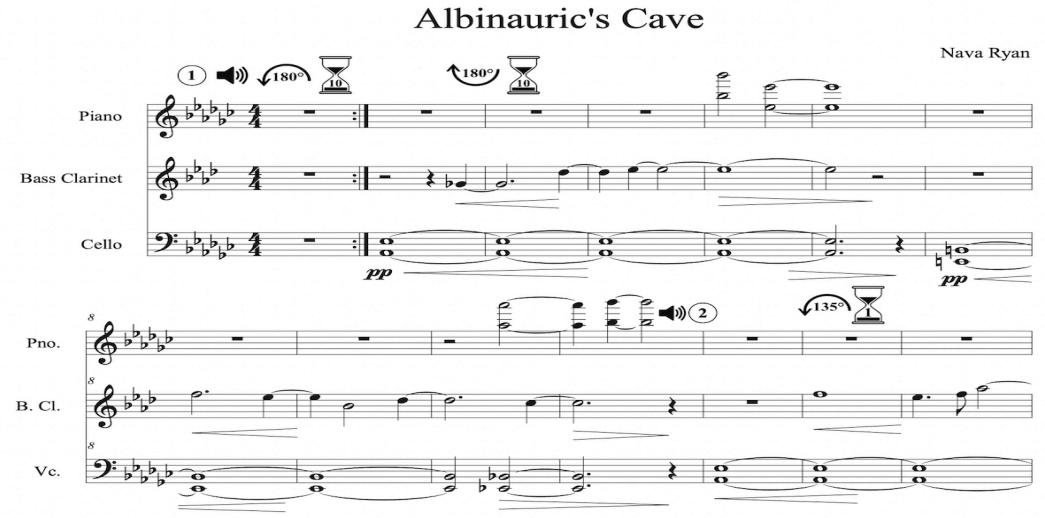

Figure 8. Gesture icons inserted into sheet music.

The addition of the symbols in *Albinauric's Cave* noticeably aided the connectivity of the live musicians and audiovisual media, and gave a greater sense of importance to each sensor movement as compared to the sensor use in *Songs of Innocence.*

In Dori's work *Arcos*, for cello and augmented violin bow, the performer plays from a real-time graphic score that is generated via the augmented bow's motion data. As seen in Figure 9, the graphic score displays various symbols that the performer then imitates. These symbols include a virtual representation of the cello's

strings, with a symbolic bowing line that hovers over a certain part of the strings and at a certain level of playing intensity, as communicated through the colour of the bow line. Other bow gestures that are communicated through the graphic score include falling circles that indicate that a new note is to be played when the dot reaches the bottom of the screen. A circular bow motion is indicated via a moving circular line. While this type of interactive, live score differs to the more prescribed and calculated approach of the graphical score elements in *Albinauric's Cave*, an obvious similarity is the use of the partial circular line to indicate that the bow moves in a particular direction. As this circular line moves gradually in Dori's work, and so dictates the time in which the circular motion is to be completed, this time function was adapted in my own score with the hourglass icon containing the number of seconds to complete the action.

Figure 9. Graphic score for Arcos (Dori, 2021).

The use of audiovisual symbols continued into my next work, *Dreamscape*. An excerpt of a draft score for this piece is seen in Figure 10. The score was littered with markings signifying the intended sequence changes, sensor movement symbols with their associated timings, as well as textual markings to indicate when a new sound sample is to be recorded. In a rehearsal with the violist, she preferred not to use the symbols, and instead just improvise with sensor movements while listening to the sonic results live. She noted that it was difficult to focus on the gestural instructions while also keeping track of the piano part while also staying in time. This preference ultimately led to the sensor gesture symbols being discarded for the performance. I believe that the discomfort for the violist was simply because we did not have enough rehearsal time to become properly accustomed to the symbols.

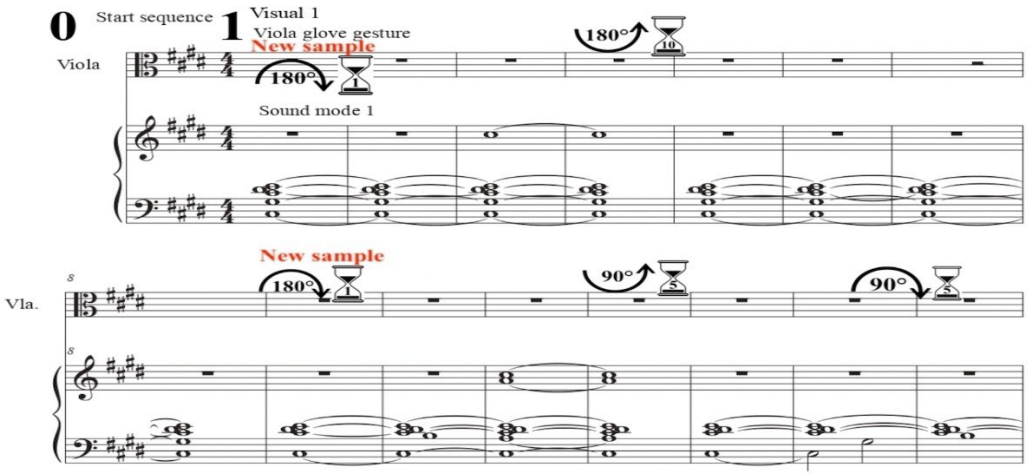

Figure 10. Draft score excerpt from Dreamscape.

In future audiovisual works, I would experiment with the placement of the symbols on the sheet music, and adjust the sheet music spacing so to allow for more room for the symbols, and to declutter the overall appearance. I would also like to experiment with how the gesture and hourglass icon could be combined, so that they can be read together more easily, rather than having them separate and adjacent. The musician involved in the recording of this work expressed some confusion with whether some symbols were applicable to their own playing. One solution would be to better communicate on the page which musicians the symbols are targeted for. This may be communicated through a short instruction at the top left of the first page, which states which players require a sensor-glove and which symbols are applicable to each musician. The other solution would be to have multiple versions of the sheet music, so that each musician's score contains only the symbols that are applicable to them.

Link to performance of *Dreamscape*: https://www.youtube.com/watch?v=mfD4IFxPxx0

Conclusion

This paper has covered developmental aspects in three audiovisual works, including managing roles between ensemble members in an audiovisual set up, sequencing audiovisual elements for ensemble format performances, and incorporating sensor-glove movement instructions in the sheet music. Musician roles were decided based on each ensemble member's level of insight into the technologies and their gestural capabilities. Gestural symbols in sheet music were helpful for dictating specific sensor-glove movements, however were not necessary when a more improvisatory performance was desired. I hope that these discussions might be of use to other audiovisual designers who look to work with small acoustic instrument ensembles or possibly even larger ensembles.

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