

# LIVE STRUCTURES: OCULAR SCORES™

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## ABSTRACT

Live Structures is a research and composition project that explores different ways to interpret data into graphic notation and compositions. The Live Structures project started in October 2017, supported by an Explore and Create Grant from the Canada Council for the Arts received by Bouchard. One of the goals of the Live Structures project is to interpret data from the analysis of complex sounds into a visual musical notation. The tool, developed in collaboration with Joseph Browne of matralab at Concordia University, is called Ocular Scores™. So far, three iterations of the Ocular Scores Tool have been created, each performing multiple functions: a) the ability to draw an image from the analysis of complex sounds that can be used as gestural elements to compose new works or to compare a complex sound against another complex sound, b) the ability to draw full transcriptions of a performance for future interpretation, and c) the ability to draw images in real time and to manipulate those images to create interactive projected scores to be performed live by multiple performers.

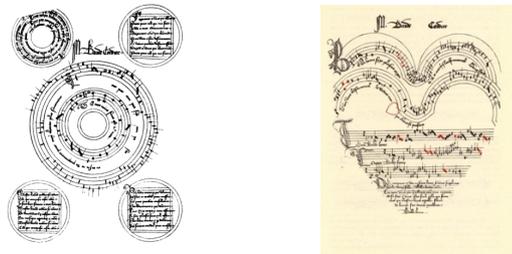
These various applications and how they can inspire composers and performers will be described in more detail in this paper.

## 1. INTRODUCTION

Music notation is by definition a visual notation: images and codes that convey a wide variation of precision and systems to express pitch over time. Musical notation that utilizes mostly images, often described as “graphic notation,” has evolved since the 1950s, with more and more composers experimenting to find new ways to express their unique musical vision.

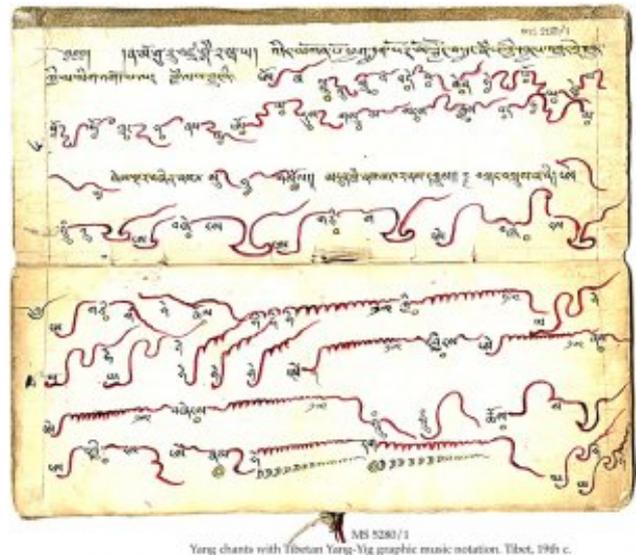
But when we look at the 14th century Baude Cordier “eye music” scores [1] (see Figures 1 and 2) or the 19th century Tibetan Yang-Yig notation [2] (see Figure 3), it is striking to see similarities with some scores that have been created in the last 60 years.

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**Figures 1 and 2.** 1380–1440 Baude Cordier creates two early examples of what has been called “eye music.”  
From *Timelines of language, communication and semiotic systems*.

There seems to be a certain “Preset of the Mind” [3] in the coding language that musicians are attracted intuitively to use, certain elements in the semantic of the graphical language that seem to repeat themselves through time.



**Figure 3.** 19th century Tibetan Yang-Yig notation from the Schøyen Collection

With Ocular Scores™, Bouchard and Browne have chosen to interpret data from the analysis of complex sounds using a custom-made tool that leaves a tremendous freedom of interpretation to the composer and the musicians. Despite being an interpretation of data, the images feel familiar. Bouchard and Browne strived to keep this sense of immediacy while creating images that are replicable.

## 2. CONTEXT

For forty years, Bouchard’s work has taken its inspiration from the world we live in: natural, sociological, and political. It is often inspired by nature’s geometry and textures, as if composing music could begin by staring with a magnifying glass at nature’s elements — water-gas-rock formations and chemical reactions — and creating from these images a series of abstract musical landscapes.

We have many tools available to analyze natural phenomena, complex sounds, and human behaviors. In the Live Structures project, Bouchard went one step further to include data interpretation to conceive of a new way to compose music: In the case of Ocular Scores™, we are translating data from the analysis of rich and complex sounds into graphic notation and symbolic systems.

## 3. IMPETUS

During the past few years, Bouchard has collaborated with advanced improvisers while she created multimedia performances. It was inspiring to work with such innovative musicians, and it made Bouchard want to be able to notate their unique collaborations in such a way that they could be interpreted by other musicians. Initially, Bouchard simply wanted to find a way to draw images of complex sounds and extended techniques and integrate those images into traditional scores. From this modest beginning, Bouchard and Browne have developed all of these other applications.

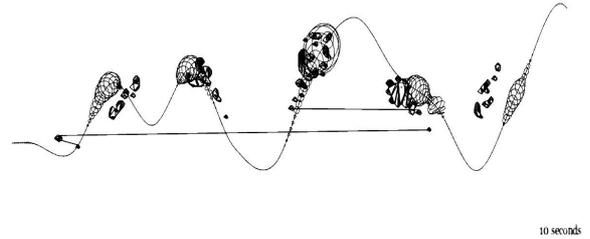
## 4. DESIGN GUIDELINES

From the start, we looked for a notation that conveyed a sense of immediacy — a visual representation that was familiar and intuitive to musicians adhering to the “preset of the mind” concept. The images had to be replicable: Created from the interpretation of the sound analysis, the images had to be a reliable interpretation of a complex sound. This graphic notation needed to contribute something unique to our already sophisticated and precise musical notation system.

Because of our limited budget, it was impossible to create a digital tool from scratch. In this first exploratory phase, it proved to be unnecessary: There are plenty of tools available that could be applied to achieve our goals. For designing the visual aspect of the tool, Browne chose to use TouchDesigner [4], a node-based visual programming language for real-time graphics and interactive media.

Our initial design process was one of elimination so that we could arrive at something elegant and practical and a tool that we would actually want to use because it would inspire us as creators and would inspire performers as well.

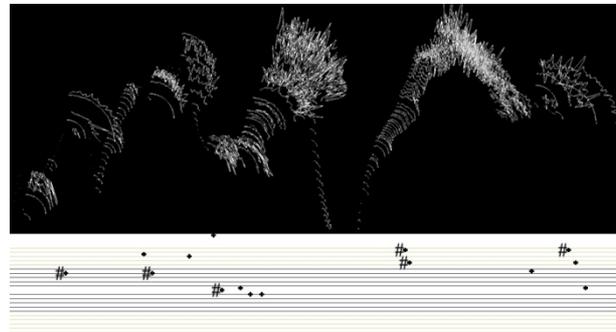
In Ocular Scores™, black lines are drawn on a white surface, as if a pen is drawing an image. See Figure 4.



**Figure 4.** This image was created with Version 1 of Ocular Scores™ and represents five short bursts of wind sounds by François Houle, recorded at the Banff Center for the Arts. [5]

We have the option to use a white line drawn on a black surface when we want to project in a theater space. We also kept the traditional conventions of time on the x-axis and frequency on the y-axis.

We have the option to plot main pitches on music staves (treble and bass) with the option to add additional lines (orange). See Figure 5.



**Figure 5.** This image was created with Version 2 of Ocular Scores™ and represents a musical gesture from an improvisation by Lori Freedman, performed and recorded at matralab, Concordia University, Montreal, Quebec, Canada. [6]

Ultimately, we were very careful not to clutter the page; whenever we add a layer of information, we always have the option to take it off.

## 5. PROCESS

Ocular Scores™ was developed in collaboration with master improvisers who tested each prototype and gave us their expert feedback. Ocular Scores™ is still in development.

## 6. OCULAR SCORES™

### 6.1 Version 1: Capturing Gestures

In Version 1, the first step is to upload a prerecorded sound file to be analyzed. See Figure 6.

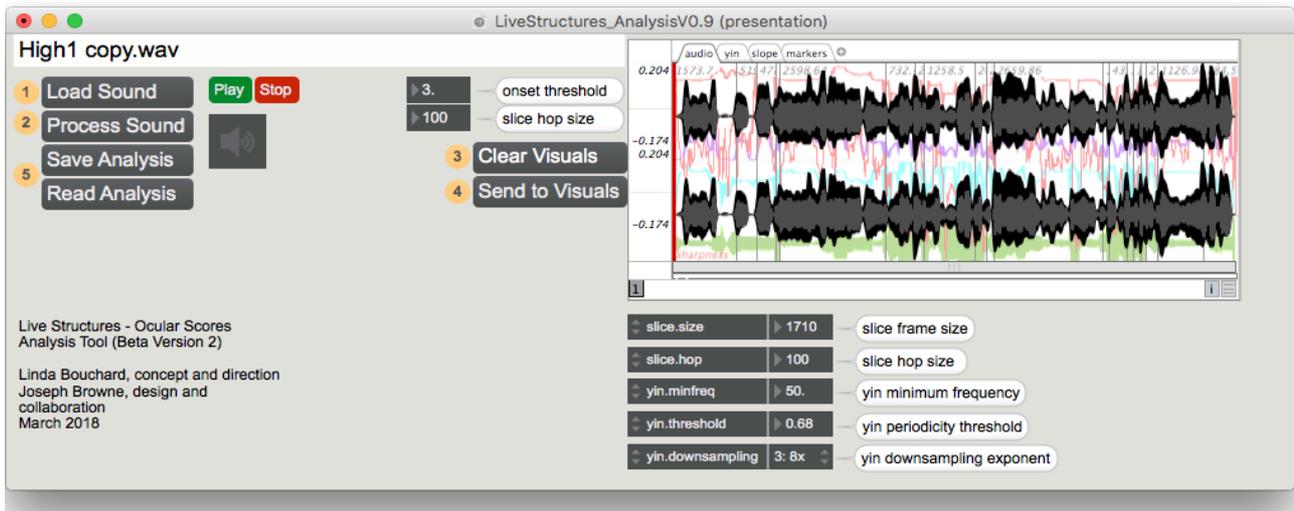


Figure 6. A short sound file is loaded into Max.

The analytical data is produced using the Max package MuBu For Max<sup>1</sup> by IRCAM [7] and their *pipo.yin* [8] audio descriptor to extract frequency, amplitude, and periodicity information from the analyzed sound file. See Figure 7.

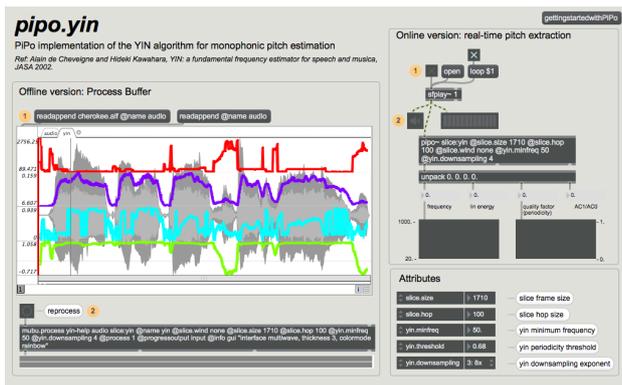


Figure 7. The analytical tool used for Ocular Scores™ Version 1 is *pipo.yin* audio descriptor from MuBu for Max package by IRCAM.

The data is then sent to TouchDesigner over a local UDP network and is translated into a visual representation of the sound. Time is plotted on the x-axis from left to right, frequency data is mapped to translation on the y-axis, and amplitude is represented by the size of the shape being drawn. Periodicity is mapped to rotation of the shape on the z-axis, which created a visual irregularity that defines when the sound file is richer and noisier. The visual has a more uniform pattern when the sound is more periodic.

A variety of scaling parameters and image-based parameters can be adjusted to create an image that the composer feels offers the best impression of that sound. We aimed to limit the available possibilities in order to maintain a cohesive vocabulary for representing sounds

visually, but enough options remain that one can truly interpret how the sound is visualized. See Figure 8.



Figure 8. This image shows the user interface from Ocular Scores™ Version 1. On the left are parameters that affect the scaling of the input data — how the image will appear spatially. On the right are parameters that affect the character of the image and repositioning after scaling. With a single data set, one can produce several distinct images.

The result is a mixture of data interpretation and intuitive decision-making.<sup>2</sup> By saving presets, we can

<sup>1</sup> MuBu For Max is a tool set for analysis of sound and motion and interactive sound synthesis and machine learning created by IRCAM in Paris (<http://forumnet.ircam.fr/product/mubu-en/>).

<sup>2</sup> Every step of the way we asked ourselves, “What does this sound look like to me? If I were to try to imitate this sound, what image would inspire me in that direction?”

replicate the same image with the same sound over and over. It is an authentic data interpretation.

The advantage of this prototype is that we have many different ways of interpreting a single musical gesture by using different presets. It is easy to create a musical score with a collection of images. [9]

It is possible to add handwritten annotations and fingerings and load them into other performance software, like ForScore<sup>3</sup>, or simply print the pages on paper. It is also easy to use this prototype as a pedagogical tool to practice new complex sounds or to imitate complex sounds from other instruments to expand one's vocabulary.<sup>4</sup>

The first full composition using this technology is called "DROP." The musician performed from a series of images that were created from the analysis of different water sounds: droplets, waves, breaking ice, etc. The images [10] were loaded into ForScore and were further annotated by the performer.

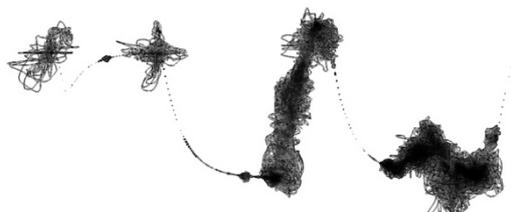
As we worked on the piece, it was revealing to see that the visual score required the same kind of commitment that a regular score requires. The same way a musician learns a score with a traditional notation, Kyle Bruckmann, for whom the work was composed, devoted time to understanding the piece, interpreting a code, and committing to specific musical gestures. [11]

A few months later, "DROP" was performed by Canadian soprano saxophone improviser Kyle Brenders. This second interpreter never heard the performance of Kyle Bruckmann, and yet, the composer was happy to hear the similarity of gestures in both performances. The character of the work was definitely recognizable. [12]

It is important to realize that by utilizing a graphic score of this nature, the composer relinquishes aesthetic control to the performer.<sup>5</sup>

## 6.2: Version 2: Live Input

In this prototype, both the analytical data and the images are produced inside TouchDesigner, bypassing Max. We can upload a sound file in the same way we did in Version 1, or we can analyze the audio input from a live performer. The images are created in real time on a continuous scrolling image. See Figure 9.

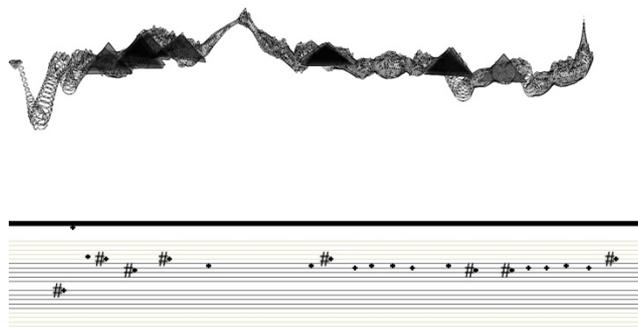


**Figure 9.** This image was created using the stereoscope shape option while analyzing a sound file of Lori Freedman improvising. [13]

Frequency analysis is achieved by using the analyze node in TouchDesigner to find the First Peak or the Highest Peak of the audio spectrum. The option to use First Peak or Highest Peak gives a more or less accurate analysis depending on the musical context — if it is a more noise-based sound, then highest peak is more accurate; if it is a more pitched-based sound, then first peak (fundamental) is more accurate.

Periodicity analysis is achieved by summing the audio spectrum and normalizing the data. If a signal is more noisy/less periodic, then the sum of the spectrum is greater. If a signal is more pure/more periodic, then the sum of the spectrum is less. Amplitude data is achieved by analyzing the incoming RMS power<sup>6</sup> and normalizing the data output.

We are able to plot main pitches by detecting onsets from the amplitude analysis. Frequency analysis is translated into note symbols that are plotted on the staff when those onsets occur, in the same method for drawing the graphical notation (as if a pen is stationary on the right side of the page and the paper is pulled from the right to left). See Figure 10.



**Figure 10.** This image was created using the mix-shape option while analyzing a sound file using First Peak. Performed by François Houle, recorded at the Banff Center for the Arts. [14]

<sup>3</sup> ForScore is an application downloadable from the iTunes store where one can upload a PDF and use it as a digital sheet-music reader.

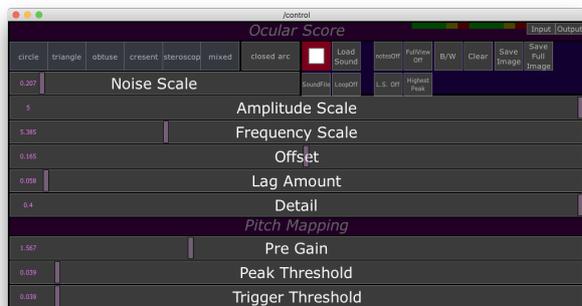
<sup>4</sup> A student could look at an Ocular Score image and play his or her imitation of that sound into the Ocular Scores tool and compare his or her image to the original. In other words, Ocular Scores could be used as a visual feedback instrument.

<sup>5</sup> The stylistic and aesthetic questions that are raised by the use of open notation such as the ones discussed in this paper, in which the harmonic language is left to the performers, is beyond the scope of this paper.

<sup>6</sup> RMS is "root mean square" and is the process used to determine the average power output over a long period of time.

This prototype continues to give us the option of creating still images to capture a gesture — 8 seconds or less (which is the size of the current window). The advantage of this second prototype is that we now have white space (silence) when there is no sound.

A number of parameters affect scaling and the character of image, and those parameters can be changed in real time to affect the image as it is created. We have similar parameters as in Version 1. See Figure 11.



**Figure 11.** In Version 2, we have more choices of shapes to represent the sounds (top left menu), and we can switch from shape to shape in real time, as we decide the best way to represent the sound being performed.

In this prototype, the continuous recording of the images, creates a long score that can be saved and exported as a very long jpg. We can import this long score into other scrolling score software for future performances.

This tool can be used to create musical scores or to document a performance for repeated performance. The long score might also be used as a visual representation of a piece to analyze the larger structural elements of a work. See Figure 12.

Immediately below the large dots in Figure 12, we see a series of small dots. This is the “long jpg” that has been captured over a period of time — a visual recording of the musical events over about a 2-minute period. The staves below track the first harmonic of the sound event in the top window.

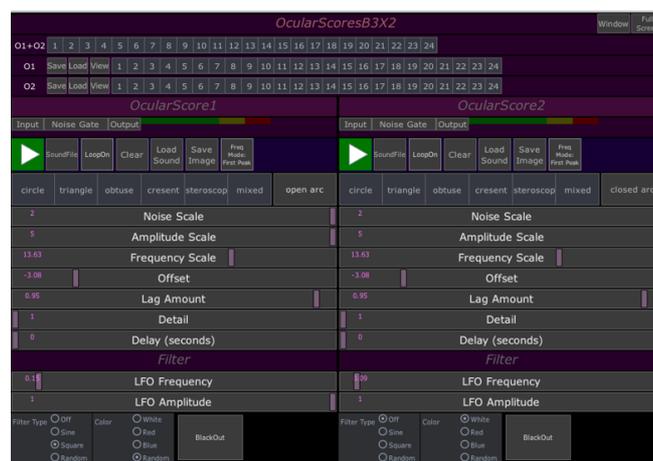


**Figure 12.** This image shows seven attacks — discrete “musical events.”

We are currently working on extending the maximum duration of the long score feature in order to be able to record with no duration limitation.

### 6.3 Version 3: Performance Applications

The last prototype being developed is a performance tool. Ocular Scores™ Version 3 is designed so the composer interacts with the graphic score as it is being created in a performance context. The composer creates a dynamic score with the help of filters that are programmed in advance with a series of presets and manipulates the graphic score in real time by choosing certain shapes for the musical gestures and by using delays; changing the tessitura of the musical gesture; adding color and distortion; and changing the size and scale of the shapes. See Figure 13 for the parameter choices.



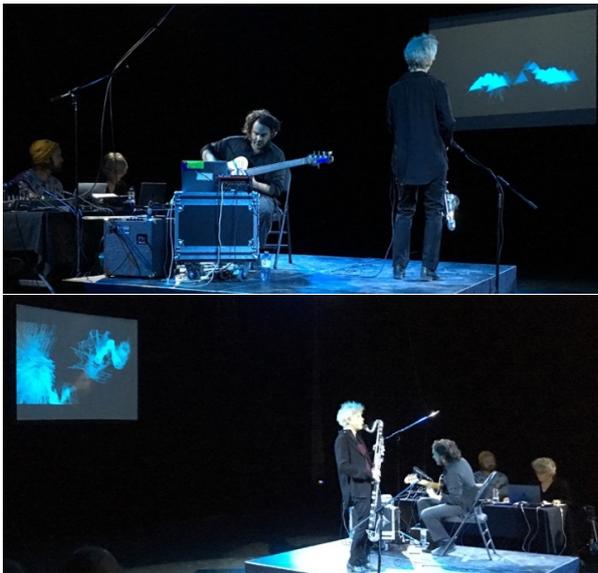
**Figure 13.** In Version 3, we have three rows of presets. The top row triggers the two rows immediately below. O1 is the preset for one Graphic Score and O2 is for a second Graphic Score. The bottom section shows how we use a low-frequency-oscillation (LFO) to shape the phrasing of the musical gestures by periodically removing the image entirely.

The following sections describe two examples of Live Structures compositions that utilize Version 3.

#### 6.3.1 Murmuration/Murmure: Live Structures #3

“Murmuration/Murmure” is a “live structure composition” for two improvisers who each interpret the other’s music. Two graphic scores, which are a visual interpretation of each improviser, are projected for the performers and the audience to see. See Figure 14.

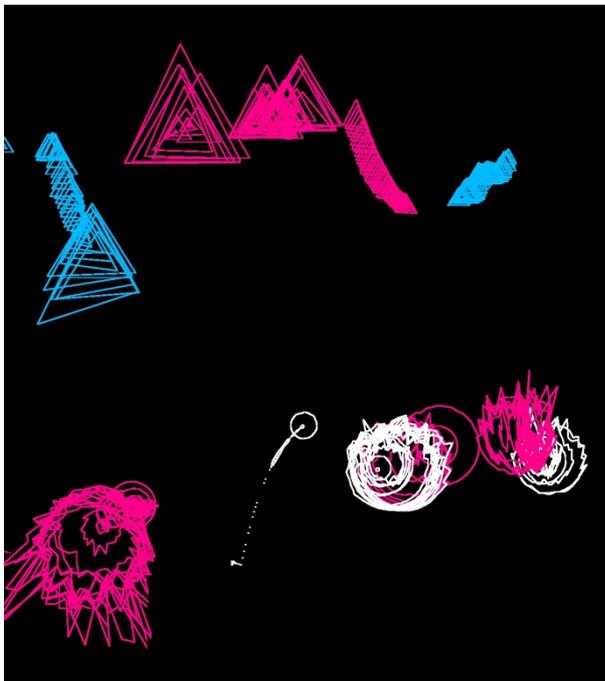
The images of the score are created in real time from the analysis of their improvised sounds. The composer controls the “structure” of the work by manipulating “live” the graphic notation system (shapes), the flow and density of the work, which unfolds as a collaborative improvisation and a committed interpretation of musical code.



**Figure 14.** “Murmuration/Murmure” was premiered on March 2, 2019, during La Nuit Blanche, MNM Festival in Montreal, Quebec, Canada with Browne and Bouchard manipulating the Ocular Score™ and Lori Freedman with Alexandre St-Onge performers. [15]

“Murmuration/Murmure” was also performed at Center for New Music and Audio Technologies (CNMAT) at the University of California, Berkeley on April 10, 2019, performed by Kyle Bruckmann and Jacob Felix Heule. [16]

See Figure 15 for examples of scores from two separate screens that were produced during the performance of “Murmuration/Murmure” at CNMAT, UC Berkeley.



**Figure 15.** Two screens created simultaneously by two improvisers.

A series of iconographic images were created from the score “Murmuration/Murmure” [17]; these images should be reproducible during specific moments of the piece no matter what the musicians are playing.

### 6.3.2 Gaggle: Live Structure #5

“Gaggle” is another way of utilizing Ocular Scores Version 3x2, where the graphic scores that are projected for the musicians to interpret are created from a sound file that is also accompanying the musicians.

In “Gaggle,” the composer is using a stereo sound file that was created from pre-recorded sounds of the two musicians from a previous project. The composer created two different mono sound files, and each musician performs the visual score that is created from one specific mono sound file. The score is created following a set of presets that are being launched at specific moments during the piece. [18]

## 7. MUSICAL CODE

Ocular Scores™ exist in the realm of interpretation, but as we worked with improvisers, we agreed that we could commit to a general musical code, mostly because most of what we had created was based on traditional principles or was intuitive.

- The score is scrolling from right to left (x-axis), so the musicians can read from left to right. The musician can choose to “read” at the left edge, in the middle, or on the right side of the score.
- The y-axis is the frequency range. If all the visual activity (shapes) are drawn at the top of the score, the musician is encouraged to play in the top register of his or her instrument (higher frequency). If shapes are drawn at the bottom of the score, it will represent the lower register.
- When the image is large and fills nearly the entire screen or page, it becomes a “landscape” or visual environment, and the frequency range is left to the discretion of the performer.
- When the shape is continuous, it could inspire a more continuous textures and/or a legato musical event.
- We use two ways to express dynamic: the density of the shape (transparency) and the size of the shapes and color.
- We use several shapes: circles, triangles, opaque shapes, crescent-like shapes, stereoscope-like shapes, and variations of those shapes. We conceived of the different shapes to express different textures. For example, we think of sharper shapes, with defined edges, as having more attack, more percussive beginning.
- We utilize three colors: white, pink-red, and blue-green. White is an open format. Pink-red is for expressing more presence, more dynamic. Blue-green is for softer, more transparent textures.

## 8. CONCLUSIONS

The initial goal of Ocular Scores™ was to explore different ways to interpret data into graphic notation and compositions. This initial assumption of using an analysis tool to create images that would be replicable has proven to be an inspiring way to produce images that can be interpreted by live musicians. The research and the three specific versions of Ocular Scores™ proved to be useful composition tools for Bouchard’s creative work.

Bouchard’s research grant is closing by the end of 2019. She is hoping to eventually create and distribute a simple app for Version 1 of Ocular Scores™.

## Acknowledgments

The Live Structures project [19] has received funding from the Canada Council for the Arts. Bouchard is grateful for residencies at matralab, Concordia University and at the Banff Center for the Arts. Visual designer and programmer Joseph Browne has been a true collaborator with tremendous creativity, problem-solving abilities, and patience. Many thanks to Sandeep Bhagwati, who supported this project from the start and kept asking pertinent questions as we were thinking our way through. Many thanks to François Houle, Lori Freedman, and Kyle Bruckmann for their invaluable feedback as we tested the tools.

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