FLUOR SONESCENCE: A SONIFICATION OF THE VISUALIZATION OF BRASS INSTRUMENT TONES

Christopher Jette

Center for Computer Research in Music
and Acoustics (CCRMA)
Stanford University
Palo Alto, CA, USA
jette@ccrma.stanford.edu

James H. J. Buchholz

Department of Mechanical and Industrial
Engineering, and IIHR – Hydroscience and Engineering
The University of Iowa
Iowa City, IA, USA
james-h-buchholz@uiowa.edu

ABSTRACT

This paper is a discussion of the composition *Fluor Sonescence*, which combines trombone, electronics and video. The trombone and electronics are a mediated sonification of the video component. The video is a high framerate capture of the air motions produced by sound emanating from a brass instrument. This video material is translated into sound and serves as the final video component. The paper begins with a description of the data collection process and an overview of the compositional components. This is followed by a detailed description of the composition of the three components of *Fluor Sonescence*, while a discussion of the technical and aesthetic concerns is interwoven throughout. There is a discussion of the relationship of *Fluor Sonescence* to earlier works of the composer and the capture method for source material. The paper is an overview of a specific sonification project that is part of a larger trajectory of work. Please see https://vimeo.com/255790972/ to hear and view *Fluor Sonescence*.

1. PROJECT OVERVIEW

Fluor Sonescence explores the creation of a piece of concert music for trombone, electronics and video using the visualization of air masses from a brass instrument as source material. Smoke is placed into the air column of a brass instrument during the production of a tone. As the smoke exits the bell of the instrument a laser illuminates a plane of the cloud and a high frame-rate camera captures the visual data (see figure 1). This visual material is then translated into sound and combined with the video. The process of constructing this work is a series of translations from sounds to visuals and then back from visuals to sounds. The resulting artistic artifact is a musical composition for trombone, electronics and video projection. The interpenetration of the translated material provides temporal and gestural continuity. The translations are mediated and not meant to strictly synthesize across media but rather to balance compositional intuition and expressive data. The basic musical material is generated by translating image to sound and these musical phrases are edited to create a musical composition. This approach of working with recorded data in a studio setting in order to create a finished composition is modeled on the approach of Musique Concrete composers working with recordings on magnetic tape in a studio environment. With Musique Concrete, the transformations of sound resulting from manipulations in playback speed, tape direction and tape splicing define a series of constraints. For composers working exclusively with tape, the source material and the operations present a set of constraints which gives rise to a range of sounds. The transformations in *Fluor Sonescence* are less extreme, with an adjustable samplerate during the reordering process and minor temporal expansions and compressions. Like the constraints of tape music, in *Fluor Sonescence* the sonification process defines the sonic palette and the organization of the material gives rise to a particular acoustic landscape.

Figure 1: A still from the video, illustrating gray and white smoke in a black frame

The constraints that determine the construction of *Fluor Sonescence* are defined by the types of translations (discussed in Section 3) and these translations occur off-line (ie. not in real time). The larger goal of this project is the creation of a real time instrument for controlling and producing both auditory and visual elements. The first step in this larger plan is the work *Fluor Sonescence*, where the composer both develops the techniques that will be incorporated in the forthcoming instrument and develops what will turn into a formalized translation process. This is also an opportunity to investigate the sonic and visual palette of working with this material. *Fluor Sonescence* serves as a first investigation of the sonic and visual material that both extends a compositional trajectory and combines research in the aesthetics of mixing sonic and visual material.

2. COMPOSITIONAL COMPONENTS

The construction process begins with the production of sound in a brass instrument and the introduction of smoke into the air column. The smoke makes the wavefront visible, revealing the undulations of the various forces involved. A cross section of the smoke is then recorded to video and this serves as the starting point for the sonic composition. The location of the whitest portion of the video is used to determine which pitch is used in the trombone part (see Section 2.2). The vertical axis of the video plane is subdivided and a pitch is associated with each region (more in Section 3.1. The array of available pitches changes as the piece traverses different formal sections. The trombone pitch is drawn from an irrational overtone series and the remaining overtones are rendered as sine tones, each of which is associated with a vertical division of the screen (see Section 3.2 & 3.3). The amplitude of the sine tones (ie. electronic material) is controlled by the brightness (amount of white) in their respective portion of the video matrix. This translation process yielded the raw material for *Fluor Sonescence*. Through manual interventions of amplitude envelopes and by introducing rhythmic subdivisions, the electronic and trombone material were each sculpted to follow the perceived dramatic contour of the video. The end result is a composition where the sound of a brass instrument produces video, which is used to generate a score for trombone and accompanying electronic material.

The audience experiences visual and sonic material that is generally tightly coupled. By shaping dynamics, the insertion of silences and varying the cross domain mappings the composer aims to create a dramatic formal structure while still adhering to the translations from one domain to another. The process of composing the final work is a blending of the video and sound material to construct a compelling flow of material. In performance, this presentation of both visual and sonic material creates a situation where the audience listens to the sound and interprets the sound as being causally related. This *causal listening* described by Chion([1]), places the visual information and the the multiple sound streams in a tightly coupled relationship. This relationship is reinforced because during composition the overall scaffolding of the sound components were designed ahead of time, and the movement of the video material provides the pitch and amplitude information.

2.1. Visualizing Air Motions

Visualizations were created by holding steady tones, scales, and other note variations on a horn while injecting aerosol into the brass tubing 0.5 meters before the bell. This allowed the visualization of the steady and unsteady jets of air issuing from the bell

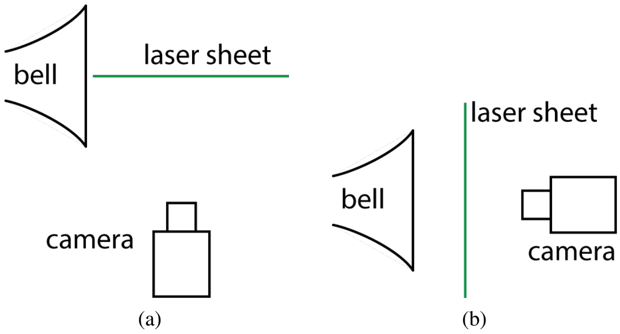

Figure 2: Camera and laser sheet orientations used to capture images of smoke emanating from the horn. a) parallel orientation; b) perpendicular orientation.

as the notes were played, using smoke emerging from the bell of the horn to render the air visible.

Theatrical smoke was pumped deep into the the horn using a plastic tube of inner diameter 6.4 mm and outer diameter 9.5 mm. The tube slides over a barbed rigid nylon tube that is seated in a hole in the horn. Silicone is used to insure no leakage and the nylon tube does not protrude into the air column. The smoke accumulated in the horn during rests, resulting in intense bursts of high image intensity when notes were initiated, and lighter, lower-contrast patterns during held notes or musical phrases. The smoke patterns were imaged using an IDT NX-4 high-speed camera with a Nikon 35 mm f/2 lens, and recorded at various framerates (ranging from 2HZ to 5000HZ). Two camera orientations were used, consisting of viewing perspectives into the bell and perpendicular to the axis of the bell. The smoke was illuminated by a Laserglow LRS-0532 diode-pumped solid-state laser, providing continuous illumination of green light (532 nm) with an output power of approximately 6 W. A lens mounted on the laser aperture spread the beam into an expanding sheet of light approximately 1 mm in thickness. Images of the flow patterns were acquired in the illuminated plane with the sheet either oriented along the axis of the horn, such that the flow progressed within the plane of the sheet, or perpendicular to the axis of the horn, such that the flow passed through the sheet, as illustrated in Figure 2. Images were also acquired using white light produced by an LED lamp and softbox modifier; however, they were not used here because the contrast was reduced, and deemed less visually appealing and resulted in a weaker audio translation.

The result was the acquisition of somewhat complex flow patterns. The initiation of sound produced a burst of air from the bell in the form of a *starting jet* that is well-known to organize into a propagating vortex ring [2]. A laser sheet cutting through the axis of the vortex ring would render it as two counter-rotating vortices. A steady tone or sequence of notes would tend to produce a nominally more parallel flow, but highly susceptible to perturbations due to the musician's unsteady breath, intermittent separation and reattachment of the flow from the surface of the curved, expanding bell of the horn, and natural instabilities in the jet due to the presence of the straining field in the emerging wind. Due to the topological constraints of the vorticity field, which generally require the vortices to ultimately form closed loops [3], the evolution of perturbations typically resulted in reorganization of the flow into vortex rings of all sizes, such that the vortex pair pattern is ubiquitous in the visualizations. Imaging with the laser sheet perpendicular to the horn axis resulted in much more erratic fluctuations in intensity as the smoke-marked flow structures passing through the sheet had only a very short residence time in the light.

2.2. Previous Sonification Work

This composition extends work developed by the first author in previous compositions where recordings are translated to a score and real time sonification of a dancer or an instrumental soloist is a compositional element. The translation of recordings into a score is described in *Textual and Sonic Feedback Loops: Simultaneous conversations as a collaborative process in cmetq* [4] and emphasizes the importance of the composer interacting with the translation algorithm by hand in the studio environment. In translating *Fluor Sonescence*, the primary data does not come from an audio recording, but rather video. The composer extends the minimal high level control of the translation procedure of earlier work to new software for *Fluor Sonescence*. This new software employs the same detailed attention and rehearsal of performative gestures before creating an ideal translation across domains. This practice of translation of recordings is also explored in *#chronicled: Two realtime concert reviews sonified* [5] where recordings from a local newspaper facility serve as source material for sonification. In this case the sonification results from the performance of typing actions on a cell phone.

The sonification of dancers also informs this new work. The dance sonifications began with the work *SoundLines* and uses lines of the video matrix as an audio waveforms while exploring different different means of triggering sound. To increase variety, the waveform is smoothed to create a different timbre and multiple lines are employed for polyphony. The composition *utuquq* uses this sonification of the live video feed as a component of a piano and electronics work where one hand is dedicated to playing the piano and the other to playing the kinect or video camera. In *In Vitro Oink* ([6] a Wii-Remote is used to sonify movement, a practice which is extended in *Psionic* where A Muse EEG Headband is used for movement data sonification and also synthesis based on the EEG signal data. This use of the movement vocabulary of both an instrumentalist and a dancer is an opportunity to develop a unique means of translating data. The performer and the composer work together to discover and map meaningful data. These data mappings explore both tightly coupled and less direct relationships between movement and sound. These various translations of movement and biometric data into sound inform the techniques and software used in the translations of *Fluor Sonescence*.

With *Fluor Sonescence* the sonification moves beyond the performer and ties the sonification directly to a physical aspect of the instrument. The intention here is similar to that of sonifiying a performer, to compose with meaningful information that is inherited from the performance. With this composition we extend the aesthetic palette to include visual material that is the result of sound production, creating an extended perceptual experience from the existing data. The format of the presentation draws from the tradition of presenting silent film with live instrumental accompaniment. The black and white film and the smoke echoes the candle projectors of early film. This presentation blends aspects of the history of cinema with a minimalist electro-acoustic setup in the proscenium stage.

STAGES	RESULT	IMPLICATION
Sound production with brass instrument & smoke in air column	Smoke makes sound visible	The amplitude & note choice of player determines visual material
Laser illuminates a cross section & this is recorded to video	A particular plane of the sound is visible & serves as the representation for a 3d space	The camera settings determine what is visible (zoom level & frame-rate)
Video pixels are translated to pitch [trombone & electronics]	Common notation material & array of frequency and amplitude values	Outcome determined by: overtone series chosen, subdivision of visual space and translation rate
Raw material from translation is sculpted by hand	A composed score and a composed electronic score	Human intuition (aesthetic & logistical concerns) dominate this shaping process

Figure 3: The results and implications of the four stages of the compositional process.

3. COMPOSING

In his discussion of synchresis, Choin notes

> ”Let us note that in the cinema, causal listening is constantly manipulated by the audiovisual contract itself, especially through the phenomenon of synchresis. Most of the time we are dealing not with the real initial causes of the sounds, but causes that the film makes us believe in.” [1].

This highlights the primacy of visual stimuli and influenced the decision in creating *Fluor Sonescence* to begin with visual media for a sound work. The visual material serves as a starting point in order that it will define the types of motion in the sound part. The following will describe how the composition is organized, followed by an examination of the compostional process. Figure 3 provides an overview of this discussion drawing out the results and implications of this approach.

To compose this work, the first step was the creation of video material from the large collection of still images of the capture process. After concatenating the stills into and determining a suitable speed for playback of the gray-scale material it was important to balance the black and white across all video to insure similar contrast in all sections of material. With this basic visual processing in place the act of composing the sonic and visual flow of the piece was undertaken. Moving back and forth between the development of the sonification software and the processing of the video at this stage enabled the constraints of each process to inform the other. This workflow also enables the composer to shift the focal point of concentration between aesthetic and technical issues. The continuous shifting makes for an enjoyable working process and allows work on one aspect to advance while contemplation and reflection on another occurs.

The composition of the sonic aspects of *Fluor Sonescence* are derived from data in the video material. Greater detail about the technical aspects of each translation will be discussed in Sections 3.2, 3.3 and 3.4. In more general terms, the video is black, gray and white, where white smoke is introduced into a black frame. From the perspective of a computer vision system the greater the density of smoke results in a cluster of white pixels and whitish-gray pixels. In this way, the sonification calls attention to the boundaries between opposing forces in the distribution of energy, where there are ridges of relative low pressure between moving air masses.

The formal structure of the piece is articulated with changes to rate of playback in the video and the movement from one collection of pitch material to the next. The pitch collections are held constant for each of the four sections while playback rate is constant within each video clip. Hence, on the phrase level, *Fluor Sonescence* is a series of different vignettes where the pacing and pitch emphasized by each clip is constant while there are changes across adjacent clips. The four sections of *Fluor Sonescence* are framed by three pauses which are articulated by silence and a black screen. The material within the four sections was first organized by intuitively grouping together video material and then organizing those video clips into a time line. This first arrangement of material is therefore primarily informed by visual concerns. The video was then used to generate pitch material for the trombone and fixed electronics.

Each of the four sections uses a different collection of pitch material. This pitch material is constructed by generating a geometrically expanding array of thirty values that results in a similar distribution of pitches below, within and above the trombone range. Consider the array A containing 30 frequency values, indexed from $i = 1$ to $i = 30$.

$$A = \left[78, 78 \times 1.145, 78 \times 1.145^2, ..., 78 \times 1.145^{29}\right] \qquad (1)$$

This particular array of thirty values is used in the first section of *Fluor Sonescence*. The spectrally rich, monophonic trombone is nested between a collection of sinetones articulating an irrational overtone series. Using the given pitch collection, the translation of the video to sound produces a section that has a particular distribution of sonic and visual-movement energy.

The video determines which tones are heard. Moments of fusion and separation occur within the electronics as well as across the trombone and electronics as a result of pitches coming in and out of audabilty. Each video clip is joined to the resulting trombone and electronic material and then these audio/visual clips are placed into the initial time line. The organization of the clips as a result of purely visual flow, is then reviewed and altered so the section makes sense both visually and sonically. This technique is an intuitive collage process, where the material is considered for what it does in both domains and how that contributes to the emergent form. This strategy of organizing the material first with visual flow and then with visual and sonic flow is a deliberate step to counteract a personal bias for organizing a work with an emphasis on the sonic components. *Fluor Sonescence* is an audio visual composition and it was important to design a working process that would result in a balanced treatment of material based on my own personal bias for organizing sound first. Each new composition is an opportunity to both extend a line of inquiry (in this case the translation of image to sound) and to further develop my own abilities and sensitivities as a person who composes sound, image and movement in time.

3.1. Compositional Process

Using software that leverages earlier work discussed in Section 2.2, *Fluor Sonescence* is composed in three layers; the trombone part, the fixed electronics and live electronics. These components are used in conjunction and opposition to articulate the markers of formal structures and the aesthetic elements that define the work. The end result of this composition presents the audience with a video and sonic composition, so the workflow emphasized working with visual alone, sound alone and then the interplay of these two.

Fluor Sonescence is constructed in layers where structural phrases and elements unfold on multiple timescales, both within single layers and across multiple layers. This compositional approach is informed by the multiscale analysis of landscape described by Hay et al. [7]. They describe a multiscale framework in order to capture the complexity of processes and patterns observed across a landscape. Presenting multiple layers: trombone, fixed electronics, live electronics and video projection, *Fluor Sonescence* strives to present a rich perceptual environment of sonic and visual information for the audience. This work is not a literal translation of any one ecological system, but rather draws from the conceptual model. This model serves as an ideal during points of critical reflection in the compositional process. By unfolding processes both within and across multiple layers, gestures create a network of interrelated material that imitates the patterns of a natural landscape (or soundscape for that matter). The result of a rapidly advancing wave of smoke on the video screen can be be heard in the dissipation of a sound mass into a deep reverberant space. Similarly, a series of rapidly ascending pitches in the trombone are interrupted by a sharply articulated electronic mass, which in turn is replaced with a sure and triumphant spectrally distorted trombone tone. It is through these series of interactions that *Fluor Sonescence* seeks to represent the deep web of interactions found in the natural world. As Curtis Roads notes,

> Human beings respond intuitively to context- dependent cognitive impressions that are difficult to formalize, like wit, irony, tension, surprise, virtuosity, humor, and clever twists and transitions. [8]

It is hoped that the interplay of perceptual information presented in a multiscale framework within *Fluor Sonescence* gives rise to this range of cognitive impressions. During the composition of this work, this quote served as a touch point when considering the effectiveness of material.

3.2. Trombone

To create the trombone score, optical flow analysis of the video's center of mass is used to determine both pitch and amplitude of the notes. The *cv.jit.centroid* object implimented by Jean-Marc Pelletier [9] provides the points at which the sum of all pixel values are equal on both the top and bottom, and the left and right sides. The vertical centroid is used to determine which of eleven pitches are played by the trombone. The video, which is used to generate sonic material, presents the audience with black and white image of smoke (see Section 4). As described in Section 2.2 the video is created in order to visually represent the sound emanating from the bell of a brass instrument. Human attention is drawn to the whitest portion of a mostly black image which means the visual attention is focused on the apex of the white portion. As described in Section 3 this perceptual focal point is used to set the pitch and amplitude of the trombone part. As Grond and Hermann point out,

> the tight relation between action and perception is important for ... engagement with the sound: [if] the sound is clearly anchored to a physical cause. [10]

In *Fluor Sonescence*, the visual focal point is tightly coupled to the moving line of solo instrument in order to create a correlation between physical movement in the video and sonic movement in the trombone.

The pitchwise translation of centroid to pitch polls the video space in order to determine when the centroid has moved. While

Figure 4: A still from the video with a red hatchmark indicating the position of the centroid.

an accurate translation necessitates a polling rate aligned with the framerate, the ultimate goal in this case is the production of a musical line that is both playable and aesthetically satisfying. To achieve a polling rate that excludes extraneous information while retaining relevant detail, the strategy of manual intervention was implemented. In creating the translations, the update rate is manually set by the mouses X position. To produce the ideal take, the video clip was watched several times and various translations attempted. This enables the composer to both memorize the visual trajectory and attempt to best represent it. The multiple *rehearsals* enable the composer to hear what pitch material the video is resulting in and to practice until a suitable take or takes are achieved. Working in short segments like this also affords the opportunity to emphasize different rhythmic or pitch figures as well as an opportunity to study the relationship between the visual and sonic material. The end result is a simple compositional tool that enables the composer to both study and craft material in a tightly coupled feedback loop between action and result. This simple tool provides an intuitive gestural means for sculpting material.

3.3. Fixed Electronics

Where the trombone is generated from a single centroid in the Y plane, the fixed electronics uses blob detection to identify multiple areas of intensity. This approach leverages the multiplicity of visual objects in the video matrix as material for control of individual components of a soundmass. Like the trombone, the vertical position of a blob determines which of the available sinetones is activated and the size of the blob detected determines the amplitude of the sinetone. In some cases, the threshold for detection of similar blob quantities is used as a criteria in determining which section a clip fits in.

To create distinct characters the timbre of the four sections is unique. In section one and three pure sine tones are the base element, while two and four use impulse trains with narrow band resonators to achieve percussively varied fixed tones. The four sections of *Fluor Sonescence* have unique sonic characters which are the result of the timbre of the sonified data, different impulse responses for convolution reverb and unique live processing of the trombone.

In Section 3 the calculations used to derive the pitch material for each of the four sections is discussed. The range of the trombone constrains which pitches are used for the instrumental part and are employed in the fixed electronics. The electronics are an undulating cluster of pure tones that fuse into a single sonic mass. The perception of this mass varies as the relative amplitudes change and as the trombone plays different pitchs. The combination of sonic elements into a mass is motivated by considering the myriad of droplets and the currents of air which combine these drops to form clouds.

The presence of a solo performer with a spectrally rich monophonic instrument stands in contrast to the additive synthesis of the fixed electronics. The fixed electronics provide a billowing mass of sound information for the listener reflecting the shifts and movements of the source imagery. This compositional choice reflects the perceptual role the soundscape (fixed electronics), in contrast to sound objects (trombone), plays in the perception of the listener. As Walk and Nees note,

> Although the soundscape may not require a particular response at any given time, it provides ongoing information about a situation to the listener. [11]

The trombone's solo line traces the most visually vibrant component of the video material while the fixed electronics extends and surrounds this apex of perceptual information with an undulating resonance of the larger scene.

3.4. Live Electronics

Fluor Sonescence is a composition created in the studio environment where the composer has the ability to rework and craft every microsecond of the fixed elements of the piece. This is balanced with material that is presented live in each performance. The trombone sound production and live processing of the trombone sound must leverage the abilities of the performer to manage sound in real time in reaction to the acoustics of the space and the atmosphere of the performance/audience. The interface for managing the performance is the trombone and the goal of the composer is to create a score that provides ample information and is suitably open to interpretation.

Fluor Sonescence provides the performer with a fixed notation score and a maxpatch that includes a levelmeter, timers that indicates the bar, beat and the amount of elapsed time. The trombonist is able to perform the trombone part and blend with the electronics the way they would perform with another instrumentalist. In order to extend the sound of the trombone and create sonic continuity across layers, the trombone sound is presented in the speakers in addition to live processing. The live processing algorithms are triggered by the elapsed time counter. From performance to performance, the settings do not change, providing a predictable interaction for the performer. The proximity of the trombone to the microphone and the micro-adjustments of pitch and amplitude of the performer serve to shape the sound of not only the trombone in performance but also the live electronics. In this way the electronic components of the live material, which are close in timbre at times to the fixed electronics, become imbued with elements of the live performance. Because *Fluor Sonescence* blends multiple layers together, the electronics inherit aspects of this performative liveness.

The live processing uses a range of means to manipulate the sound of the trombone with filters, spectral manipulation, feedback, waveshaping and granulation. The audio is used both as a control signal and as audio stream in the live processing. The control envelopes for these algorithms are both composed and derived from live amplitude data. Using amplitude as control information echoes the translations of the composition process. This serves to obscure the distinction between live and fixed elements and enables the performer to influence the shape of the piece through the trombone as interface. Indeed, the trombonist does not need to be concerned with this process, but rather the composer must be concerned with making certain the mapping of the data is scaled in a manner that produces material that is suitable to the aesthetic of the piece and that is perceptually salient.

4. CONCLUSION

Fluor Sonescence is an interesting point in the formalization of a sonification approach. This piece continues a line of inquiry and looks forward to a new method of generating material as well as an audio visual controller. The piece is an opportunity to deeply consider the propagation of sound from a brass instrument. Often sonfication and visualizations are used to present a large amount of data. In the case of *Fluor Sonescence* the compositional process is an opportunity to consider that data and explore it as a result of the images and sounds. This compositional process and the investigation of known patterns of air mass flow has reinforced a commitment to an aesthetic focused on considering the richness of subtle motions. The audience feedback on *Fluor Sonescence* has been very positive and many have reported that they sense both continuity and friction across the visual and sonic domains. This project will move forward with a further formalization of the sonification strategies and the development of a mobile instrument based on this research.

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