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System Of Shadows, an Interactive Performance Environment for Trumpet/Flugelhorn and Kyma

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SYSTEM OF SHADOWS, AN INTERACTIVE PERFORMANCE ENVIRONMENT FOR TRUMPET/FLUGELHORN AND KYMA

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ABSTRACT

This paper summarizes our history with designing coherent real-time processing algorithms within Kyma that enable the spontaneous processing of acoustic instruments using the Capybara-320 and Pacarana synthesis engines in interactive real-time performance. Compositional and performance issues for the current work, *System of Shadows*, are examined, discussed, and performed during the demonstration, focusing on the composer's Kyma processing algorithms and the musical score used by both performers.

We posit relevant data surrounding the interactive performance issues involved in a complex real-time processing work of this nature, and discuss our collaborative creative process. Real-time performance choices by the trumpeter, directed improvisation and interaction between the two performers (and the formal compositional structures these decision help shape), real-time programmatic choices, and Kyma's virtual control parameters are discussed in the context of the larger dynamic performance environment.

1. INTRODUCTION

System of Shadows, a real-time, interactive composition for trumpet/flugelhorn and Kyma digital synthesis system, demonstrates the composer's continuing work with interactive performance environments in which the live performer's music controls and drives all of the computer processing. A combination of analysis/resynthesis, granulation, and multi-delay algorithms, each with random factors operating in tandem with the ever changing live input, form the central approach to generating the timbrally rich computer music layers.

Utilizing a fixed macro structure traversing three through-composed movements, the acoustic performer is given a notated performance path through the music, always allowing for temporal variability. The algorithms' pseudo-random processing spontaneously presents the performer(s) with distinct levels of uncertainty and unpredictability regarding the occurrence of certain sonic events. The composer's intent here is to create an environment where the duration of the performance, from the initial gesture to the concluding moment, is completely controlled by the live performer, yet allows for spontaneous musical interaction within the small-scale events, creating a unique sonic landscape for every performance. The working methods involved in this collaborative creative process are described below, and sections of the work are performed during the live presentation, to highlight the interactive performance decisions, specific synthesis processing algorithms, and structural considerations.

2. KYMA.X AND HISTORICAL PRECEDENTS FOR THIS CURRENT WORK

2.1. Early Work – 1990s

The composer has worked with Kyma as a composing and performing platform since its earliest incarnations in 1990. Before genuine low latency real-time digital performance processing was actually possible or practical (even though all of us in the field used the term as if it did exist!), the composer presented two ICMC papers outlining the central aspects of his algorithmic program COMP2 running within Kyma, which still influence many of his current compositions. The first paper described the proportional recursive algorithms that generated frequency and duration values for any number of computer instruments during compilation and performance run time [1]. The purpose of this approach was to unify considerations of compositional process and structure, and to remove the computer processing from the artificial confines of the separate

'score' and 'orchestra' distinctions maintained by the MUSIC-n languages of that era.

The second paper addressed the emerging realities of real-time performance environments [2]. *Discourse*, a composition for bass trombone and Kyma, utilized a set of twelve ratio values to generate all of the composition's attributes, from large-scale formal structure down to micro details of frequency, timbre, and duration. Many of the Kyma algorithms interacted with the trombone music in real time, largely in the realm of dynamically controlled processing of the live sound. What was missing at that time was genuine real-time analysis and resynthesis of the live trombone sound, as the computational latency was still too large for effective live multi-channel performance.

2.2. Real-time Finally 'Real' – 2000s

Eventually, through advances in hardware processing power (Capybara-320 synthesis engine, 1998), and driven by the updated Kyma.5 software (2001), practical real-time analysis and resynthesis was achieved early in the twenty-first century [5, 6]. The composition *Lyra*, for violin and Kyma, took full advantage of this real-time capability, establishing a performance environment where the live performer's music controlled and drove all of the computer processing. Composed for Patricia Strange, and recorded on her CD *Ghost Strings*,[1] this work was initially outlined at ICMC 2003 [3] and then elaborated in *Organised Sound* [4]. Subsequent software updates included Kyma.X, a 2003 native code re-write for of Macintosh OSX [7]; and again to run on the Intel-based Macintosh as well as PC platforms (2006).

3. COMPOSITIONAL ISSUES

System of Shadows began as a series of discussions between us in 2003. Ruppenthal heard Strange's performance of *Lyra*, and asked Belet to compose an interactive work for him. Five years of discussions (often in tandem with excellent wine) ensued before the music made its way to manuscript paper. Composed and rehearsed throughout 2007, the music benefited from constant input by Ruppenthal. In its current incarnation, *System of Shadows* shows the active involvement of us both, as it should.

System of Shadows is structured in three movements, performed without pause: 1) Aurora Borealis; 2) Andromeda's Dream; 3) Zephyr Apparition. Like its predecessor *Lyra*, the live performer's music drives all of the Kyma algorithms in performance real time, with analysis/resynthesis forming the basis for several of the processing algorithms. The two outer movements are high-energy structures utilizing C trumpet (unaltered trumpet for Movement 1, and muted, using the Yamaha 'Silent Brass,' for Movement 3), whereas the middle movement is more restrained and lyrical, and is scored for Bb flugelhorn. The virtuosic gestures were designed to highlight Ruppenthal's extended technical skills and the timbral capabilities of the instruments, while still preserving a larger idiomatic abstract narrative. This is not virtuosity for its own sake, rather a means to a greater expressive end. All three movements are through composed, which creates a fixed macro structure and performance path through the music (although this does not fix the music's duration, which is variable with each performance). In addition, the performer is invited to improvise throughout, both working around the notated score and responding to the computer music layers as they unfold.

Most of the algorithms incorporate various aspects of pseudo-random processing, which presents the performer with a level of uncertainty and unpredictability (e.g., machine performance spontaneity) regarding when (or if) certain sonic events will occur. The ideal performance setting is eight-channel surround sound, so the unpredictability also extends to where sonic events may occur. While the large-scale formal structure is maintained for every performance, most of the small-scale event details are variable, creating a unique sonic landscape for every performance. Performance time, from the initial attack to the concluding cadence, is completely controlled by the live performer (described in more detail in the 'Programming Issues' section below).

4. PERFORMANCE ISSUES

For *System of Shadows*, we collaborated closely to define which instruments from the trumpet family would give the desired results in terms of timbral flexibility, emotive acoustic quality, and translation of the visceral characteristics of each of the three movements. The score was composed to highlight the inherent strengths of each instrument, and also those of the performer. While not a compendium of extended trumpet techniques, the work requires the trumpeter to have total and instantaneous access to all contemporary performance practices of the instrument.

From a performance perspective, the most compelling aspect of … *Shadows* for the trumpeter is that the Kyma computer software analyzes or 'listens to' the trumpet and flugelhorn in real time, and then generates or 'composes' the processed live instrument sounds essentially instantaneously, spinning them into an eight-channel mix that contributes to a tightly-woven, but ever constantly changing duet between the two performers - all with no perceptible time delay. While instigating the lyrical material of the work, the trumpeter must also respond to

[1] *Ghost Strings*, audio CD, Patricia Strange, violin. IMG Media (CD-02-01), 2006.

the Kyma performer as an ensemble instrument in real-time performance. The Kyma-processed sound similarly 'blows' with the trumpet and flugelhorn, thus creating a continually revolving performance landscape; maintaining a recognizable structure, while details change dramatically from one performance to another.

The continuous segue trajectory of … *Shadows* offers multiple challenges for the trumpeter as the performer must change equipment (including horns, mouthpieces, mute changes, microphone position), and stage positions during the performance, while driving the shape of the piece from the notated score, and keeping a continuity of call and response with the Kyma processing. The challenge here is to seamlessly create a dynamic complement as counterpoint to the constantly varying and often unpredictable Kyma-processed trumpet/flugelhorn sounds, which are constantly moving and changing through the multi-channel performance environment. While the trumpeter is in the driver's seat here, s/he must also complement the Kyma-captured ending gestures of each movement (in dynamic, timbre, and intonation) and use them to define the subsequent sonic quality and character of the next movement. As illustrated in Figure 1, Kyma continues to process the trumpet sounds from the ending gestures of Movement 1, while a stage position and instrument change occur before segueing into Movement 2.

clicks, spoken utterance, imperfect notes, and instant changes in dynamic and intonation created by the dialog with the Kyma processing. This extended musical palette creates its own musical dialog. For any improvisation to cohere in a sonic environment of this type, decisions on the part of the trumpeter regarding intonation matches and dynamic choices, and lyric or narrative gesture must be made spontaneously and with split-second decision, as the trumpet-driven sounds are sculpted around the performer and the audience.

As in any ensemble situation, spontaneous flexibility, acute listening and a sixth sense of the myriad of possibilities that are key to achieving a reciprocal balance, and a trading of musical ideas, between the live trumpet/flugelhorn and the 'spawn' from the Kyma processing. As we have discovered over the course of performing *System of Shadows* for two years, predictability of small-scale events is not high on our expectations list, as random occurrences within the improvisational confines of the performance have a higher probability (which is our aesthetic preference for this work).

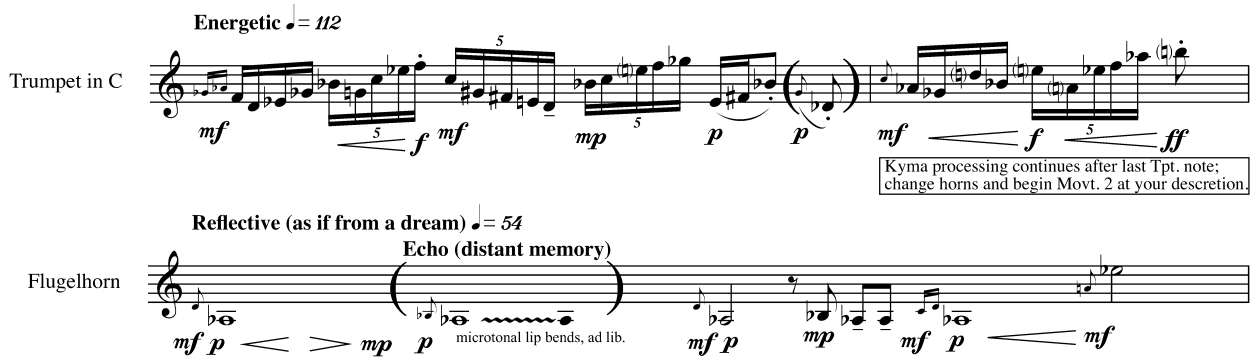

Figure 1. Final gesture (Coda) of Movement 1 followed by the first gesture of Movement 2.

The composer provides a precisely notated musical score, yet has given room for improvisation within the written musical gestures that provokes an ongoing dialog with the Kyma-processed trumpet/flugelhorn throughout. The result is that … *Shadows* is a dialog for two performers with the Kyma processing functioning as point/counterpoint to the live instrument. The trumpeter must also be able to work seamlessly with the Kyma algorithms, instantly reacting to all processing of the horn and/or any sound that is picked up by the microphone. At any time, randomly, the actual notes of the score can share the acoustic environment with residual artifacts of the trumpet or flugelhorn, such as inhalation/exhalation, valve

5. PROGRAMMING ISSUES

5.1. Live Trumpet and Flugelhorn Drive the Computer Processing

All of the computer music is generated in performance real time from the live trumpet and flugelhorn music. Each movement employs a different horn: C trumpet for Movement 1, Bb flugelhorn for Movement 2, and C trumpet with a Yamaha 'Silent Brass' mute for Movement 3. The three audio signals are sent directly to the Capybara (or Pacarana) DSP hardware unit as direct input audio (microphone signals for the unaltered trumpet and

flugelhorn, and line output from the 'Silent Brass' mute, a built-in feature of that device). These audio input signals are the sole source for all of the algorithms running within Kyma. There are no stored samples, and no sounds are saved after a given performance. The music starts from nothing, and returns to the same oblivion once it has occurred. Each performance is therefore unique, and is largely controlled by the performer on stage.

Because of the segue nature of this composition's movements, it was necessary to construct a set of algorithms that would run throughout the total duration of the composition. This differs from earlier compositions whose formal structures were determined, in part, by the positioning of algorithms on the TimeLine. Here, any section within a movement, and any movement itself, can occur at any point in the TimeLine. To accommodate this, all processing algorithms for all three movements run all the time (even when the output from a given algorithm is zero), and the coordinated efforts of the trumpeter and Kyma performer determine the actual structural location within the music. Figure 2 shows the macro Kyma TimeLine, with the primary processing algorithms running constantly from the beginning until the end at Time 20.00.

The Track 1 algorithm is a short WaitUntilAmp Sound (beginning at Time 0.00), which requires a nonzero input value to generate a 'true' statement, which then triggers the TimeLine to proceed. In this case, the TimeLine is compiled, loaded to the DSP hardware, and started by the Kyma performer. Even though the program is running, the TimeLine remains at Time 0.00 'waiting' for a nonzero input value. This is similar to the start of both *Still Harmless [BASS]ically* and *Lyra* (Belet 2003b). Here the input for the WaitUntilAmp Sound is the live trumpet audio signal, and the amplitude of the trumpet signal is zero until the performer performs the score's initial gesture (see Figure 3).

This enables the performer to control the actual start of the composition so that the real-time processing begins immediately with the initial trumpet attack. The opening gesture is marked *forte* so that a relatively high threshold value can be used within the WaitUntilAmp Sound to prevent quiet on-stage sounds (e.g., adjusting the music stand, blowing air through the horn to warm it up, or emptying the spit key) from starting the Kyma processing prematurely.

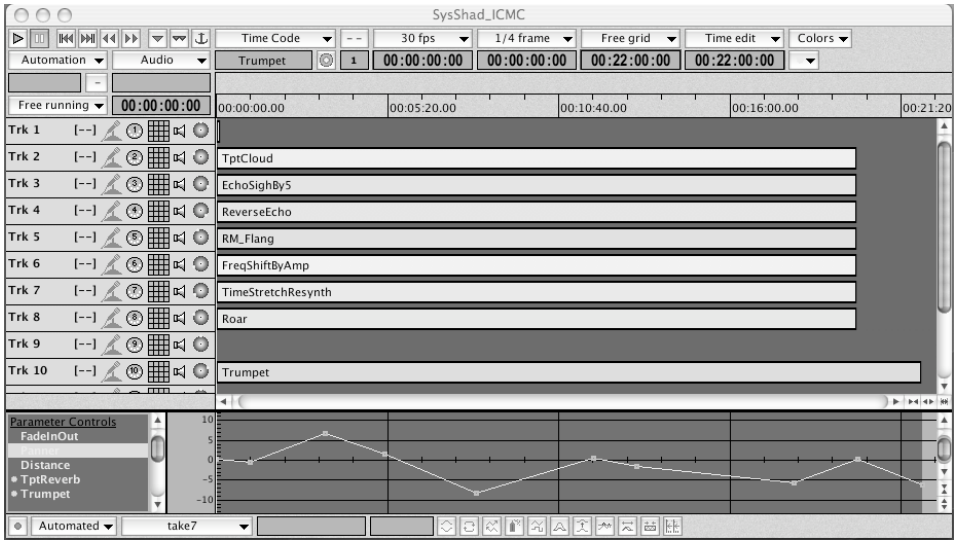

Figure 2. Kyma TimeLine for *System of Shadows*.

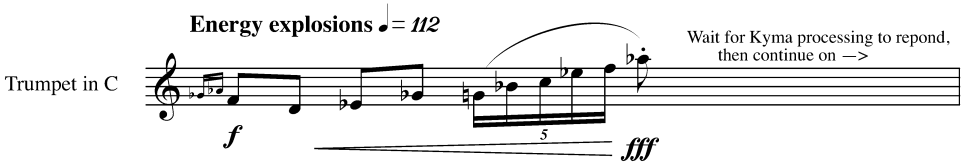

Figure 3. Opening trumpet gesture for *System of Shadows*.

5.2. Kyma Algorithms Examined

The remaining independent algorithms (Tracks 2-8 on the TimeLine) run throughout the composition. The Kyma performer manipulates various parameters of these algorithms during the performance, primarily to establish the processing context for each movement and also to change some detailed aspects within each movement. This process is described in more detail below (see 'Interactive Performance Considerations').

These seven algorithms are titled, in TimeLine track order: *TptCloud*, *EchoSighBy5*, *ReverseEcho*, *RM_Flang*, *FreqShiftByAmp*, *TimeStretchResynth*, and *Roar*. The final algorithm, labeled Trumpet (Track 10), is a Mixer with direct and reverb trumpet/flugelhorn signals. The relative amplitudes of the dry and wet signals are controlled by the Kyma performer, both to match the 'liveness' of the concert hall and to adjust levels during the performance, if necessary. The output from all of the algorithms, computer processed and live instrument, are controlled within Kyma by the Kyma performer. As the trumpet/flugelhorn signals are used directly as input by the algorithms, they bypass the concert hall audio board at this stage. Only the final multi-channel output is sent to the house board for distribution to the audio speakers in the hall. The sound engineer actually has nothing to do once the outputs from the DSP hardware are sent out to the house board, as all of the signal levels are controlled, equalized, and balanced before arriving at the board.

TptCloud is based on a SampleCloud Sound, in which the live instrument input is cyclically recorded into a 4.33-second buffer. This constantly updating file is the input to the SampleCloud sound, which generates a granulation complex (up to 28 simultaneous grains) using a sine envelope for the grains. Each grain is randomly selected from the buffer (due to a high Jitter value within the TimeIndex parameter). The real-time amplitude of the trumpet/flugelhorn signal is analyzed and used, in conjunction with random values, as a dynamic function to generate the individual grain durations and the overall grain density (see Figure 4).

The trumpet/flugelhorn input is read into another cyclic buffer within *EchoSighBy5*, this time with a 6.18-second capture duration. This file is the dynamic input for five DelayWithFeedback Sounds, each with a different delay time (ranging from 6 samples to 3.82 seconds) and feedback factor. This complex creates sounds with pseudo-random capture and start times (i.e., the performer cannot predict which instrument gestures will be captured and processed, nor how fast the response will be to the original input sound), that wrestle and cascade with descending frequency and duration (increasing rhythmic gestures) as the amplitude diminishes on successive echoes.

ReverseEcho is a CrossFilter Sound that interprets the trumpet/flugelhorn input as an excitation for a dynamic response filter with increasing pulsed amplitude values. As both the live instrument input and filter characteristics constantly change, the pulsed filtering often creates the illusion of pre-echoes of the live sound.

RM_Flang is a single sideband ring modulation processor coupled with a flanged comb filter. The unaltered trumpet/flugelhorn sound is mixed to the modulated signal, and this combined signal is the input to the flanging filter. The final output is the ring modulated complex and the flanged signal mixed together.

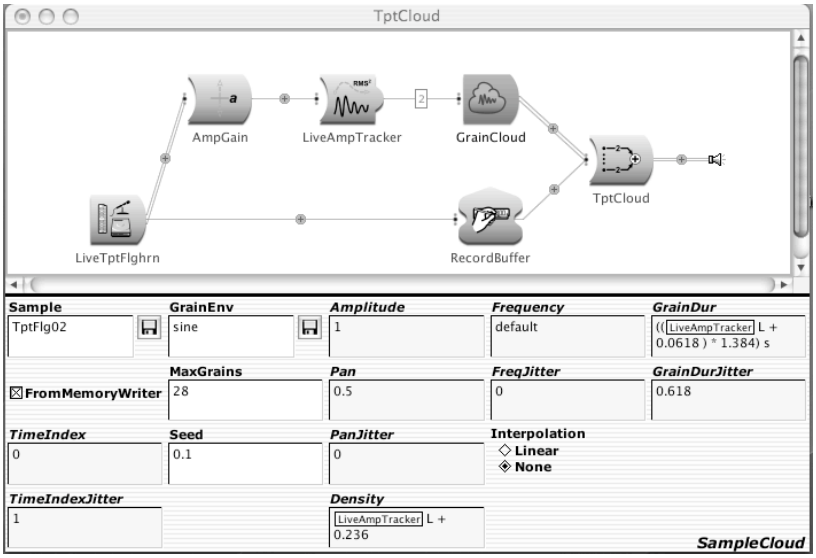

Figure 4. Kyma graphic structure for the *TptCloud* algorithm, showing detailed parameters, including random and trumpet/flugelhorn amplitude functions (via 'LiveAmpTracker'), for the SampleCloud ('GrainCloud') Sound.

FreqShiptByAmp is an analysis/resynthesis module based on a LiveSpectralAnalysis Sound. As the name implies, this Sound analyzes the trumpet/flugelhorn signal and produces amplitude and frequency envelopes for controlling a bank of oscillators for resynthesis. The frequency of the analyzed signal is inversely controlled by the amplitude of the instrument, so that loud trumpet/flugelhorn input tones generate a low frequency resynthesized output, and vice versa.

While there are no random aspects to this algorithm, the minute changes in performer air pressure (amplitude variations that always occur and that we don't usually notice in performance) generate dramatic changes when mapped to the frequency domain. Combined with the inverse control function, this process creates very unexpected sonic results, which can be a working musical definition of random.

TimeStretchResynth is another analysis/resynthesis module. Here, however, the frequency and duration of the analyzed signal are controlled by the Kyma performer. The trumpet/flugelhorn sound is recorded silently into a 60-second cyclic buffer, so that the resultant output is delayed by at least a minute, and sometimes longer. This creates an interesting aural disconnect, as the processed sound occurs far apart from its original context. This Sound requires careful monitoring by the Kyma performer so that this temporal disconnect creates an interesting new context rather than just odd meanderings through past material.

Roar is yet a third analysis/resynthesis algorithm. The trumpet/flugelhorn sound first passes through a low pass filter before the analysis stage, where the analysis frequency (but not the duration) is again controlled by the Kyma performer. The analysis is further modified by a SpectrumModifier Sound with random control of which analyzed tracks will be selected for resynthesis. To prevent excessive bass rumbling and percussive clicks instead of deep growl tones, the resynthesized signal runs through a high pass filter with a 20 Hz cutoff frequency. The signal is then modified by a HarmonicResonator Sound, a rich filter with resonances at a given frequency and its harmonics. The 'given frequency' here is a complex of 48 randomly generated frequencies created during compilation by a Script SuperSound. This sound literally roars, creating a very deep resonance that has an earthy and visceral quality.

6. INTERACTIVE PERFORMANCE CONSIDERATIONS

By means of the trumpet performer's improvisatory commentary, the notated score is both a clear performance map through the composition and also a blueprint for tangential excursions. As all of the computer music is real-time processed trumpet/flugelhorn music, the performer generates and controls the entire composition as it unfolds. Following the score during performance, the Kyma performer has cues for changing specific processing parameters for the various algorithms. These 'hot' parameters are controlled using Kyma's Virtual Control Surface [VCS], which appears on the computer screen upon compilation of the TimeLine (see Figure 5).

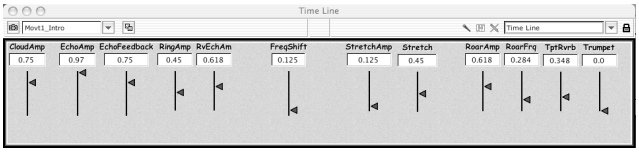

Figure 5. Virtual Control Surface set up for the beginning of *System of Shadows*.

Some of the controls are amplitude parameters for specific algorithms (CloudAmp, EchoAmp, RingAmp, RevEchoAmp, FreqShift, StretchAmp, RoarAmp, TptRvrb, and Trumpet), while others are timbral (EchoFeedback, Stretch, and RoarFrq). Table 1 lists the timbral parameters and their associated Kyma algorithms, with a note on the parameter's processing effect.

Virtual Control Parameter	Algorithm & processing effect
EchoFeedback	*EchoSighBy5* - amount of the delayed signal that is fed back and added to the Input
Stretch	*TimeStretchResynth* – scales the frequency of the resynthesis oscillators, and separately stretches the duration of the cyclic buffer sample
RoarFrq	*Roar* - scales the frequency of the resynthesis oscillators without affecting the timing or duration of the amplitude envelopes, here also lowered two octaves (RoarFrq * -4)

Table 1. Timbral 'hot' parameters and their associated algorithms.

These controls are useful when establishing a baseline mix level for a given hall. From this starting point several parameters can be changed simultaneously and instantaneously using saved presets: this is the plan for setting up each movement and for shaping major sections within the movements. In Figure 4 above, preset 'Movt1_Intro' displays the initial parameter values for *System of Shadows*. The Kyma performer can also change individual parameters anytime during the performance to balance the processed output with the acoustic realities of the concert hall, and also to add expressive processing values as demanded by any particular performance. An important synchronization occurs on the final trumpet

note, when the Kyma performer needs to change the VCS preset to halt most of the Kyma processing (see Figure 6).

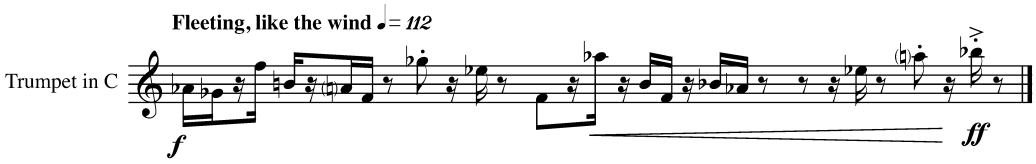

Figure 6. Final trumpet gesture of Movement 3.

These hot parameters can be scaled to any range; all of the parameters in this work are scaled between 0.0 and 1.0, thus providing conceptual and operational consistency.

7. DEMONSTRATION OF KYMA ALGORITHMS (CONFERENCE PRESENTATION – TRUMPET, FLUGELHORN, AND KYMA)

The Kyma algorithms used for *System of Shadows* will be demonstrated during the lecture-demonstration portion of the conference presentation. We will demonstrate the three instrument configurations used for the three movements, along with the hot parameters controlled via the Virtual Control Surface. Screen shots of the TimeLine and individual algorithm structures will be projected on a screen for the audience to see. The Trumpet algorithm will be presented first to establish the direct and reverb signals, followed by the seven primary processing algorithms described above in order. The full composition environment will also be performed to show the workings of the WaitUntilAmp control algorithm. As time permits, questions and follow-up demonstrations of specific details will be explored.

8. CONCLUSIONS

System of Shadows manifests a fully interactive performance environment in which the live trumpet and flugelhorn drive all of the real-time computer processing, in which the performer can improvise with and respond to the computer music that is generated, and in which the Kyma performer can modify and shape large-scale parameters of the algorithmic processing. Each performance is a unique musical event, from the overall duration of the composition to small-scale gestures, while the formal structure remains elastically constant. Random factors within the Kyma algorithms interact with the constantly changing live instrument input to create spontaneous computer music gestures, which enhance the interactive focus of the environment. From the genesis of the composition process through each successive performance, our emphasis has been on a process of mutual collaboration.

9. ACKNOWLEDGEMENTS

The composition *System of Shadows* is the result of many years of musical support and camaraderie by Allen Strange, Patricia Strange, and Stephen Ruppenthal. Twenty years of artistic encouragement and technical support has generously flowed from Carla Scaletti and Kurt Hebel of Symbolic Sound Corporation.

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