Tabula rasa

an interactive electroacoustic work for flute, piano, cello and live computer

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by

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ABSTRACT

Tabula rasa is a creative artistic endeavor in a form of a musical composition whose primary purpose is to produce an aurally and intellectually engaging work of art through cross-pollination of two seemingly disparate media. In order to establish series of inseparable aural and structural co-dependencies the piece is to utilize a real-time interaction between the traditionally trained acoustic chamber music ensemble consisting of flute, piano, and cello, and the modern day technology, namely computer.

ACKNOWLEDGMENTS

I would like to use this opportunity to thank my wife Anamaria and my son Sebastian for their unquestionable support and patience they have shown throughout the many years of my education and which have ultimately led to the completion of this thesis. I would also like to thank all my mentors and professors without whose guidance I would have never reached this important milestone of my career. I would like to thank all my friends, colleagues, and fans whose encouragement and moral support kept me going. Finally, I would like to thank all of the sponsors who have generously enabled me to pursue education in the United States.

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I. GOALS

The following is a list of artistic, intellectual, and technical goals of this project:

- Evaluation of various forms of interactivity between technology and acoustic instruments within the scope of a single work
- Assessment of different means of coordinating chamber ensemble and a computer
- Aesthetic considerations of merging traditional acoustic aesthetic with the style fostered by the contemporary technology
- Expansion of notational tools and/or methods in order to optimize delivery of critical information as well as reinforce synchronization between acoustic and electronic counterparts
- Concerns of targeting appropriate venues and/or performance spaces based upon the aesthetics of the resulting work of art
- Optimization of the performance interface for the purpose of fostering more complex forms of interactivity while minimizing technical limitations

II. CONTEXTUAL DEFINITION OF INTERACTIVITY

Considering that the term *interactivity* encompasses broad spectra of conditions and/or interrelationships even when placed within a relatively narrow context of electroacoustic music, in order to utilize it unambiguously and effectively, it is necessary to define its scope as it pertains to this thesis.

Interactivity in the inherently multidisciplinary electroacoustic art usually is observed in two basic forms: as a concert work utilizing some kind of synergistic relationship between technology and performer(s), or as an installation that fosters active participation by the listener/perceiver. Naturally, in real-world examples the distinction between the aforementioned two flavors of interactivity is less obvious. Yet, unquestionably the interactivity in any interactive electroacoustic work of art can be analyzed as a blend of two approaches.

Tabula rasa is conceived as a concert piece, utilizing the well-established performance tradition and consequently the performance aesthetics most commonly associated with this genre. Given its intellectual complexity, it also fosters active participation from listener(s) despite their ostensibly passive role in the music making process. Therefore, just as any other concert work, *Tabula rasa* carries an element of an interactive installation, yielding favorable results only through the audience's active involvement in perceiving the work.

III. SYNERGY BETWEEN TRADITION AND TECHNOLOGY

Whenever facing an attempt to produce a gratifying mix of two seemingly disparate ingredients, it is necessary to induce a sense of symbiotic coexistence. Often such rapport is generated through a carefully balanced mix of the two elements, less so utilizing a third element, a catalyst that would mask the differences while promoting stability of a new compound.

In the realm of interactive electroacoustic music as defined here we commonly find the first approach to be more-or-less the norm. This is simply because the aforementioned disparity under such conditions can be wittingly masked by having both elements share their sonic material and/or structural traits, the only difference being means of their production and/or propagation. Therefore, the third element or a catalyst in this case would be but a redundant member of the mix.

Tabula rasa is no exception—it thrives upon the coexistence of traditional instruments and modern technology, an interaction which on surface seems relatively simple. However, given that the superimposition in this case occurs in real-time, the resulting hierarchy manifests as an ever-changing array of interactions and interrelationships.

III.a. ACOUSTIC INTEGRITY

Considering that *Tabula rasa* employs traditional performing forces, one of its focuses is integrity of the acoustic material presented by the live performers. Such integrity is attained through use of traditional compositional techniques whose primary purpose is to strengthen interrelationships between various musical elements and their aggregates, namely via tonal and/or formal interdependencies. In order to investigate its implications, we will return to this topic in chapter VI where we'll take a closer look at the basic building blocks of the acoustic material.

III.b. COMPLEMENTING TECHNOLOGY

Technology in this particular work is presented primarily via utilization of computer in conjunction with the Cycling 74's *MaxMSP* software[1]. The aforementioned software, or more precisely visual programming environment, enables a composer to transform a computer into a Digital Signal Processesing (DSP) powerhouse, allowing for a variety of DSP processes to be applied to an incoming sonic stream, in this particular case to the sonic data gathered from the

[1] For additional information on this software package please visit http://www.cycling74.com (last checked September 2005).

acoustic instruments through the use of microphones. Each instrument has a dedicated microphone in order to enable computer to perceive and, more importantly, manipulate each instrument separately in real-time, ultimately allowing for concurrent yet unique processing of one or more instruments. The streams, which are a combination of “dry” (amplified) and “wet” (processed) signals, are pre-panned in order to diminish generation of possibly false and/or illogical sound sources and their final mix is outputted through speakers. For this purpose stereo format has proven to be the best choice; apart from the obvious logistical benefits, such as minimizing possible feedback, this configuration has proven to be the most integrated option for the given purpose.

It is important to emphasize the symbiotic relationship that is established through aforementioned marriage between instruments and technology: the sound that is generated purely by acoustic means is gathered via microphones, processed, and then outputted by computer using a predetermined range of parameters, enabling instrumentalists to not only perceive the complementing sound, but also to react upon it by adjusting their interpretation within the parameters provided by the score. Such synergy therefore represents a perfect circle of co-dependencies in which each of the participating counterparts contribute critical and, perhaps more importantly, unique aspects of the final mix. To put this in practical terms, if instrumentalists were to make no sound, no sound would have emanated from the computer. Yet, if one would prevent the computer from generating sonic material which was otherwise impossible, or at least impractical to render utilizing strictly acoustic means, the resultant sound would be perceived as structurally and aurally incomplete.

While the computer's manipulations of the sonic data are often on their microscopic level difficult, if not impossible to account for (i.e. granular synthesis consists of a large number of tiny snippets of a sound that has just occurred; these snippets are furthermore randomly interspersed to generate a "swarm" of overlapping layers whose density, intensity, and spectral translation are dictated by the predetermined range of modular parameters), their macroscopic timing as well as relationship to surrounding material requires tight control. In order to satisfy this prerequisite, every single one of the symbiotic instances are initiated by a technician at the computer (or composer, as was the case with the premiere and several of the performances that followed) who utilizes graphical front-end and a common input interface (at the time of this writing mouse and keyboard). The necessity for such a seemingly redundant solution is simply due to the fact that at the time this work was composed, the only way to generate cues from recorded acoustic material in a form that would be perceivable by computer, was to analyze either a) spectral (frequency or pitch content) or b) dynamic data (fluctuations in amplitude or loudness envelope) of the incoming sound events via Fast Fourier Transform algorithm (a.k.a. FFT). While dynamic data analysis can yield quite accurate results when dealing with isolated events, this particular work thrives predominantly on densely populated spectral content whose analysis not only introduces inaccuracies in both types of approaches, but also excessive latency, especially when dealing with lower frequencies of the spectrum. For this reason an FFT was deemed inadequate and the implementation of the active computer's sensing of the incoming data for the purpose of cueing was abandoned. In addition, considering that *Tabula rasa*, like other works that fall under the genre of interactive electroacoustic music, requires continuous monitoring of the sonic material generated by the computer in order to alleviate potential problems of a technical nature, and furthermore calls for real-time adjustment of the resultant temporal and dynamic parameters, there was simply no other practical or easily deployable solution but to assign these critical responsibilities to a human.

III.c. CATEGORIZATION OF DEPENDENCIES

Another very important aspect of the synergy described in the previous section is the ability to instigate, as well as to disengage its activity under a wide range of conditions. As a result, each of its instances has a potential to exhibit uniqueness by linking different parameters and therefore establishing different set of dependencies between the acoustic and electronic counterparts. In order to fully exploit this potential, *Tabula rasa* resorts to various catalysts and/or conditions throughout the work in order to yield maximum variety, while retaining structural intelligibility through use of the same core idea (in this case the form of synergy) akin to a traditional work of art that builds its entire structure from a central idea or motive.

Based on their respective conditions and/or catalysts, every dependency that occurs throughout the work can be defined as a subset of one or more of the following categories:

- ALTERING ACOUSTIC PROPERTIES OF THE PERFORMANCE SPACE
    - Reverberators and delay lines
    - Sound placement

- ENHANCING SPECTRAL AND/OR DYNAMIC PROPERTIES OF INSTRUMENTS
    - Reproduce textures that are by themselves reproducible by the acoustic ensemble and/or individual instruments, but not feasible concurrently with the existing acoustic part (i.e. doubling of flute’s melody at an interval)

- Extend sonic capabilities of one or more instruments (i.e. applying granular synthesis to a diminishing envelope of a piano note)
- Complementing overall texture (i.e. "sample and hold" looping for the purpose of thickening the texture)

- ALTERING TEMPORAL AND/OR STRUCTURAL PACE
  - Through interspersed events of undetermined length
  - By providing extended decay and/or release envelopes

- SYNTHETIC MATERIAL[2]
  - Theatrical element (i.e. the player's "pretend play" is accompanied by a synthetic event)

While every single one of the given types of dependencies carries a distinct function, their spheres of existence often overlap with each other. Therefore, one will commonly notice the presence of more than just one of these dependencies in any particular synergistic instance. I will dedicate special attention to each of the instances throughout the score in the chapter VII.

It is important to point out that each of these types of dependencies affects the overall perception of the work's performance differently and usually in more than just one way. For instance, while altering of the acoustic space has a direct effect exclusively on the spectral domain, it also may affect the temporal element and subsequently the work's pace, as performers may feel inclined to pause at any given fermata (as provided by the score) longer in order to allow for the envelope of a reverberated (or delayed) sound to dissipate. Given the volatility of such interactions, the score

[2] *Tabula rasa* purposely refrains from resorting to a purely computer-generated material as one of its core ideas is to utilize the computer as an extension, rather than replacement of the live ensemble. However, this kind of relationship should not be regarded as a norm, nor as one that suggests that the electronic part is subordinate to acoustic material. Instead, it should be observed as part of a conscious aesthetic decision on the composer's part whose purpose is to reinforce integration between the two seemingly disparate counterparts.

in particular places calls for tighter control of envelopes via *Tabula rasa*'s graphical user interface in order to prevent localized malformations and/or distortions of the overall structure. For a detailed breakdown of how each of these dependencies may affect the perception, please consult Table 1 provided below.

DEPENDENCY	PERCEPTIVE EFFECT				
	Spectral	Temporal	Dynamic	Structural	Theatrical
ALTERING ACOUSTIC PROPERTIES	X	X			
ENHANCING SPECTRAL AND/OR DYNAMIC FEATURES	X		X		
ALTERING TEMPORAL AND/OR STRUCTURAL PACE		X		X	
SYNTHETIC MATERIAL			X		X

Table 1. Cognitive repercussions of synergistic dependencies.

As can be observed in table 1, some of the dependencies do have a direct effect on the structure of the work. Thus, it is implied that some of the synergistic instances can and do introduce elements of indeterminacy. We will revisit this important aspect in the chapter VII.

IV. PERFORMING FORCES

So far, we have looked at some of the *Tabula rasa*'s core concepts in order to clearly define their specific purpose and function within the scope of this work. In the following chapter we will focus on applying these notions onto actual performing forces in order to provide a rationale for the aesthetic and logistical choices provided below.

Choices for the acoustic ensemble were not entirely subordinate to the technological concerns and limitations. Quite the contrary, the choice of flute, piano, and cello has been instigated by several predetermined factors:

- The work was commissioned by the NeXT Ens whose performing forces offered (among others) these three instruments[3].

- While there was an option to utilize additional instruments from the NeXT Ens, the concern over "bleeding" of multiple microphones on-stage, as well as other technological complexities have called for a smaller performing forces which in turn would allow for tighter coordination and integration with the technological counterpart.

- The trio in question is commonly found in the traditional repertoire. This has inadvertently generated a greater sense of polarity between what is commonly seen as a traditional ensemble and modern day technology. The resulting tension proved to be a strong structural asset, as well as a great source of inspiration.

- The three instruments in question offer clearly different timbral and textural possibilities. Each of the instruments carry distinct effective ranges and timbres, as well as their function: the flute poses as a primarily monophonic instrument, the piano has an ability to produce uniquely thick textures, while the cello offers something in between these two relative extremes.

The technological ensemble consists primarily of a computer and a technician whose role is to monitor computer's operations as well as interact with some of the aspects of the performance

[3] NeXT Ens performers at the *Tabula rasa*'s premiere (whose recording is included in this document) were Carlos Velez (flute), Shiau-uen Ding (piano), and Hayk Babayan (cello).

(namely envelopes and levels of individual DSP processes), albeit in a subtle and as non-intrusive fashion as possible. One could therefore refer to such person as another performer. However, for the purpose of clear distinction between a traditionally trained performer and a modern day technologist as well as for the sake of clarity, from this point on please allow me to refer to this particular role as simply a *technician*.

The choice to use a technician in conjunction with semi-independent (albeit pre-programmed) computer stems from both practical and aesthetic reasons, some of which have been already touched upon in the chapter III, section b:

- The computer, while incapable of generating true random numbers, does unquestionably offer absolute indifference when compared to a human. Its process of manipulating data is entirely unhampered by the psychological and emotional biases which plague every conscious human decision. As humans, no matter how deliberately we try to free ourselves from our immediate or long-term influences, we always find ourselves partial to such conscious efforts and are therefore unable to separate ourselves from our own awareness. For this reason, the computer functions as a unique and irreplaceable member of the ensemble with its inimitable strengths and weaknesses.

- At the time this work was created there was no reliable mechanism that would be capable of extracting important cue data from the music material emanated by the acoustic instruments, and propagating such information in a timely fashion to the computer. This fact has led to utilization of the cue-based mechanism that would be scored appropriately and executed by a technician.

- While the technician does hold critical control over the DSP processes that are pre-programmed into the computer, their role, once a process has been set into motion is that of a bystander. Technician is neither aware nor capable of fathoming what happens inside the computer. Therefore, the technician’s role is critical, yet his or her ability to influence computer’s output (provided that they stick to their role as indicated in the score), is minimal at best.

- The technician does also have an ability to affect some of the envelopes and/or levels of individual DSP processes. While most of these are to be adjusted during the dress rehearsal, depending upon individual interpretation, some of the processes may require rounding of their decay and/or release envelopes in order to retain the forward drive and subsequently structural integrity. All of these are individually annotated in the chapter VII.

With the aforementioned performing forces in mind it can be said that *Tabula rasa* is scored for flute, piano, cello, and interactive computer. The omission of the technician in this case is a direct result of the aforementioned reasons.

V. PERFORMANCE CONSIDERATIONS

In order to successfully deploy *Tabula rasa* in a concert setting, it is important to read the following chapter about its prerequisites and possible caveats. The chapter is subdivided into two parts: technological prerequisites and aesthetic considerations.

V.a. TECHNOLOGICAL PREREQUISITES

The following technological prerequisites are of critical importance as they not only delineate relatively strict conditions under which this work is feasible, but also warn of potential issues and shortcomings that may crop up during setup and performance.

V.a.i. Hardware

Based on its function, hardware required for *Tabula rasa* can be subdivided into three aspects: audio input, computer/DSP console, and audio/mix output. Please note that none of these prerequisites deal with the obvious requirements, including (but not limited to) acoustic instruments, namely flute, piano, and cello.

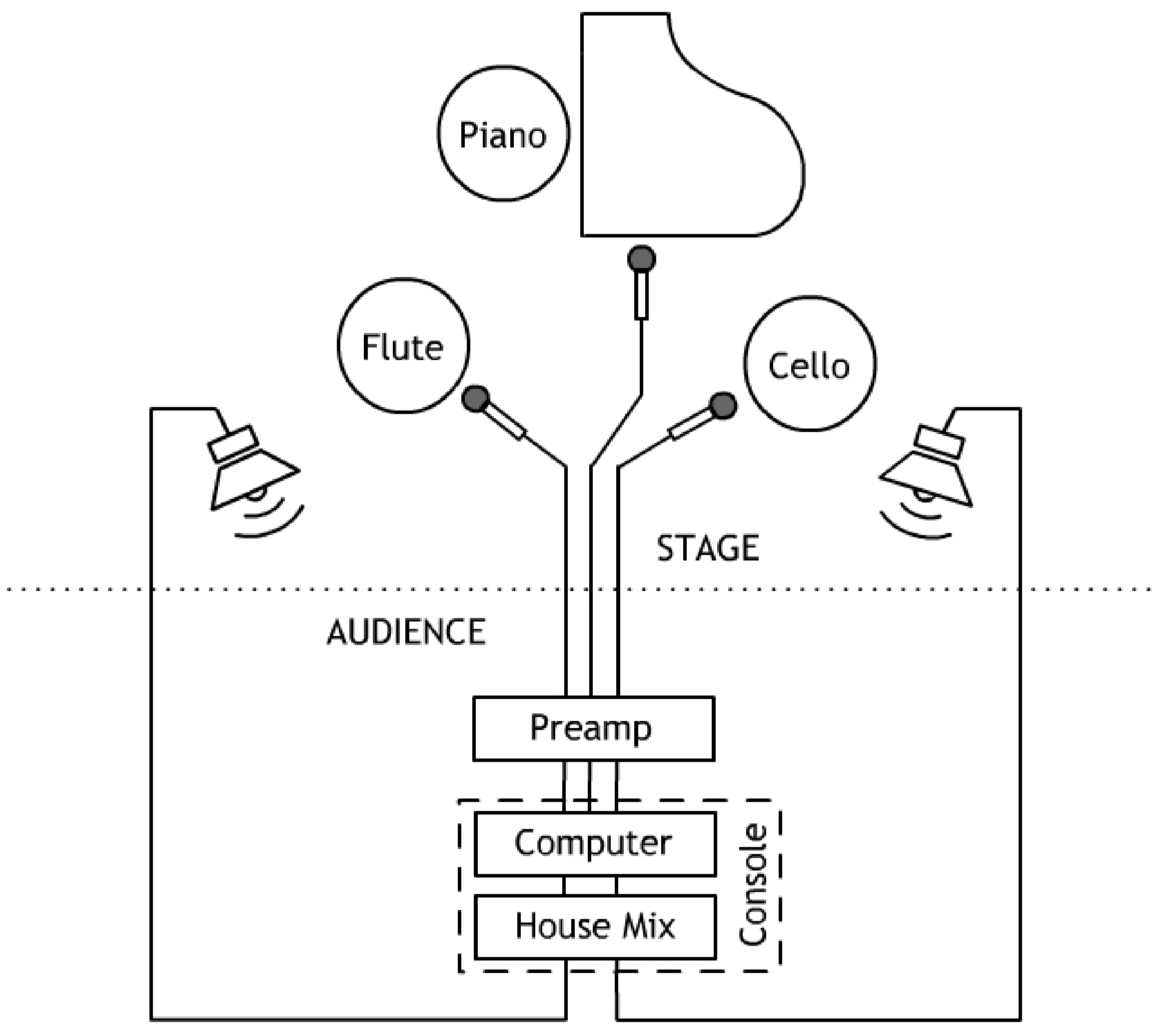

Figure 1. Detailed technical setup.

The audio input consists of:

- 3 hypercardioid (a.k.a. unidirectional) microphones
    - While hypercardioid microphones are generally more nasal and seldom capture the spectral richness of acoustic instruments, they are the best choice for this particular setting as they will minimize bleeding-over of instruments into each other's feeds.
    - The three microphones should be positioned so that each of them is facing in a different direction, so as to further minimize pollution of sound sources.
    - By default the piano lid should be propped high. For this reason one should take special care in positioning cello microphone so that there is minimal bleed-over from the piano into cello microphone.
    - For visual representation of the setup please consult figure 1.
- 3 sturdy boom microphone stands
- 3 preamps
    - An analog or digital mixer with high fidelity preamps is also acceptable, such as the Mackie 1604, however it is important that the preamp-ed channels are not connected directly to the main output because both "dry" and "wet" signals are to be managed by a technician via computer. For additional information regarding use of a mixer for this purpose please consult "audio output" section below.
    - Preamp gain should be adjusted as needed in order to provide a strong output signal into the computer.
- 3 XLR cables to connect microphones with their respective preamps
- 3 cables to connect respective preamps with 3 distinct audio inputs on the computer's soundcard
    - Type and length will depend upon individual setup.

Computer/DSP console requires following elements:

- Computer compatible with the Cycling 74's *MaxMSP* software
    - At the time of writing these instructions either an x86 PC with Microsoft Windows^{tm} operating system or an Apple Macintosh^{tm} computer.
    - Either portable or desktop computer is acceptable as long as its computational power is no less than that of a 1.8GHz G5 (Apple) or a 1.8GHz 64-bit AMD Athlon 3000+ (measured run-time CPU[4] utilization on these machines is approximately 70%).
- Either high-quality shielded internal PCI soundcard, or, preferably, an external soundcard (i.e. RME Hammerfall HDSP) with at least 3 monaural audio inputs and a stereo output.
    - Use of external soundcard should minimize electromagnetic interference with other components that are commonly found inside a computer.
    - Stock internal and external soundcards commonly suffer from intolerable input-output (a.k.a. I/O) latency[5], but more importantly usually do not offer 3 monaural inputs. Therefore, they should be avoided.
    - Latency settings on the soundcard should not exceed 20 milliseconds. For the best possible experience they should be 10 milliseconds or less.
- Keyboard and mouse (or other similar Human Input Device, a.k.a. HID) for interaction with the computer interface.
- Power cables (as needed)
    - Power strips
    - Plug adaptors
    - Extension cords
- Stereo output cables that will feed the resultant sound from the soundcard outputs into the main house mix
    - Type and length will depend upon individual setup.

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[4] CPU = Central Processing Unit, a.k.a. processor.
[5] Audio input-output latency, commonly measured in milliseconds (ms), is amount of time that takes a computer to perceive, process, and then output a snippet (a.k.a. buffer) of sound. Anything above 10ms is going to be perceivable by a human ear and is therefore deemed as inadequate. Latencies involving sending the signal from microphone to computer and from computer to the speakers are commonly so small that they are generally imperceptible to our ears. Therefore, for this purpose they are to be considered irrelevant.

Finally the audio output aspect comprises of:

- Mixing board
    - If mixer is to be used also as a preamp, it will need to be capable of providing at least 3 AUX SENDS. These will enable forwarding of the preamp-ed feeds from each of the three instruments to the computer while keeping each instrument's feed distinct and unpolluted. Furthermore, this will allow for the necessary occlusion of the preamp-ed signal from the main mix.
    - Output should be stereo with the two incoming channels from the computer panned 100% left and 100% right respectively. Levels of all inputs and outputs should be generally set to so-called Unity (a.k.a. 0dB crossing where no signal amplification or attenuation takes place).
    - The board should be physically positioned near the computer.
- Speaker amplifier(s)
- 2 speakers
    - Must be placed in front of the microphones to minimize possible feedback. For additional info please consult the figure 1.
- 2 XLR cables to connect the mixing board with the amplifier
- Power cables (as needed)
    - Power strips
    - Plug adaptors
    - Extension cords

For a visual diagram of the equipment setup please see Figure 1.

V.a.ii. Software

The *MaxMSP* software, due to its modular design encourages third-party additions which usually provide very useful higher-level functionality. However, utilizing such additions in works can also be problematic as they are not a part of the standard software package and therefore may be hard to obtain. In order to minimize this potential issue, *Tabula rasa* comes with pertinent externals included. Yet, considering that *MaxMSP* is under perpetual development and cannot be guaranteed to be forever backwards-compatible, prior to deploying *Tabula rasa* it is highly advisable to seek current maintainers of the externals in question or, alternately to rebuild them based upon their previously released source code in order to ensure compatibility with the current version of *MaxMSP*.

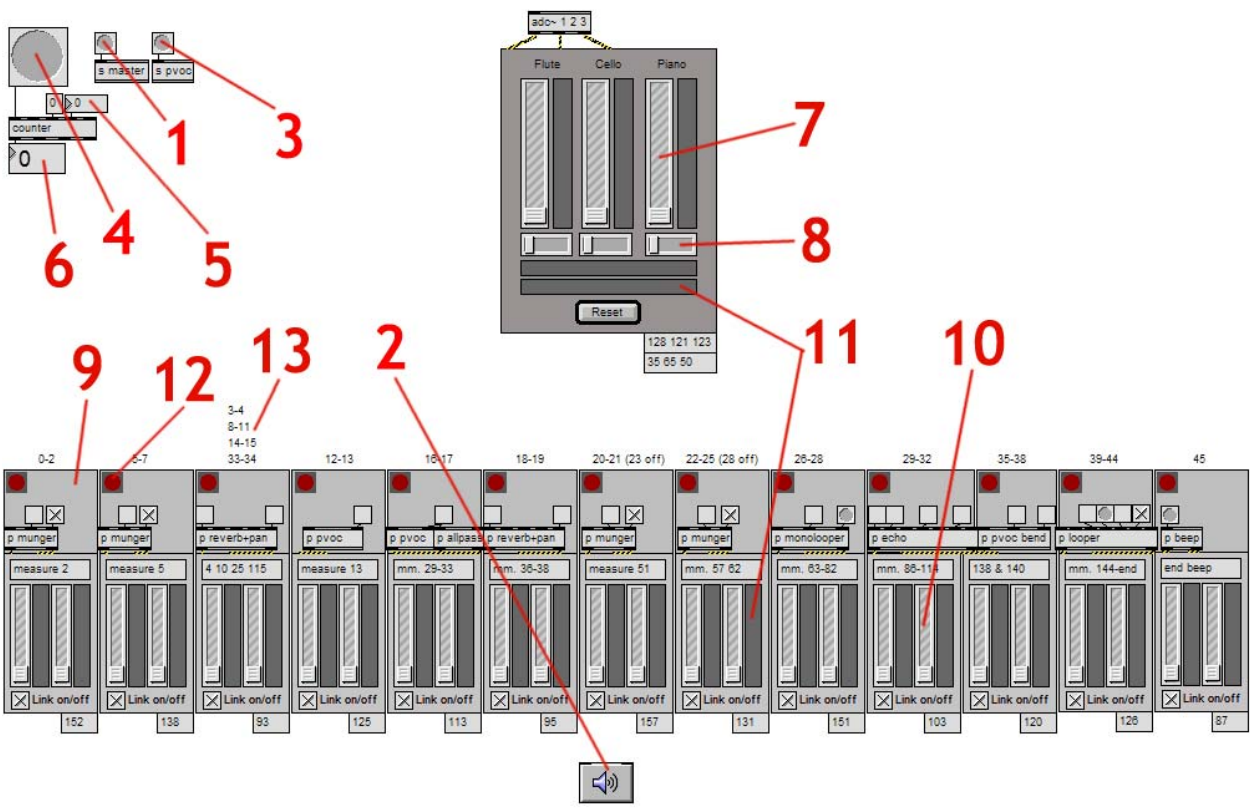

Figure 2. *Tabula rasa* patch user interface.

#	FUNCTION
1	"Reset" button resets all attenuation and panning faders to the last saved position
2	Toggles patch and DSP processing on/off.
3	Reconfigures two transposition sub-patches (needs to be performed every time the "2" is toggled ON, otherwise it will have no effect)
4	Cue triggering button. Every time it is pressed, the cue number increases by one.
5	Cue number reset. Either click and move mouse up or down to alter current number (it will be updated upon mouse button release), or click on the triangle on the left-hand side and type in the desired number. Once the number has been set, the "Current cue" display number ("6") will reset to the newly selected cue. <u>It is important to note that the first cue is numbered 0 and therefore if the piece is ever to be rewound back to the beginning, the cue number reset should be set to -1!</u>
6	Current cue display number.
7	Input console volume faders for the "dry" output.
8	Pan faders for the "dry" output. Generally, they should not require any attention unless stage configuration significantly deviates from the default one.
9	One of the DSP sub-engines[6].
10	Left and right channel volume faders for each of the DSP sub-engines. They are linked by default as all of the panning is automated. As a result, the user should move only one of the faders if necessary and the other will follow. The faders can, however, be unlinked by toggling the "link" check-box, should one of the channels prove to be more feedback prone. Please note that when unlinked, each fader must be moved individually.
11	VU meters for input console and one of the DSP sub-engines respectively (each sub-engine has separate VU monitors for each of the channels).
12	LED[7] indicator that shows when a particular DSP sub-engine is active (some of the engines happen to overlap with each other in order to minimize abrupt cutoff to their release envelopes).
13	List of cues which affect a particular DSP sub-engine (some of them occur more than once).

Tabula 2. The legend for the figure 2 annotations.

[6] DSP sub-engine (or simply sub-engine) refers to a particular DSP algorithm that provides unique treatment to the incoming sound and therefore resulting in a uniquely sounding output. Each sub-engine is represented as a framed box with its own volume faders (10), VU meters (11), and a LED activity indicator (12).

[7] LED = light-emitting diode. In this case it is a virtual on-screen representation of such device with identical behavior.

1. SYSTEM SETUP
    a. When starting and configuring computer it is important to minimize loading of various resident programs that may degrade the computer's performance. For more info on how to perform this alteration, please consult your computer manual.

    b. Some computers are designed to speed-step their CPU based on the current workload in order to conserve power and minimize heat dissipation. Depending upon the quality of this feature's implementation, the process of speed-stepping on certain hardware may cause glitches in sound. Therefore, it is advisable to pursue information on how to disable this feature, so that the CPU is made to operate at its maximum speed despite the fluctuations in the workload.

    c. Some hardware may generate excessive background noise with its cooling fans. It is therefore important to use hardware that emanates low levels of noise even at highest workloads (some of suggested solutions would be liquid-cooled systems, fanless and/or sound-proof computer cases, or simply with low-RPM [8] cooling fans).

2. SOUNDCARD SETUP
    a. Once computer boots and *MaxMSP* software has been loaded it is important to check the soundcard setup; *MaxMSP* may choose any recognizable soundcard present in the computer and therefore the user needs to ensure that the right one is selected.

    b. To check this setting, please click on the "OPTIONS" pull-down menu, followed by clicking on the "DSP Status" option. For additional info regarding this step, please consult the *MaxMSP* documentation. Settings that are of most concern are:
        i. Currently selected soundcard
        ii. Sampling rate (it should be at least CD-quality or 44,100Hz)

[8] Low number of rotations per minute (RPM).

iii. Buffer length, which affects the overall latency[9] (smaller is better). For more info on latency please consult the previous section under the heading of "Computer/DSP console."

c. Often, certain hardware exhibits consistent noise better known as the "ground loop." Thankfully, it is readily recognizable as its carrier tone is equal to the frequency of the alternate current (i.e. in Europe it would be 50Hz, while in United States it is 60Hz). In order to alleviate this problem one can do one of the following:
   i. Check the wiring in the performance space (something that is not always feasible or practical)
   ii. Ask for assistance from the stage manager and/or on-site sound engineer.
   iii. Seek other solutions by using the latest technology and/or consulting other knowledge resources (i.e. Internet).

3. INSTALLING EXTERNALS
   a. *Tabula rasa*, apart from the built-in *MaxMSP* objects also requires two following externals which need to be installed prior to deployment of *Tabula rasa*, so that they are accessible to *MaxMSP* when it starts up (for more info on how to perform this installation please consult the *MaxMSP* documentation):
      i. *freeverb~* (a reconstruction of Manfred Schroeder's reverberator based on allpass filters)[10]
      ii. *munger~* object from the Dan Trueman and R. Luke DuBois's PeRColate library[11]

   b. It is advisable to test the newly installed objects by running some of the accompanying tutorials in order to ensure both that the objects work as expected and that the computer outputs glitch-free sound under the current configuration.

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[9] One should experiment with various latency settings as some of the computer hardware may not perform well with very low latency settings. This problem is commonly exhibited by a stuttering sound that emanates from the computer when DSP output is activated.
[10] For more info on *freeverb~* please visit http://www.akustische-kunst.org/maxmsp/ (last checked September 2005).
[11] For additional information on *PeRColate library* please visit http://music.columbia.edu/PeRColate/ (last checked September 2005).

4. CONFIGURING THE PATCH[12]

a. Once the *Tabula rasa* patch has been loaded, the user will be greeted by the interface shown in figure 2 (please note that the following steps are associated with the legend provided in the table 2).

b. To operate the patch, first click on the “Master” button indicated with the number 1. This will restore all volume and panning faders to their optimal positions which should be used as a reference for the purpose of fine-tuning of the final mix.

c. Make sure that the house mix faders on the main mixing console are pulled all the way down.

d. Pressing button 2 will start the patch by enabling DSP processing (“wet” signal) as well as “dry” output. Please note that both “dry” (non-processed amplification of instruments) and “wet” signals are mixed and passed through this patch. CPU utilization at this point should spike, reaching its maximum and remaining there for the remainder of patch’s lifecycle.

e. Bring the house mix levels slowly up making sure that there is no feedback. Should feedback prove to be the problem, please test your sound levels on the patch and the mixer.

f. With the DSP input active, it is important to test whether each of the instruments is being channeled into appropriate inputs: 1 for flute, 2 for cello, and 3 for piano. For this purpose one could use the VU meters included in the input console (please see figure 2 for more info).

g. Once DSP processing has been enabled, button marked with the number 3 needs to be pressed in order to reset two pitch-shifting mechanisms (score instances 12-13 which

[12] “The patch” refers to a set of pre-programmed instructions that are presented visually as series of interlinked objects. This also includes the front-end interface that is used for real-time manipulation of the underlying DSP engine.

transposes flute signal by a minor third upwards, and 16-17 which transposes cello a perfect fifth upwards). Their values can be properly set only after the DSP processing has been enabled, otherwise the interval of transposition in the two aforementioned instances will be incorrect.

h. At this point performance is ready to begin. The technician can cycle through cue points by clicking on the button marked with the number 4. For the sake of streamlining the interaction with the patch, the technician may opt to alter the patch in order to associate the cue button with a keyboard command.
    i. Each of the instances has a starting and a stopping cue point, while some also include interim cues. This means that a number of of the cues render DSP processing inactive, as indicated in the score (for the extended notational devices that illustrate this particular aspect and their explanation please consult chapter VI, section a).
    ii. When using mouse for triggering cues it is advisable to use a conventional external mouse device rather than a touchpad, as latter can be configured to sense “taps” as button clicks which can cause accidental brushes with the touchpad’s surface to be misinterpreted as clicks, ultimately leading to potentially disastrous run-time side-effects.

i. For additional information regarding other aspects of the patch user interface, please consult the legend that is provided in the table 2.

V.b. AESTHETIC CONSIDERATIONS

Apart from the straightforward technical concerns and caveats addressed in the previous section, there are also aesthetic matters surrounding the deployment of this work which require careful consideration. It is of utmost importance that they be given ample attention as their shaping will inadvertently affect every facet of the work, including concerns of technical nature.

V.b.i. Performance Space

While it is obvious that *Tabula rasa* relies heavily upon the traditional concept of chamber music, its optimal performance space is not necessarily confined to traditional performance spaces. Quite the contrary, considering that most of the contemporary venues at the time this work was written employ alternative, if not unusual spaces, yet they commonly encourage art that poses as a bridge between now heavily fragmented music tradition of the 20th century, this work can and does fit into such context as much as it can within a contemporary chamber concert. Furthermore, it is conceivable that a number of traditional performance spaces may be inadequately equipped to provide the technical requirements for this piece.

Given that *Tabula rasa*'s genre can be classified as a blend of relatively distant styles and/or traditions, before its inclusion on the program it is important to consider whether its unusual aesthetics would complement or hinder the targeted venue. Some such considerations may be of practical nature; for instance, if *Tabula rasa* is to be the only composition on the program that requires technical support and/or deployment of various equipment, then its inclusion will not only make it appear out of place aesthetically, but will also likely prove to be uneconomical. It is also important to acknowledge possible subjective concerns that may play a vital role in ascertaining programmability within the context of a particular event. However, due to their intangibility which comes as a result of the inherent subjective character, such considerations are not going to be addressed within the scope of this thesis beyond merely acknowledging their importance.

V.b.ii. Stage Setup

The acoustic chamber ensemble should be centered on the stage both in terms of left-right and front-back axes. This will ensure that there is ample room for the speakers to be placed in front of the ensemble, while enabling an uninterrupted line of sight between the members of the ensemble as well as the ensemble and technician. Some of the performance spaces may require adjustments to the default setup due to various acoustic limitations. Should such prove to be the case, it is advisable to remain as close to the default setup as possible.

For a detailed visual representation of the stage setup, please refer to the figure 1 found in the chapter V, section a.

V.b.iii. Targeted Audience

While anyone may benefit from experiencing this work, a carefully targeted audience is critical for success of any artistic venue. *Tabula rasa* is best tailored to either mature art *connoisseurs* who have been exposed to multimedia arts, or younger audience who are comfortable with contemporary pop arts that rely upon technology, yet who lack that link with the traditional arts of the *Common Practice* period. Please note that the aforementioned recommendations have been given within the context of the culture in which this work has been brought to fruition.

V.b.iv. Music Program

The extra-musical program is an unavoidable facet of contemporary arts. Whether it is absolute or abstract, conscious or subconscious, its existence is an inevitable (by)product of the creative process. *Tabula rasa*'s program can be best defined as consciously abstract. Even the title, although in part inspired by author's experiences, is designed to target primarily audience suggesting their abandonment of implied expectations, rather than a musicologist or a theorist that may delve into an analysis of this work. More importantly, the title may mislead some to believe that the work is series of unrelated images where pauses designated by fermatas should be given ample attention. Quite the contrary, fermatas are to be used in a relatively conventional fashion and while their cumulative effect at times will clearly have delineating function, this particular role should never be overemphasized as it may inadvertently cause structural imbalance, if not total annihilation of forward motion, rendering the work sterile.

On a more practical side, the written music program (which should not be mistaken for the aforementioned extra-musical implications) that is to appear in the program notes should always be the same:

Tabula rasa   --Ivica Ico Bukvic

Please note that the actual frame around the program notes is optional and is shown here in order to facilitate better understanding of spatial proportions. The pun program notes play upon the work's title serves to further reinforce curiosity among audience members, but also, perhaps even more importantly, minimize if not completely obliterate their expectations.

V.c. ACOUSTIC INTERPRETATION

One of the primary concerns for performers is the fact that score for the most part lacks time signature and tempo designations. This intentional omission on author's part is compensated by rhythmic extremes and familiar expressive devices which seem feasible only under certain conditions. As such, performers are given a certain amount of flexibility whose cumulative effect is guaranteed to remain within boundaries predetermined by the composer.

In terms of actual interpretation, this work can be viewed from two perspectives: a) as a whole and b) as series of distinct sections. Individual sections call for varied treatment that ranges anywhere between emotionless and mechanical to lyrical with ample use of *rubato*. None of these sectional approaches are explicitly stated in the score. Rather, performers are encouraged to seek them based upon their own training in traditional music performance. The work as a whole is dominated by a neo-Impressionist character with its modal material and quasi-sectional separation between ideas and/or moods. With this in mind we can conclude that *Tabula rasa* calls for a neo-Impressionist-like umbrella treatment of the localized cells which in themselves at times deviate significantly, albeit momentarily from the character of their parent.

V.d. COORDINATION OF TECHNOLOGY

Apart from the technological concerns that have been addressed earlier in this chapter, there are additional pointers regarding use and coordination of technology during run-time that require special attention:

- During rehearsals, if a particular cue needs to be interrupted, stopped, and/or restarted, the best course of action is to cycle through the cues by clicking on the “cue triggering” button until all DSP sub-engines have been disengaged and then reset the cue position to desired position using “cue number reset” button (for reference please refer to figure 2 and supporting table 2 found in chapter V, section a).

- Altering the house mix (a.k.a. main mix) during performance should be avoided. All changes to both “dry” and “wet” levels should be performed via the *MaxMSP* patch.
    - Memorized attenuation fader levels should be used as reference. They can be recalled by pressing the “reset” button (marked as “1” on the figure 2 found in the chapter V, section a).
    - While adjusting the sound mix, one should carefully consider how the audience’s presence will alter acoustic properties of the performance space. In most cases this will diminish “liveliness” of the room, but may also encourage feedback via reflections from the audience seated in the first row.

- Reverberating sub-engines have proven to be most volatile in terms of potential feedback, despite the utilization of phase inversion and other complementing deterrents. Their control therefore requires utmost attention via adjustment of volume faders at run-time.

- As indicated earlier, some of the decay/release envelopes may prove to be excessive, especially when using some of the doubly-linked reverberating sub-engines. These can be treated in one of the following ways:
    - They should be allowed to dissipate entirely before proceeding.
    - Their attenuation should be accelerated through use of the volume faders of the respective DSP sub-engine.
    - They should be overlapped with the events that follow once they become soft enough as to not impede and/or overshadow the ensuing musical material.
    - Combination of the above

- Several places require coordination between a particular instrumental part and technician. These cues should be always instigated by the performer in order to minimize their level of distraction. Commonly, the cues in question do not require an eye contact. Rather, a non-invasive common cueing mechanism, such as a head nod, has proven to be sufficient even in moderately dark performance spaces. A detailed breakdown of cues that require this kind of treatment is provided in chapter VII.

VI. SCORE

The following chapter is not meant to be an exhaustive study of *Tabula rasa*'s score or the musical material it consists of. Rather, it is designed to provide critical explanations of the extended notational devices in a format most useful to the performers, as well as shed light on some of its most salient aspects for the purpose of fostering better musicianship. <u>Therefore, all performers ought to read it prior to rehearsing</u>. Analytical portions of this chapter can also be used as the foundation for an in-depth analysis and as such are provided for the indulgence of those who may be seeking deeper understanding, whether to facilitate pursuit of scholarly work or to simply satisfy their curiosity.

VI.a. EXTENDED NOTATIONAL DEVICES

Tabula rasa utilizes a number of nonstandard notational devices whose purpose is to efficiently depict interactions between various members of the ensemble, improve score legibility, as well as minimize reliance upon traditional elements whose meaning was deemed to be overly restrictive:

- TEMPO
    - For the most part tempo markings are either omitted or are illustrated by descriptive words whose meaning most closely conveys the character of a given passage. This kind of loose tempo treatment is however restricted by the presence of a broad spectra of rhythmic values whose interpretation encourages a very narrow band of logical tempo possibilities.

    - Occasional exact tempo markings are confined to sections where tight coordination between parts is required, including passages which ask for pulse-like and/or mechanic interpretation.

- METER
    - Due to the fact that for the most part the piece lacks meter, the work's pace as well as sectional division is dictated by two kinds of bar-like limiters:
        - DOTTED BARLINE denotes relative milestones at which one or more instruments are to synchronize (shown in figure 4).
        - REGULAR BARLINE marks places at which all three instruments are to be in vertical synchrony. Its occurrence is limited to sections with strict tempo and/or pulse (shown in figure 4).
        - DOUBLE BARLINE separates rubato-like and tempo-driven sections. For this reason, it is also observed as structural and formal delineator (figure 5).

    - Some of the metric conversions are of relational nature and are denoted by referencing existing rhythmic value as the new durational pulse value (figure 3).

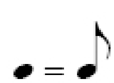

Figure 3. Referential meter conversion (page 6, bottom system).

Figure 4. Full vs. dotted barline comparison (page 7, bottom system)[13].

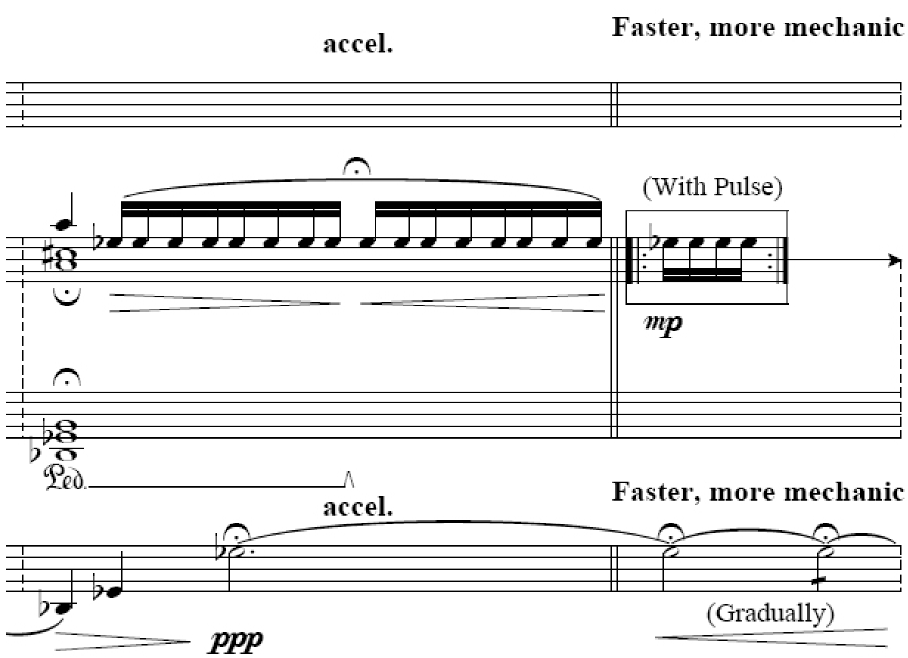

Figure 5. Double bar example (page 5, bottom system).

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[13] All score references reflect locations in the printed score. Manuscript locations of the same will in most cases differ due to revisions and/or formatting adjustments that have been incorporated into the final score.

- RHYTHM
  - Rhythmic durations in the non-temporal sections should be regarded as relative or referential, rather than absolute, while tempo-driven sections should be executed as accurately as possible.

  - Major durational values with fermatas should be generally treated as flexibly timed prolongations (either of silence or sound) (figure 6).

  - Minor durational values with fermatas are designed as “temporal cushions” whose sole purpose is to encourage vertical synchronization in places where rhythmically such feat would seem rhythmically impossible otherwise (figure 6).

  - Accumulating and diminishing number of notehead flags suggest gradual increase or decrease of speed of the execution respectively.

- PITCH CONTENT
  - Most of *Tabula rasa*’s pitch content utilizes straightforward traditional notation.

  - ACCIDENTALS are treated as valid only within “measures” (as delineated by the three versions of barlines defined above) in which they have been presented. Courtesy accidentals for the repeated altered notes in different registers are provided in the score (figure 7).

  - QUARTER-TONE utilization occurs only in the cello’s part. It is denoted by conventional 20th century microtonal notation (in figure 8 the three notes in question should be ¼-tone flatter than Eb, Eb, and ¼-tone sharper than Eb, respectively).

Figure 6. Long vs. short fermatas (pages 5 and 7, top system, respectively).

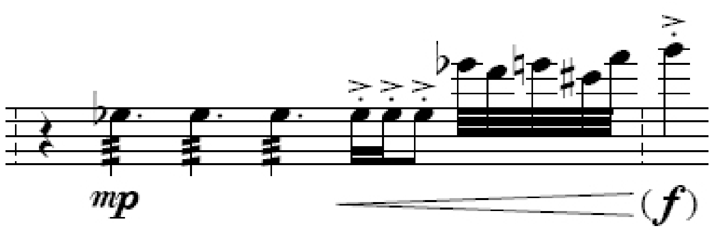


Figure 7. Use of accidentals (page 6, bottom system).

Figure 8. Quarter-tone notation (page 6, bottom system).

- CUSTOM NOTATIONAL DEVICES
    - MULTIPLIERS are values written above material that is to be reiterated predetermined number of times (figure 9b). The placement of iterations depends upon their rhythmic relation to other concurrent material, requiring either strictly timed uninterrupted repetitions, or allow for arbitrary breaks between each instance.

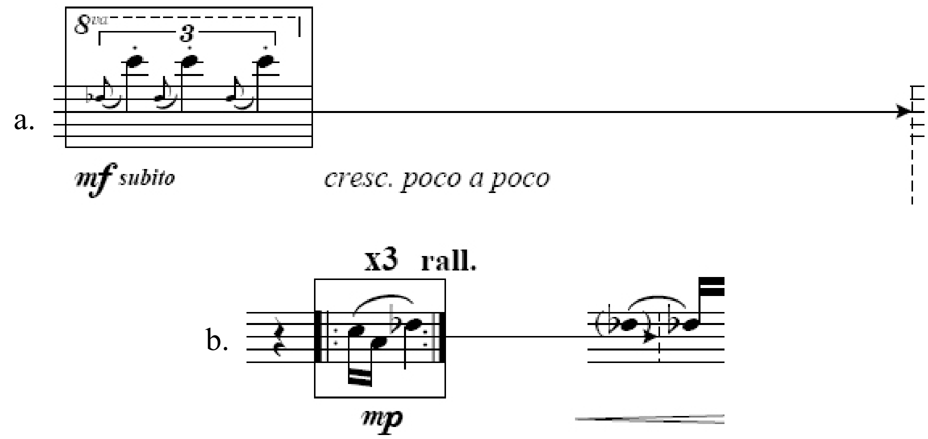
    - DURATIONAL ARROWS (figures 9a and 9b) provide referential duration of a particular event (or set of events) in order to facilitate accurate sync with other parts.

- LUTOSLAWSKI-LIKE BOXES come in two forms. One is a box with timed duration (figure 9a) and other is with a specified number of repeats (figure 9b). They should be treated as continuously repeated material. Some of the boxes introduce elements of aleatory. They will be addressed separately under the heading of "aleatoric elements."
    - Repeat signs within the boxes are considered as optional courtesy notation as it is implied that all boxes suggest finite number of repetitions. This number is measured either by durational arrows reflecting total allotted time, or by the multiplier specified above the box. Therefore, whether the boxes are presented with or without repeat signs, they should be always treated as recurring objects. This similarity, however, should not be confused with their varying ways of quantifying their recurrence (figure 9a vs. 9b).
    - Boxes can have other embedded boxes in which case they should be treated like mathematical parentheses. Namely, inner boxes' iterations should be satisfied before new iteration of the "parent" is to commence. For instance if a "parent" box with a durational arrow (suggesting timed number of recurrences) has two boxes inside, each with a 2x multiplier above them (suggesting specified number of occurrences), then the execution would require that each of the two embedded boxes are to be repeated two times (two iterations of the first box, followed by two repetitions of the second) to satisfy one occurrence of the "parent" box. This should be repeated for as many times until the end of a durational arrow of the "parent" box is reached.

- ALEATORIC ELEMENTS (figure 10) are Lutoslawski-like boxes with the word "RANDOMLY" written inside. This suggests random shuffling of the events presented within the box (their order does not have to be necessarily as written).
    - Some aleatoric boxes include events that are separated by parentheses. Such events should occur less frequently than other elements of the aleatoric set.

- DSP CUES (figure 11) are brackets visually similar to “multiple ending” delineators in a conventional score. They are populated by numbered cues that are positioned above the bracket. These cues should be timed by the technician as indicated in the score (except for a few mid-bracket cues that require sync from a performer, as indicated in chapter VII).
    - Each bracket denotes a durational lifecycle of a particular DSP sub-engine’s instance.
    - Every bracket has a DSP cue at the beginning and the end.
    - If more than one instrument is affected, concurrent horizontal brackets will be presented in multiple parts. However, for the sake of legibility only the topmost bracket will have the cue numbers stated.
    - Active DSP’s capture of incoming sound from microphones is marked with solid line, while sections that process previously captured data rather than live input are marked with dotted line. This is to indicate places which are less likely to cause feedback and/or technical problems.
    - Some of the processes with dotted brackets will have inner cue points. Places at which such cue points are to take place will be denoted by a momentary change of the dotted line into solid.

- A THEATRICAL ELEMENT (figure 12)
    - The theatrical element uses unconventional noteheads in order to clearly distinguish itself from other notational devices. It is also associated with a footnote (denoted by an asterisk) that is used to further clarify its function and/or execution.
    - *Tabula rasa* utilizes only one such element in the cello part at the very end of the piece, where computer-generated sine-tone is accompanied by a silent attack of the bow on the strings.



Figures 9a and b. Boxes whose number of repetitions is specified via total allotted time (a, page 13, bottom system) or using numerical multiplier (b, page 3, top system).

Figure 10. Aleatoric box (page 7, top system).

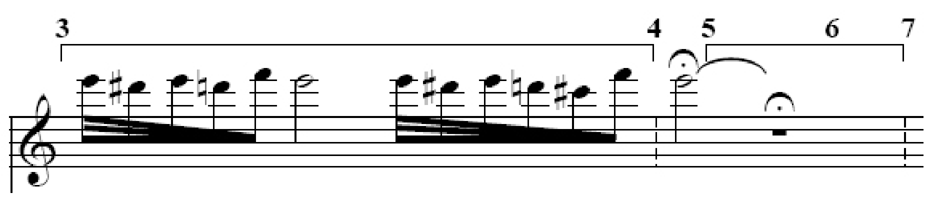
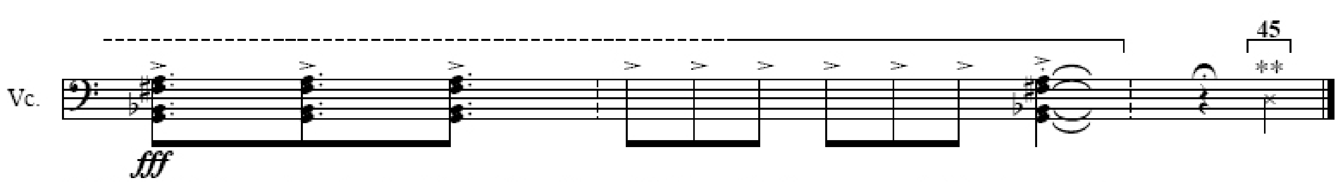


Figure 11. DSP cues (page 2, bottom system).



** Act as if playing a pizz. note when the final "beep" sound is triggered by the person controlling the computer.

Figure 12. Theatrical element (page 13, bottom system).

VI.b. MOTIVIC INTERRELATIONSHIPS

On a motivic level, it can be said that most of *Tabula rasa*'s acoustic material grows out of the opening idea presented in the piano part (figure 13). More specifically, it is based on rhythmic, registral, ordering, and intervallic permutations of a) two implied triads presented in the first six thirty-second notes (a major ascending and a minor descending), and b) closing motive with a descending minor third, followed by an ascending major third (cumulatively a subset of 014).

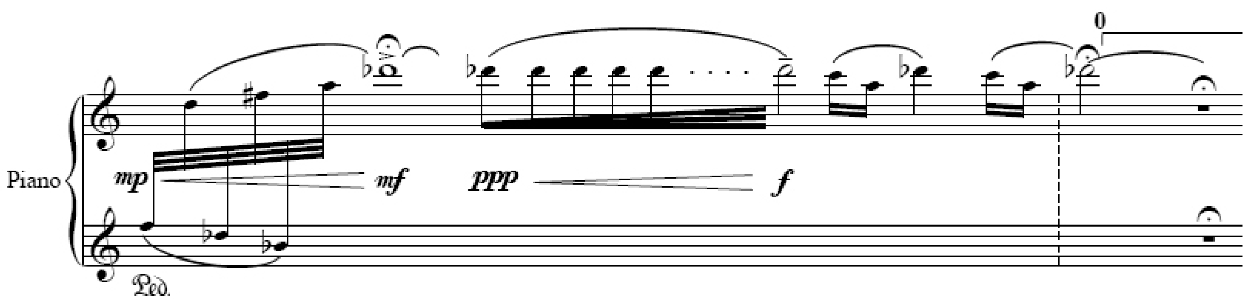


Figure 13. *Tabula rasa*'s germinal idea (page 2, top system).

For instance, let us observe the three examples found in figures 13a, b, and c. Chord in figure 13a is constructed from a major triad D-F#-A with a minor triad stacked on top of it A-C-E. It is therefore obvious that example 13a is derived from the opening 6-note progression. 13b is a collection of two 014 sets: Db-C-G# and D-A-B. In this particular example, the two sets are deprived of their parent's rhythmic character and as such they are perceived to be a moderately distant relative. In figure 13c we have another example of 014 sets, but in this case their presence is obfuscated by overlapping. For instance, while the right hand has the obvious A-Bb-Db and A-C-Db, left hand depends on the right hand to generate 014 sets: first two notes of the left hand Gb and F are coupled with right hand's A, while left hand's E and Eb are coupled with right hand's C.

Figures 13a (page 3, top system), b (page 3, top system), and c (page 8, bottom system). Examples of motivic derivatives.

Such juxtapositions can at times become rather complex in order to generate modal structures whose cumulative effect detracts from otherwise rather poignant minor second. Subsequently, a majority of the material presented in *Tabula rasa* can be linked to the opening passage utilizing similar analytical methods. This kind of interdependency not only reinforces structure, but also promotes aural cohesion in conjunction with economic use of music material.

VI.c. OVERALL FORM

As suggested by the work's unusual mix of localized styles, characters, and techniques, as well as their collective neo-Impressionist character, *Tabula rasa* does not thrive upon any of the dominant traditional forms. While outwardly sectional in design, in its core it is driven by an organic process of subconsciously evolving material whose permutations pose as subliminal links to consequent passages. The equally important computer's part complements this design by altering and/or enriching timbral, rhythmic, textural, and occasionally structural parameters. As such, *Tabula rasa* on the surface may appear to lack larger scale unity.

In order to deemphasize its ostensibly sectional nature, various unifying elements have been interspersed throughout the work. One such element is the opening ascent to Db which, until the very end acts as the absolute ceiling of the pitch-oriented material generated by the ensemble. Yet, just before the piece ends, in the last savage-like push this barrier (as well as many others) is finally shattered and the melody reaches the glorious D, bringing the piece to an apparent closure. This triumph is however very short-lived, as what immediately follows is the last mocking synthetic Db generated by the computer which in one swift blow dispells all the tension that has been in the making since the beginning of the piece. And while one could question its purpose, others could sense a greater sense of connectedness with the opening by alluding to the cliché of tonality in which a piece is expected to begin and end in the same key, chord, or (if everything else fails) a simple note. Similarly, other aspects worth considering are how the work ramps-up its energy to reach the aforementioned break-away at the very end, how the individual segments and/or ideas are interspersed as well as how they relate to each other both in terms of character and musical material.

VII. CHRONOLOGICAL BREAKDOWN OF INTERACTIONS

In the following chapter, we will focus on sequential categorization of each of the synergistic interactions between the ensemble and various DSP processes in order to provide both practical and analytical data necessary for their proper execution and interpretation. But before we move on, <u>it is important to emphasize that by default performers ought to be regarded as the primary regulators of the overall work's pace (except in select places where either computer's temporal distortions to the work or technician's shaping of specific cues takes momentary precedence, as indicated below). Therefore, most of the cues that require sync between the ensemble and technician should be left to performers' discretion</u>.

CUE	DSP[14]	REMARKS	CAUTIONS	DESCRIPTION
-1	OFF	“Rewind” position for restarting the piece		Starting point
0	ACTIVE	DSP engine captures only 3 seconds of sound so it should be engaged immediately following piano’s execution of Db.		Granular Synthesis + Reverb
1	ON	The longer the previous cue, longer will granular synthesis process the prerecorded stream. Its onset will initiate the granular decay with residual reverb release envelope.	LOOSE[15]	
2	OFF	This cue will instantly mute the sub-engine. Therefore it should be triggered once the reverb release has become silent.	LOOSE	
3	ACTIVE	Initiate reverb		Reverb
4	OFF	There will be residual reverb envelope even though the DSP sub-engine is turned off.		
5	ACTIVE	Same as 0-2		Granular Synthesis + Reverb
6	ON		LOOSE	
7	OFF		LOOSE	
8	ACTIVE	Initiates first reverb	VOLATILE[16]	Doubly-Linked Reverb + Panner
9	ACTIVE	Initiates second reverb	VOLATILE	
10	ACTIVE	Cross-pollinates the two reverb signals	VOLATILE	
11	OFF	There will be residual reverb envelope once the DSP sub-engine is turned off.	RELEASE[17]	
12	ACTIVE	Initiate transposition of flute’s part with a fade-in envelope		Pitch-shifting
13	OFF	Disengage pitch-shifting with a quickly decaying envelope		
14	ACTIVE	Initiate reverb	VOLATILE	Doubly-Linked Reverb + Panner
15	OFF	There will be a residual reverb envelope once the DSP sub-engine is turned off.		

[14] When DSP is ACTIVE microphone input is being actively monitored and processed. When DSP is ON, the input is not any more active but the sub-engine is still generating audio output by processing captured stream, or is simply outputting the remainder of a decaying envelope. ONESHOT denotes short one-time event that requires no OFF cue.
[15] LOOSE refers to a cue whose timing can be more flexible and is left to technician’s discretion.
[16] Processes requiring special adjusting volume faders at run-time due to their volatility are marked as VOLATILE.
[17] Events marked with RELEASE caution may utilize manual control of the release envelope via volume fader (for additional information please consult chapter V, section d).

CUE	DSP	REMARKS	CAUTIONS	DESCRIPTION
16	ACTIVE	Initiate process with a fade-in envelope		Allpass Delay (flute) + Pitch-shifting (cello)
17	OFF	Disengage process with a moderately decaying envelope		
18	ACTIVE	Similar to 14-15 (internal settings are somewhat different, thus requiring a separate sub-engine)	VOLATILE	Doubly-Linked Reverb + Panner
19	OFF			
20	ACTIVE	Sporadic grains applied to cello's part should be allowed ample time as there is a fade-in envelope of moderate length. <u>This particular sub-engine turns off on the cue #23 due to its moderate release envelope.</u>		Granular Synthesis + Reverb
21	ON		LOOSE	
22	ACTIVE	Densely populated grains generate a continuous crescendo, resulting in a wall of sound.		Granular Synthesis + Reverb
23	ON	Following this cue, there will be still residual reverb release envelope which should overlap with the material that is to follow. This aggregate DSP sub-engine will be triggered once more before being shut off with the cue #28.	LOOSE	
24	ACTIVE	Same as 22-23, but should be allowed to crescendo longer in order to generate more tension (may also require ramping-up of level faders). Both this one and the previous sub-engine cue are going to be terminated in the cue #28 in order to allow for the residual reverb release envelope to subside.		Granular Synthesis + Reverb
25	ON		LOOSE	
26	ACTIVE	Silently begin capturing piano and cello		Sample and Hold
27	ON	This particular cue needs to be timed before the entrance of the entrance of piano's right hand. Pianist should give a nod to the technician so that maximal possible buffer is captured. As soon as this cue happens, the computer will continue to loop piano and cello parts until the activation of the next cue.	CUE[18]	
28	OFF	Needs to be in sync with instruments	STRICT[19]	

[18] Cue points that require cues from performers are marked in the CAUTIONS column with the word CUE.
[19] Some cues require strict timing, usually in sync with instruments. They are marked with the word STRICT.

CUE	DSP	REMARKS	CAUTIONS	DESCRIPTION
29	ACTIVE	Engage DSP on flute (needs to be initiated before flute begins playing)		Random Echo + Pitch-shifting
30	ACTIVE	Engage DSP on piano (needs to be initiated before piano begins playing)		
31	ACTIVE	Engage DSP on cello (needs to be initiated before cello begins playing)		
32	OFF	Turn off DSP on all instruments, initiating long decay envelope	RELEASE	
33	ACTIVE	Same as 14-15	VOLATILE	Doubly-Linked Reverb + Panner
34	OFF			
35	ACTIVE	Initiate upwards-sweeping pitch-shifting on all three instruments with a quick fade-in envelope		Sweeping Pitch-shifting
36	OFF	Disengage DSP with a quick fade-out envelope		
37	ACTIVE	Same as 35-36		Sweeping Pitch-shifting
38	OFF			
39	ACTIVE	Silently begin capturing piano and cello		Sample and Hold + Granular Synthesis + Delay
40	ON	This particular cue needs to be timed exactly on the downbeat. As soon as this cue occurs, the computer will continue to loop piano and cello parts until cue #44 has been triggered.	STRICT	
41	ON	Add granular synthesis of the loop		
42	ON	Amplify granular synthesis		
43	ON	Engage allpass filter on the mix		
44	OFF	Immediately disengage DSP, followed by a short residual decay envelope from the allpass filter		
45	ONE-SHOT	Must be executed in sync with the cello's theatrical mock-attack by the bow, generating a brief Db5 sine tone. This event should not immediately follow previous cue as it may be overpowered by the allpass filter's decay envelope.	CUE	Synthesis (Sine Tone)

From an analytical standpoint, it is important to note that events 29-32 introduce elements of indeterminacy, while every DSP instance employing granular synthesis serves as an example of computer generated aleatory (the latter reaffirms an interesting parallel that exists between algorithmic composition and aleatoric execution). The computer's part therefore matches in terms of structural as well as expressive importance aleatoric passages generated by the acoustic instruments. Furthermore, events 29-32 as well as every other event with LOOSE cautioning, play an important role in affecting work's overall pace and subsequently structure. From the table it is also apparent that strongly reverberated DSP instances, namely the so-called doubly-linked reverbs, are the most volatile ones, requiring careful run-time control. Most of these, however, will not require much attention beyond the dress rehearsal configuration.

It is also important to observe how each of these interactions affects the overall work. Based on the Table 1 found in the chapter III, secton c, we could therefore conclude the following:

- Reverb-only events, such as 3-4, are the ones that *alter acoustic properties*.
- Events that provide distinct difference between acoustically produced sound and its processed counterpart *enhance spectral and/or dynamic features*.
- Any event encourages loose timing and/or decay/release envelope manipulation, as well as events that involve element of randomness in respect to their timing and/or duration, *alter temporal and/or structural pace*.
- The closing theatrical cue that is the sole example of *synthetic material*.

As mentioned earlier, most of the cues thrive upon more than one of these dependencies. Correspondingly, some of them do not always follow the aforementioned logic. For example, cues 0-2 offer reverberation. However, if we take into account that in this particular case reverberation is provided in order to generate "warmth" to the real-time granularization of the sampled piano, we will conclude that its primary function in this instance is to enhance spectral and/or dynamic features of an instrument in conjunction with the concurrent granular synthesis. But this is not all that the aforementioned instance affects. Due to the loose timing of the cues 1 and 2, this particular instance also affects the overall timing by altering the temporal and/or structural pace.

VIII. CONCLUSION

Tabula rasa, as a contemporary interactive electroacoustic work employing traditional chamber ensemble in conjunction with the contemporary technology, can be observed as both an artistic and scholastic endeavor. While its content is primarily a fruit of author's intuitive and creative process, the questions and challenges its deployment has brought forth have served as a foundation for further scholastic and creative work.

Considering that at the time this work was written, there was an apparent gap between the traditional (a.k.a. "classical") music and contemporary technologically driven arts, a gap which was cultivated among music consumers. For this reason, the use of technology in order to expand timbral, structural, and subsequently textural properties of a traditional chamber ensemble (in this case flute, piano, and cello) was seen as the most effective solution for bridging the aforementioned unfortunate trend. Perhaps one of the most critical aspects of the computer's participation was its absolute indifference towards the music-making process and therefore an ability to generate absolute and unhampered decisions. Consequently, it was concluded that coupling technology with a traditional ensemble had a tremendous potential and was chosen to be the focal element of this work.

In terms of interactive technology, attempts at generating an entirely independent artificial system that would in its participation match artistic output of the human performers proved to be too daunting a task. There were palpable limits requiring immense amounts of time and resources, such as a need for at least partial reconstruction of complex decision-making processes that occur within human's brain, generation of a modular database in order to enable the computer to reference its actions (akin to the human ability to memorize, recall, and compare), as well as preloading of the aforementioned database with aesthetical inclinations that are inherent to a traditionally trained musician. On a more practical side, this goal was simply unattainable due to current limitations of the sound analysis technology; in its current state the FFT method introduces unacceptable latency overhead rendering it useless for the purpose of perceiving and analyzing cues as well as other pertinent musical content generated by musicians in order to enable computer to actively participate in the music making process. While there were potential solutions which could have potentially bypassed use of FFT entirely, none of them proved to be either robust or reliable.

As a result, the only viable time-conscious option was to provide the computer with a technician who would serve as its eyes and ears, executing and fine-tuning the output in order to foster perfect synergy between instruments and technology. This way, the problem of lack of reliable perception mechanism was entirely circumvented, while concurrently allowing for the computer to retain its uniqueness and independence once its DSP sub-engines have been set in motion.

MaxMSP software, as an abstract visual programming environment geared towards DSP offers an incredible amount of flexibility while allowing for rapid and efficient development. Hence, it was chosen as the foundation for the technological aspect of *Tabula rasa*. With the help of a few externals which have offered abstractions of some of the higher-level DSPs, the author was able to focus primarily on the artistic merit of their interactions with the acoustic material, rather than being diverted by endless debugging sessions of the underlying technology.

Another advantage of *MaxMSP*-like programming environments is that they can be utilized to generate efficient user-friendly interfaces for the purpose of real-time human interaction with various parameters. *Tabula rasa*'s *MaxMSP* patch focuses on providing verbose data as well as serving as the mixing hub. This way, house mix controls do not require any manipulation beyond initial configuration, allowing for the entire setup to be run by a single person via computer.

Tabula rasa utilizes various forms of dependencies between computer and the ensemble, such as altering of acoustic properties, enhancing spectral and/or dynamic features, altering temporal and/or structural pace, or simply complementing the texture with synthetic material. Through such symbiotic exchanges, the computer is capable of affecting spectral, temporal, dynamic, structural, and theatrical aspects of the work. More importantly, doing so enables it to introduce elements of aleatory and even indeterminacy. Coupled with the computer's inherent, yet unmatched indifference, its role in the overall mix is justifiably that of an equal participant with a unique voice, rather than a subordinate effects processing machine.

While its use of the technology could be perceived as cutting edge or even avant-garde, *Tabula rasa*'s treatment of the acoustic material suggests neo-Impressionist roots. Yet, the coexistence of these apparent polarities speaks of unbreakable mutual dependency. Such peculiar marriage of historical style and contemporary technology has allowed for vital reduction of unknown variables; by building upon the known heritage whose form of presentation as well as medium was still very much innate to the culture in which the work was created, the composer was able to focus primarily on the introduction of technology in a way that would best complement the preexisting foundation, thus adapting the old chamber music idiom to the culture of the present times. While *Tabula rasa* is not the first piece to incorporate contemporary technology into traditional acoustic idiom, instead of the rather common "one performer vs. one computer" interaction it extends the idiom by employing multiple instruments and processing them concurrently in real-time. As such, it belongs to a relatively small pool of fringe works that offer far greater technological as well as expressive complexity of interaction between the two counterparts.

In terms of aesthetics, *Tabula rasa* attempts to fuse what is traditionally perceived as two distant forms of musical expression. While our cultural biases may suggest these two counterparts to be very much different, *Tabula rasa* shows them as mutually dependent with their cumulative artistic and expressive potential being far greater than that of their individual treatment. Each of the elements brings forth its strengths which in turn limit the scope of the counterpart's contextual inadequacies: acoustic instruments alleviate the paradox surrounding concert venues that rely solely upon the so-called tape music medium, while technology brings traditional ensemble into a contemporary setting that a common audience member is easier to associate with. This union was further reinforced by contrasting a more contemporary concept of aleatory/indeterminacy and the traditionally predetermined musical material, all of which are present both in the computer and the instrumental parts. Naturally, new concerns have sprang up as a result of this unsuspecting union, such as the technology overhead that is associated with this work's deployment. However, such limitations have come to be regarded as a lot less invasive than the benefits they are associated with.

It is important to point out that the conscious choice of a targeted audience has played a part in the overall compositional process. Historically, composers have always catered to some kind of an audience (even if that audience was limited solely to the author of the work). With *Tabula rasa* there was a conscious effort to carefully consider its audience scope and the resulting repercussions. Namely, the goal was to broaden audience's interest in contemporary arts by closing the artificial gap between traditional and contemporary, as well as between pop and academic art. As a result, *Tabula rasa* has been targeted towards audience whose background, apart from the obvious prerequisite of general arts awareness, suggests interest in technology and at least superficial knowledge of musical heritage. This is not to say that the work was designed to be enjoyed exclusively by the listeners who fit the aforementioned description. Rather, the implication is that the work has had an audience-oriented agenda which in return has greatly helped shape its aesthetic choices, ultimately resulting in a predominantly positive reception and consequently repeated performances. In this respect, it can be said that the work has clearly met its expectations, suggesting that this particular consideration is an important aspect of any creative process.

Judging from the performer feedback, it is worth noting that the instrumentalists have welcomed the extended notational devices juxtaposing complex timing, rhythmic relationships, loose metering, and contextual tempo markings. By retaining score legibility, this particular combination has allowed for a relatively low learning curve as well as enabled performers to maintain their expressiveness. Similarly, in order to maintain aforementioned efficiency, the cueing notational devices have kept details away from the score while keeping instrumentalists aware of the computer's presence. By relegating technological aspects to a "technician," musicians were relieved of a potentially daunting task to monitor and shape computer's actions in conjunction with their own. This is not to suggest that such a feat would be impossible, but rather that the management of the two distinctly different approaches to the music-making process would likely result in their cross-pollution and consequently questionable aesthetic outcome. The performers had been also very receptive to the expressive character of the Neo-Impressionist score. Acting as the familiar foundation, this particular aspect has helped them assimilate technological aspects with ease and comfort.

It is also worth pointing out that there are some aspects of this work which have left room for improvement and as such will be likely addressed in one of author's subsequent creative endeavors. Namely, the interaction between technician and performers remains somewhat inefficient. In one of the future works of similar scope, I anticipate utilizing my own software *RTMix*[20] whose focus is to provide efficient coordination of performing forces and therefore bridge this gap. Other consideration is expansion of communication interfaces with the computer through use of generic MIDI controllers. While this alteration would allow performers to have

[20] For additional information or to obtain *RTMix* please visit http://meowing.ccm.uc.edu/~ico/RTMix-doc/index.html (last checked September 2005).

finer control over some of the aspects of DSP, its implementation will likely require additional research in order to quantify its potential repercussions on the independence of the computer's part. Finally, there is a consideration of moving future projects or even back-porting *Tabula rasa* to an open-source platform in order to ensure best possible longevity and compatibility, in this case namely utilizing *Linux*[21] operating system in conjunction with the *Pure-data*[22] (a.k.a. *Pd*) software which is in its function and scope almost identical to *MaxMSP*.

IX. MEDIA CONTENTS

This thesis is accompanied by the following media:

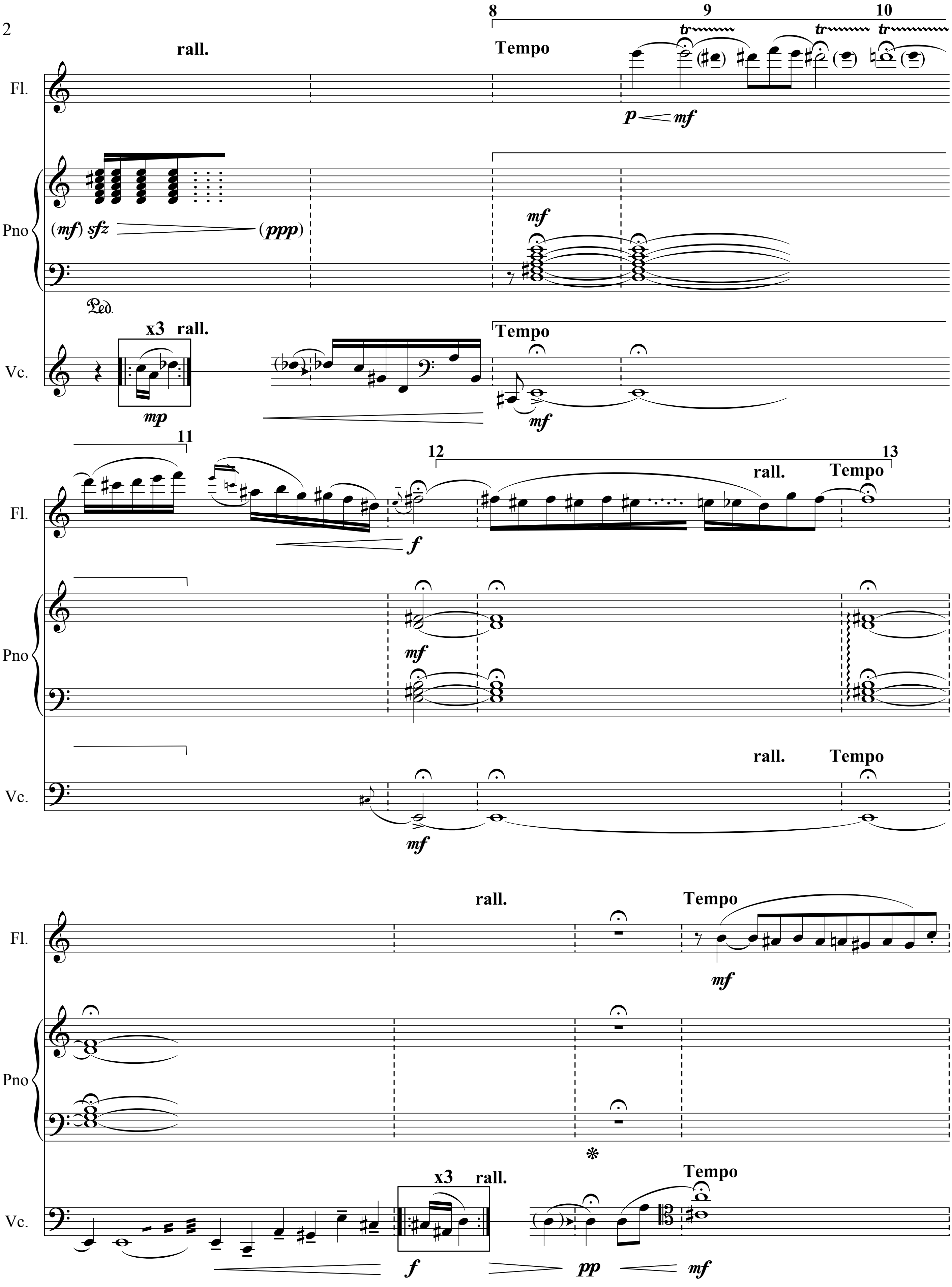
- *MaxMSP* patch, found in the "Max" folder.
- *MaxMSP* externals required to run the patch, located in the "Externals" folder.
- Recording of the work's premiere in MP3 format in the "Recording" folder performed by the NeXT Ens which consists of Carlos Velez (flute), Shiau-uen Ding (piano), and Hayk Babayan (cello).
- A plain text file with the thesis abstract.

[21] For more information on *Linux* please consult http://www.linux.org (last checked September 2005).
[22] For additional information or to obtain *Pd* please visit http://puredata.info (last checked September 2005).

X. SCORE

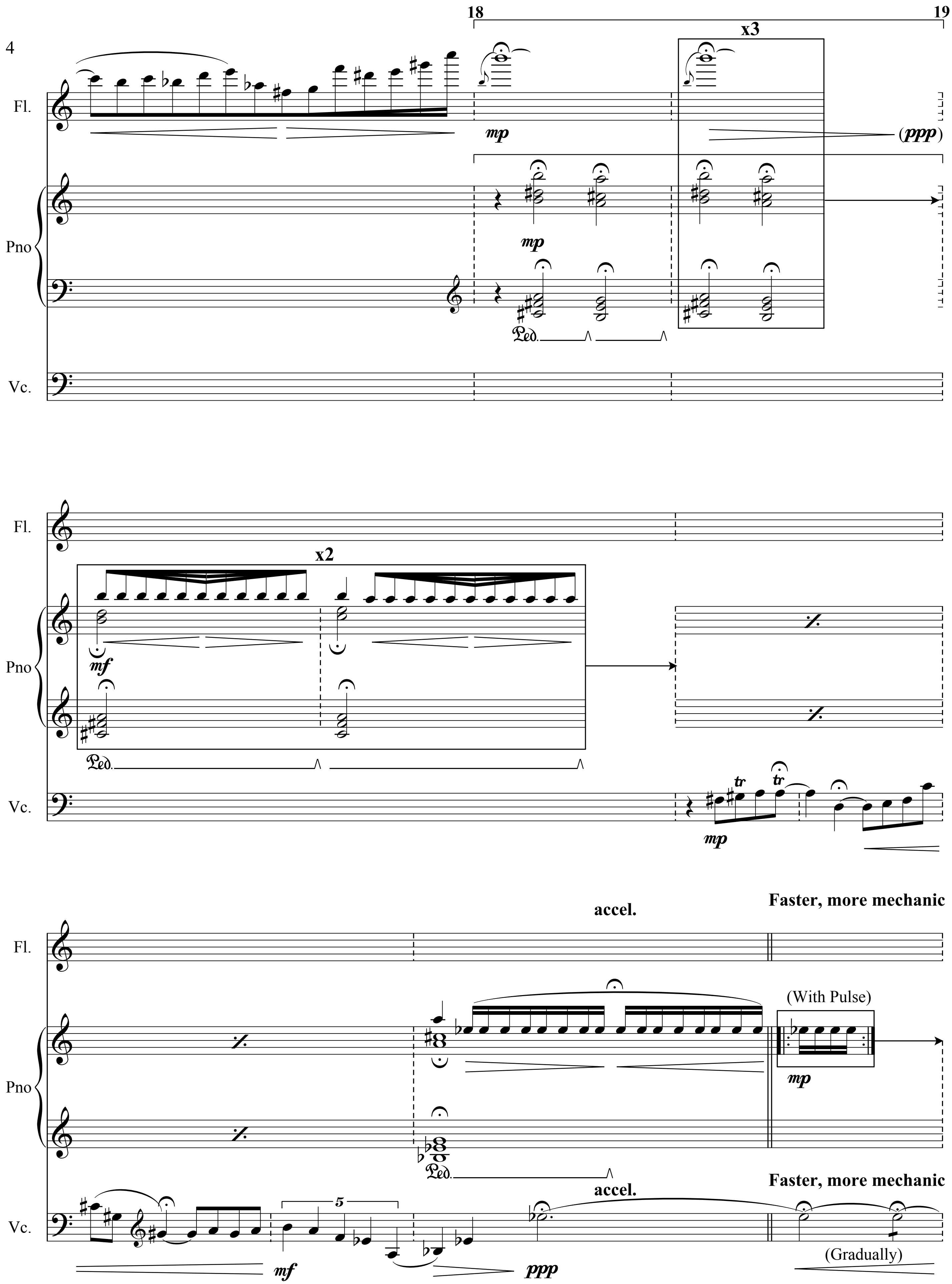
Tabula rasa

Ivica Ico Bukvic



rall.
8
Tempo
9
10
tr
Fl.
p
mf
Pno
(mf) sfz
(ppp)
Ped.
x3
rall.
Vc.
mp
11
12
13
f
x3
rall.
pp


Fl.
Pno
Vc.
mf
mp
mf
14
15
cresc.
f
x2
tr
ff
(f)
16
17
x4
x3
x3
rall.
rall.
mp


18
19
x3
Fl.
Pno
Vc.
mp
(ppp)
mp
Ped.
x2
mf
Ped.
tr
tr
mp
accel.
Faster, more mechanic
(With Pulse)
mp
Ped.
accel.
Faster, more mechanic
5
mf
ppp
(Gradually)


Fl.
Pno
Vc.
sfz
(ppp)
mf
20
21
sul pont.
norm.
(Gradually)
mp
(r.h.)
Ped.
22
23
(f)
p subito
f
sfz
mf subito
RANDOMLY
24
25
pizz.

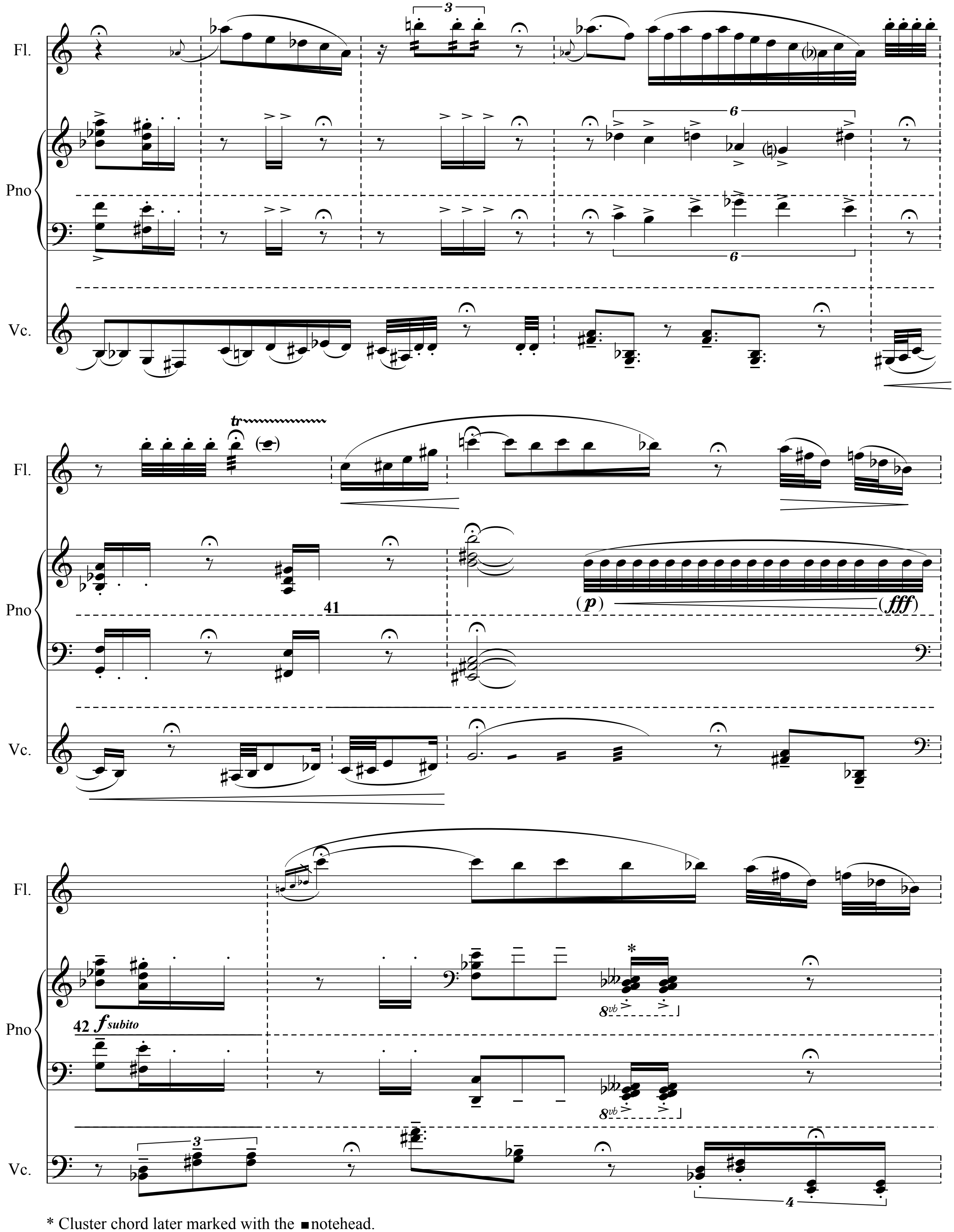

Fl.
Pno
Vc.
RANDOMLY
ppp
f
(Gradually)
(r.h.)
26
27
x5
(l.h.)
(ppp)
mf
cresc.
OCCASSIONALY
ff
Sensa misura
pizz.
arco


Fl.
Pno
Vc.
pizz.
arco
p subito
Freely
28
29
mf
30
31

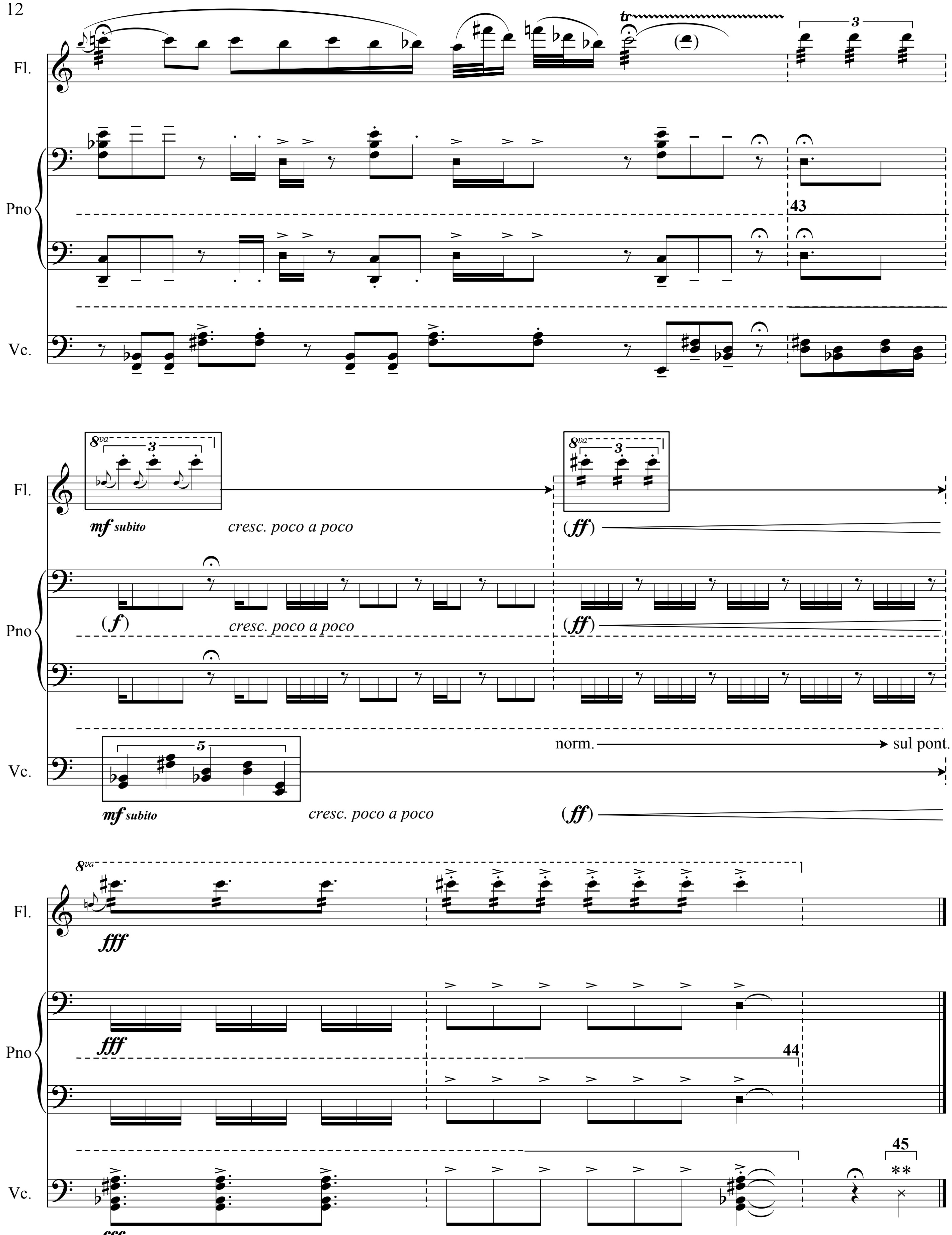

32
Fl.
4
Pno
muted
pizz.
arco
Vc.
sfz
33
Long!
mp
mf
f
sfz
simile
mf


34
x3
accel.
Long!
Fl.
cresc. poco a poco
sfz
Pno
cresc. poco a poco
mf
Ped.
Vc.
cresc. poco a poco
accel.
Long!
Fl.
Pno
(r.h.)
(l.h.)
f
Vc.
f
35
36
37
38
♩ = 120-130
Fl.
mp
tr
mf
Pno
f
mp
f
mf
♩ = 120-130
Vc.
sul pont.
mp
sul pont.
mf


rit.
♩ = 140
Fl.
Pno
f
(ppp)
f
x3
8vb
rit.
pizz.
♩ = 140
Vc.
sfz
5
39
x3
40
x3
arco
(ppp)
f
f
6
cresc. poco a poco
f
cresc. poco a poco
cresc. poco a poco



* Cluster chord later marked with the ■ notehead.



** Act as if playing a pizz. note when the final "beep" sound is triggered by the person controlling the computer.

Deo adiuvante 12/13/2004