Historical Virtualization

Analog and Digital Concerns in the Recreation, Modeling and Preservation of Contemporary Piano Repertoire

CHRYSI NANOU AND **ROB HAMILTON**

ABSTRACT

Modern efforts to preserve and reinterpret canonic musical works in the contemporary piano repertoire often take advantage of new technologies, fundamentally changing core aspects of the works themselves. By approaching preservation as a form of virtualization—in this case the creation of a functional interpretative model of each musical work—artists and researchers can create robust and performable digital versions of important musical systems. This paper introduces the idea of virtualization as a compositional modeling technique and offers three case studies in which digital versions of contemporary piano repertoire were designed and developed.

The piano holds a central role in contemporary performance practice, acting simultaneously as a bridge to a rich history of composers and pedagogues and as a sounding board for new explorations and extensions of musical performance. Composers seeking timbral and spatial modifications to an instrument that is for all intents and purposes fixed and immobile have successfully explored physical preparations and alternate excitation techniques, as well as electronic and computer-based processing, to modify the sounding affect of the piano—engineering diverse performance modalities that modify, simulate and extend the capabilities of the instrument [1,2].

For musicians whose practice includes electroacoustic and computer-based performance, the rich history of works featuring extended piano systems offers opportunities to update or enhance these systems, leveraging *virtualization* as a means to simplify, reinterpret and preserve musical interactions. Physical systems that prove difficult to recreate or unwieldy to configure can be replaced by well-tuned parameter sets for computer-based processes. Aging software systems that have become obsolete can not only be recreated using newer and more platform-agnostic means but can also be represented and notated using musical notation formats that have lasted for hundreds of years. And works based around specific performative techniques can be explored in previously unconsidered fashions by transplanting physical gesture from the analog domain to the virtual.

Chrysi Nanou (pianist), Stanford University. Email: <chryssie@ccrma.stanford.edu>. Center for Computer Research in Music and Acoustics, Stanford University, Stanford, CA 94305, U.S.A.

Rob Hamilton (educator), Rensselaer Polytechnic Institute. Email: <hamilr4@rpi.edu>. Department of the Arts, Rensselaer Polytechnic Institute, 110 8th St, Troy, NY 12180, U.S.A.

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VIRTUALIZATION

Interpretation is an essential element of musical performance. Artists make use of instructions and data as described by composers to build their own personal interpretations of a given work. Within the context of the preservation and recreation of musical works, artistic interpretation plays a key role in crafting artful solutions that preserve the integrity of a musical system. When reconstructing analog musical systems as digital or virtual systems, core functionalities from the analog domain must be recreated or virtualized within the digital domain.

This article describes a series of such virtualizations created for three iconic contemporary works of the piano repertoire that address extension of the instrument's analog practice into the digital domain for purposes of digital emulation of analog processing as well as analog representation of generated digital data to combat technology-dependent obsolescence. In John Cage's prepared-piano work *Primitive*, a time-consuming and restrictive physical preparation is sampled and triggered by a Disklavier, with individual string-muting handled by easy-to-install (and easy-to-remove) 3D-printed string mutes. In Alvin Lucier's *Nothing is Real*, analog sampling and filtering through the physical volume of a teapot is replaced by a virtual teapot equipped with digital filters, rendered in 3-dimensional space and controlled by a pianist's hand gesture. And in Jean-Claude Risset's *Duet for One Pianist*, the work's algorithmically generated digital accompanist's role is transcribed into traditional notation for archiving in the face of the software's precarious situation.

PRIMITIVE

Composed by John Cage in 1942 for a choreography by Wilson Williams, *Primitive* was one of Cage's earliest works—starting with 1940's *Bacchanale*—to use a physical preparation of

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the piano to create a highly percussive and varied piece. The work features a relatively simple preparation of only eleven notes, employing screws and bolts placed between the specified strings, spread out across four octaves of the piano (see Fig. 1). In addition, two small screws are added to two specified pitches, giving them a secondary preparation.

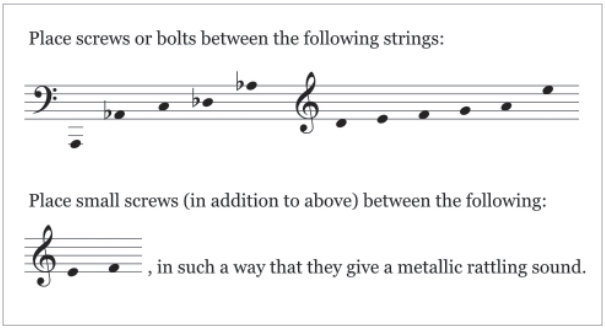

Fig. 1. Cage's instructions for string preparation in *Primitive*. (© Robert Hamilton)

Cage's style of piano preparation is an effective method for reproducing a high-level timbral shift within his piano scores, in that the specified notes themselves undergo a transformation. In *Primitive*, the lower-level sonic details of that transformation—contingent on the specific physical properties of the objects used, the manner in which they are inserted between strings, their location along the string's length and the individual characteristics of the piano itself—are very much left as indeterminate. This apparent dichotomy between control through preparation and indeterminacy as a desired component of Cage's work is captured in his own words on his personal evolving views toward such preparations and their implications:

> When I first placed objects between piano strings, it was with the desire to possess sounds (to be able to repeat them). But, as the music left my home and went from piano to piano and from pianist to pianist, it became clear that not only are two pianists essentially different from one another, but two pianos are not the same either. Instead of the possibility of repetition, we are faced in life with the unique qualities and characteristics of each occasion [3].

While Cage's works for prepared piano are extremely popular among pianists and as such are widely performed, the necessity to physically modify a given piano for performance makes it difficult to include such works on mixed programs containing both prepared and unprepared repertoire. Indeed it has become common practice for multiple pianos to be used for such programs. For artists comfortable with contemporary musical performance practices and paradigms, the potential to leverage digital technologies provides an opportunity to explore works with complex physical modifications without constraint, at least from the analog domain. One concern with a completely generalized digital solution for piano preparation is the extent to which such an approach removes artists themselves from the preparation process and the inherent homogeneity brought on by artists sharing samples and digital preparations.

Using 21st-century technologies, the creation of virtual prepared pianos is a relatively straightforward task, one that has been previously pursued using physical modeling [4] as well as sample-based architectures [5,6]. Piano note triggers, typically in the form of MIDI note messages sent by electronic keyboards, activate either synthesis or sample-based sound preparations.

By virtue of the large physical size and significant resonant characteristics of an acoustic piano, the sonic experience generated by playing one is audibly different from high-quality sampled digital keyboards and, at the same time, a physically different experience for the performer. One solution is to use a MIDI-capable acoustic piano such as the Yamaha Disklavier to drive software preparations. However, an additional solution is needed to selectively dampen individual strings of the instrument (those strings that would trigger a digital preparation) to prevent an unprepared string from sounding at the same time.

In the interest of addressing each of these concerns, we built a Disklavier-driven extensible sample-based performance system for Cage's *Primitive* that combines an artist-generated sample set with a 3D-printed set of individual piano string mutes. In this manner, we hope to preserve the physical nuances of performing such works on a traditional piano while simplifying the setup and tear-down times necessary for performers to engage these works, especially on programs mixing prepared and unprepared piano repertoire.

Virtualizing *Primitive*

To prepare our version of *Primitive*, we recorded a set of samples using the preparations outlined in Cage's score. We recorded each prepared note at three intensity levels (***p***, ***mf***, ***ff***) and two durations (short and long). A polyphonic ChucK script parsed incoming Disklavier MIDI input and triggered individual samples based on MIDI pitch and velocity. We used sample durations for a test-playback mode, but only used long-duration samples for the actual performance.

3D-Printed String Mutes

To selectively dampen strings featuring a digital preparation, we created a 3D model of a piano string mute (see Fig. 2), sized to snap into place onto each set of piano strings (see Fig. 3). We designed the mutes using parametric modeling in Solidworks CAD software and fabricated them using fused deposition modeling on a Type A Series 1 3D Printer. The material we used was PLA (polyactic acid), a biodegradable thermoplastic. We designed each mute to be easy to attach and remove, with no adverse effects to the instrument or strings. While the dampening for each muted string is not absolute—some sound from the string is still audible when

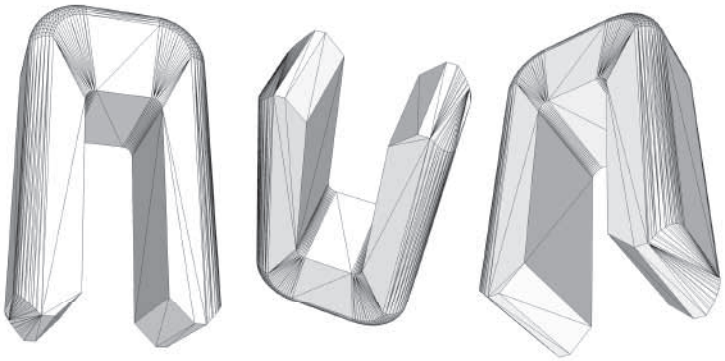

Fig. 2. 3D design for individual piano string mutes. (© Robert Hamilton)

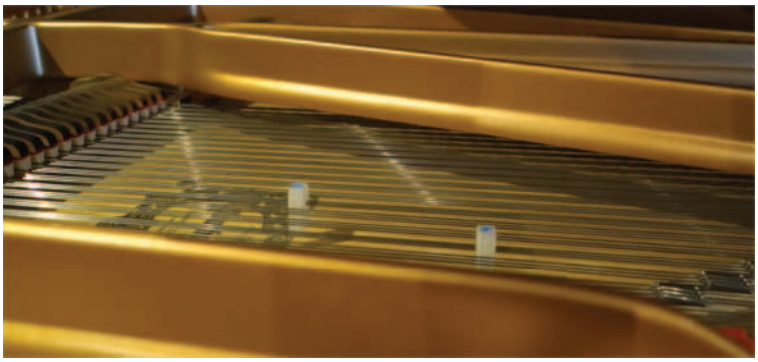

Fig. 3. 3D-printed string mutes on individual strings. (© Robert Hamilton)

Fig. 4. Virtual teapot rendered in Unity 3D. (© Robert Hamilton)

struck by the piano hammer—when combined with the sampled preparation, the resonating characteristic of the pitched string is effectively removed.

NOTHING IS REAL

In composer Alvin Lucier's 1990 work *Nothing is Real*, for piano and amplified teapot, memories—both the fragmented memory of a musical phrase and the short-term recorded memory of a pianist's performance—play a central role. *Nothing is Real* is a mixed-media work in which a pianist performs Lucier's monophonic score, itself derived from the melody from the Beatles song "Strawberry Fields Forever." The performance is recorded in real time and, upon completion of the written score, the recording is played back from a speaker situated inside a teapot.

During playback, the pianist is instructed to raise and lower the teapot's lid—changing the frequency response of the filtering imposed on the recording by the shape of the teapot's resonating body. Lucier goes so far as to notate specific filter frequencies, reinforced by holding the teapot's lid at different heights. The resultant filtering gives a performance of Lucier's work an intimate feel, reminding audiences of the historical memory of the original song as well as the short-term memory of the piano performance itself.

Virtualizing *Nothing is Real*

Central to Lucier's piece is the manipulation of the teapot's resonating body through physical gesture—the raising and lowering of a teapot lid. To model the resonating system, we coupled a simple software resonator written in ChucK with a 3D visual model of a teapot (see Fig. 4), modifying the resonating frequency and Q value of the filter based on the distance between the model's lid and its aperture. The teapot itself—rendered in the Unity game engine—could be scaled in size, with its size parameter modifying the filter in ChucK. To control the teapot lid, a Leap Motion hand-tracking device was used, with the motion of the pianist's hand in the vertical plane mapped to the "height" of the virtual teapot's lid. The live piano performance was recorded to file in ChucK and then played through a multichannel speaker system.

DUET FOR ONE PIANIST

In 1989, composer and researcher Jean-Claude Risset's series of interactive sketches for piano and Disklavier, *Duet for One Pianist*, explored the possibilities made available to pianists through the augmentation of human gesture with the reactive and computational capabilities afforded by computer systems. Risset's eight Max/MSP software patches receive incoming MIDI messages from the Disklavier, enact score-following behaviors through an analysis of the incoming MIDI stream, carry out predefined dynamic or static processes designed by the composer and subsequently generate an outgoing MIDI stream of these processes to be fed back to the Disklavier itself for acoustic rendering.

As Risset describes the process:

> In my *Duet*, I have explored some simple compositional relations between the pianist's part and the computer's part: translations or symmetries in the time-frequency space

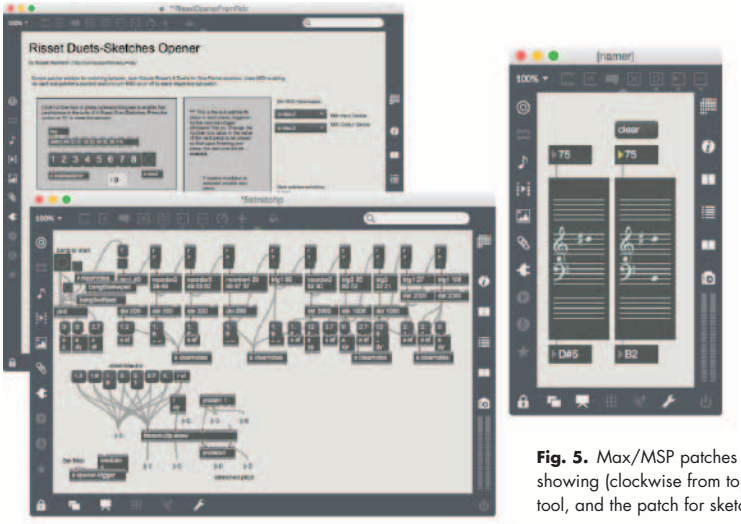

Fig. 5. Max/MSP patches for Risset's *Duet for One Pianist* showing (clockwise from top) the "Opener," MIDI diagnostic tool, and the patch for sketch #5, "Stretch." (© Robert Hamilton)

(that is, pitch transpositions or interval inversions); triggering by the pianist of specific patterns (e.g. arpeggios) or stored musical sequences which can be influenced by certain performance parameters (for instance, the tempo of the sequences follows the tempo of the pianist; or this tempo is a function of the loudness of the notes played by the pianist); canon-like imitation (the computer plays a melody derived from that played by the pianist by transposition and change of tempo) [7,8].

As computer and musical software systems have evolved, the Max/MSP software patches created by Risset and researcher Scott Van Duyne at the MIT Media Lab have required updating and maintenance. During the composer's 2008 residency at Stanford University's Center for Computer Research and Musical Acoustics, we worked to update his software to run on Max/MSP version 4.0, adding a customized performance "Opener" patch as well as a diagnostic tool to view incoming and outgoing MIDI messages (see Fig. 5).

Archival Scoring

In contrast to the incremental process of preventive maintenance required for the software patches, Risset's original hand-notated musical score for the work—performance notation for the pianist alongside a varying level of detail representing the computer's response—has remained the authoritative representation available to performers, researchers and archivists alike. We began investigating the idea of using traditional musical notation alongside captured data sets and archival audio recordings to present and preserve the real-time musical transformations and processes explored within Risset's studies [9]. A detailed semantic representation of both the interaction schema and the musical data generated by Risset's software patches would act as an archival blueprint of sorts, allowing software designers to recreate the musical processes as Risset intended, even if the original software became unstable or unusable. By capturing MIDI data from both the Disklavier (representing the pianist's actions) and from the Max/MSP patches (representing the processed output of the computer), an archival data set was created. Using this data set, an archival score was created, containing both instructions for the performer and detailed musical notation representing the output of the computer system (see Fig. 6).

Data Capture and Processing

To capture MIDI performance data, we used hardware MIDI splitters to duplicate MIDI streams from the Disklavier as well as from the Max/MSP patch, routing each data stream into an Ardour session for recording. We also simultaneously

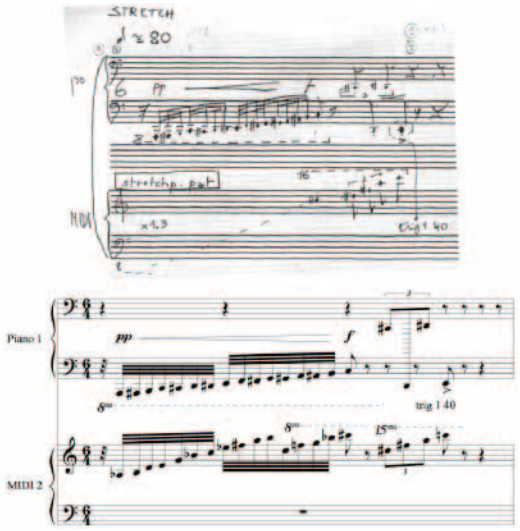

Fig. 6. Original handwritten excerpt from the sketch "Stretch" from Risset's *Duet for One Pianist* (top) and fully notated archival score of the sketch (bottom). (© Robert Hamilton)

recorded four channels of audio, creating a time-synchronized data set (see Fig. 7).

To create an archival score of each sketch from *Duet*, we first manually typeset Risset's hand-notated piano score using Finale. The computer-generated data set for each sketch was loaded into Finale and used as a guideline to score the output of the Max/MSP patch as a second voice on its own notated staff. Care was taken to replicate Risset's style of notation, mimicking barring, rhythmic style and spacing as much as possible.

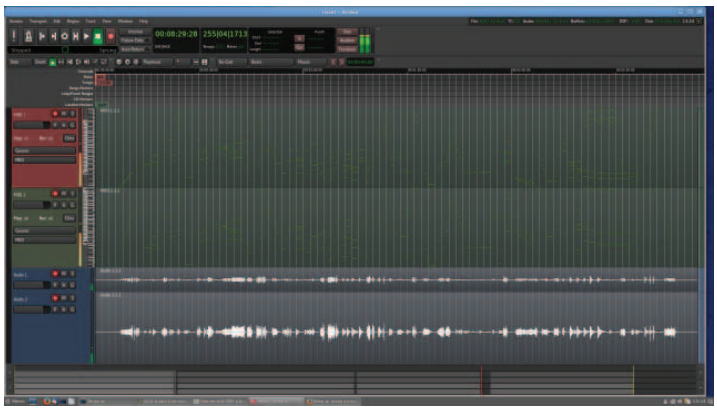

Fig. 7. Ardour session capturing MIDI data generated by Disklavier and Max/MSP on separate tracks, as well as audio capture of a performance of Risset's *Duet for One Pianist*. (© Robert Hamilton)

DISCUSSION

Researchers seeking to build virtual models of existing musical systems are forced to evaluate their work against both the intent and the result of the original composition as well as within the restrictions and context of the new modality. Such a balancing act requires careful attention to detail as well as the ability to reinterpret musical and technological components. The design and development of these virtualizations lead us to question which elements truly represent a given musical work and which can be updated, augmented or replaced without affecting the core nature of a given musical system.

The creation of virtual models for each of the works profiled in this paper were driven by different needs, yet in many ways the subjective measures of success and of failure were the same: Any new virtualization could only be deemed successful if it could be used to reproduce the original work in its entirety at a level of quality on par with the original system. For Cage's *Primitive*, while live performance with the ChucK sampler and 3D-printed mutes has much the same feel and sound of the original while greatly reducing the complexity of preparation and tear-down, sonically the experiences are comparable yet definitely different. For Lucier's *Nothing is Real*, the same fluid physical gesture of raising and lowering the teapot lid allows for a performer to coax subtle harmonics from the filtered melody, yet the intimacy of projecting sound from within a physical teapot is clearly missing. And for Risset's *Duet for One Pianist*, all the necessary semantic musical data has been captured and rendered in traditional scored notation, though the subtle timing fluctuations and discrepancies found in the original Max patches may not survive the translation to another programming language.

References and Notes

1 E. Berdahl, S. Backer and J.O. Smith, "If I Had a Hammer: Design and Theory of an Electromagnetically-Prepared Piano," in *Proceedings of the International Computer Music Association Conference* (2005).

2 D. Overholt, E. Berdahl and R. Hamilton, "Advancements in Actuated Musical Instruments," *Organised Sound* **16**, No. 2, 154–165 (2011).

3 J. Cage, Foreword to R. Bunger, *The Well-Prepared Piano,* 2nd Ed. (San Pedro, CA: Litoral Arts Press, 1981).

4 S. Bilbao and J. ffitch, "Prepared Piano Sound Synthesis," in *Proceedings of the 9th International Conference on Digital Audio Effects* (DAFx-06) (2006).

5 Dan Truman, *bitKlavier*, <www.manyarrowsmusic.com/nostalgicsynchronic/?page_id=242>.

6 M. Zbyszynski, "John Cage Prepared Piano Max/MSP Player," <http://cnmat.berkeley.edu/patch/8065>.

7 J.C. Risset, "Composing in Realtime?" *Contemporary Music Review* **18**, No. 3, 31–39 (1999).

8 J.C. Risset and S. Van Duyne, "Real-Time Performance Interaction with a Computer-Controlled Acoustic Piano," *Computer Music Journal* **20**, No. 1, 62–75 (1996).

9 C. Nanou and R. Hamilton, "For Jean-Claude: [re]Presenting Duet for One Pianist," in *Proceedings of the International Computer Music Association Conference* (2009).

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CHRYSI NANOU *is a pianist specializing in contemporary piano performance practice. She is currently a graduate student at Stanford University's Center for Computer Research in Music and Acoustics.*

ROB HAMILTON *is Assistant Professor of Music and Media in the Department of Arts at Rensselaer Polytechnic Institute in Troy, New York.*