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Digital systems for live multimodal performance in *Death and the Powers*

ABSTRACT

The opera Death and the Powers *by Tod Machover tells the story of a man, Simon Powers, who evades death by transferring his essence into his environment as his corporeal body dies. To realize the effect of the theatrical environment coming alive as the main character, the Opera of the Future research group at the MIT Media Lab developed new technologies and control systems for interactive robotics, sound and visuals in live theatre. A core component of this work is the technique of Disembodied Performance, a method and associated technological infrastructure that translates the live performance of the offstage opera singer into multimodal representations onstage. The author was principally responsible for the control architecture and Disembodied Performance software implementation, as well as the design of the visual language used to represent Simon Powers. These digitally enabled elements were created in order to support the story of the opera and facilitate the process of crafting and rehearsing the staged experience. This article reflects on the dialogue between the design of the technological systems in conjunction with the development of the story and scenography of the opera. Several design principles are presented for the role of new technologies in digital opera and music-driven performance contexts that arose during the course of this work. The discussed methods of cuing, authoring, organizing and collaborating suggest an approach for scoring the multimedia elements of digitally augmented stagecraft.*

KEYWORDS

opera
Disembodied Performance
robots
show control systems
multimedia score
abstract representation

INTRODUCTION

The application of emerging technologies is apropos in the multidisciplinary domain of opera. New technological practices have an opportunity to become a part of the scenographic medium of operatic storytelling, which leads us to ask: what stories can we tell with new technologies that could not have been effectively told before? For what stories are such technologies essential? *Death and the Powers* is one example, but a fuller answer to these questions will emerge over the coming years as new productions leverage the emerging digital resources.

In this article, I will discuss the production of *Death and the Powers*, an opera conceived and written specifically for the incorporation of new technologies, particularly those that re-envision human presence onstage. An overview of the creative motivations and process that led to the technology used in the production will emphasize the principles underlying the systems, which I had an integral role in creating and using to design aspects of the opera. These systems were constructed to facilitate the merging of multimedia elements within the theatrical practice. From facilitating multimedia content creation during the rehearsal process to allowing performers to shape and perform through complex multimodal theatrical settings, the associated methods we have evolved for *Powers* have several implications for the future of technology in music-driven digital performance.

A DIGITAL OPERA: *DEATH AND THE POWERS*

Death and the Powers is a new opera by composer Tod Machover that was developed by the Opera of the Future research group, which he directs, at the MIT Media Lab. Early on in the development of the project, Machover enlisted an interdisciplinary team of collaborators comprised of Broadway and opera director Diane Paulus, former US Poet Laureate Robert Pinsky as librettist, and Hollywood production designer Alex McDowell. The opera was given its world premiere performances in Monte Carlo, Monaco, in 2010 and, at the time of this writing, has been performed in Boston and Chicago, with future international engagements anticipated.

From the inception of the project, Machover sought to reconceptualize the role of technology in the scenography and instrumentation of opera. He proposed the notion of a 'choreography of objects' to be a central focus for *Powers* as a reaction to the prevalence of planar screens and video projection added as a technological layer on top of conventional scenic design. Machover believed that projection, particularly of live video of performers, distorted the sense of scale between the physical performer onstage and the often oversized image of that performer. He observed how such projections are increasingly common at large-scale popular music concerts and even in symphonic performances. The larger-scale image becomes the focus of the audience's attention rather than the actual performer. Coupled with the flat nature of the image, Machover asserts that the overall effect is distancing, rather than engaging the audience with the human performers. Additionally, sound reproduction through loudspeakers produces a similar lack of connection between live performer and perceived performance. What Machover identifies here is the so-called 'mediatization' of performance, thematized perhaps most notably by Philip Auslander in Liveness:

> [t]he spectator sitting in the back rows of a Rolling Stones or Bruce Springsteen concert, or even a Bill Cosby stand-up comedy perfor-

mance, is present at a live performance, but hardly participates in it as such since his/her main experience of the performance is to read it off a video monitor.

(2008: 25)

In arguing that 'the general response of live performance to the oppression and economic superiority of mediatized forms has been to become as much like them as possible', Auslander also notes that media technologies such as video projections have made incursions into '"high cultural" forms' such as symphonic music (Auslander 2008: 7, 26).

This mediatization is not a by-product of the incorporation of technology into live performance, but merely one application of it. Machover's *Powers*, however, does not adhere to this pattern of capitulation to mediatization. Instead, it seeks to reassert the audience's connection to live performers in a physical world, and it relies on technology to do so. The composer envisioned a stage and objects within the stage frame that could physically move, emote and relate to human characters in expressive and compelling ways. The objects would also have an intimate and sonic tie to the music in such a way that they would add to the audience's experience and understanding of the music. Performative utterances are given presence through a body that shares a tangible and ephemeral space and moment with the spectator. The performance is embodied in the staging, as it is with the actors. The technological stage-body is 'neither alive nor dead' (Pinsky 2010: 320); it is not one medium, but many. In her essay, 'The operatic scandal of the singing body: Voice, presence, performativity', Michelle Duncan addresses the role of voice and its essential enabler and expressive cohort, the body, in the creation or acting of operatic presence. Indeed, presence necessitates an embodiment. Duncan posits that while 'the medium that utters could be a technological apparatus used to reproduce, replay, amplify, simulate or even distort the mode of utterance […] [t]he medium at work in opera performance, however, is the carnal body' (2004: 289). *Powers* challenges this assertion: the voice is given a concrete body from which it emerges, even when that body is not a human one.

The story of *Death and the Powers* emerged from these guiding principles. The opera is framed by a prologue and epilogue told by robots in the distant future. The robots are charged with the ritual task of re-enacting the story of Simon Powers, a contemporary wealthy entrepreneur and inventor performed by baritone James Maddalena, who created the robots. The inner narrative of the opera opens with Simon Powers about to enter The System, a computerized infrastructure he has embedded throughout his house in order to preserve his consciousness and agency upon his death. Once in The System, the house – walls of bookshelves, a chandelier, furniture – stirs and comes alive as Simon Powers. While his third wife Evvy, daughter Miranda and adopted son and protégé Nicholas have to learn to accept the patriarchal character in this new form, Simon's apathy towards the material world grows. He ultimately convinces all but Miranda to take leave of their corporeality and join him in The System (Pinsky 2010).

While technology is a driving theme in the narrative as well as in the digital techniques that are required to realize the production onstage, *Powers* is very much a story about humans. The technologies developed for the production are intended to support and reinforce the human element, while the story poses open-ended questions about morality and the role technology plays in our lives. Robert Pinsky did not want to demonize the technology

Figure 1: Nicholas (Hal Cazalet) assists Simon Powers (James Maddalena) in his final preparations to enter The System, Boston performance. Photo by Jonathan Williams.

portrayed in the story as 'the taker of souls', as is sometimes conveyed in science-fiction works. Technology is not the moral subject of the story; it is presented as beautiful, mysterious and, I would argue, neutral. The role of technology and humanity's fate is not determined by the nature of the technology – a mere tool, even when sentient – but rests with the decisions made by the human characters. In Theatre and Performance in Digital Culture: From Simulation to Embeddedness, Matthew Causey writes of the productive tensions that can arise from the interaction of humans with machines in theatre, and observes that the concept of mortality can be 'brought back to the stage through the immortal nature of the machine' (2006: 138). In *Powers*, the technology serves as a counterpoint to mortality through its permanence of form and self-admitted ignorance of death. The robots are not responsible for the moral implications of immortality, for they cannot conceive of the alternative.

Design of technological components

As the technologies we have created directly represent technologies in the diegesis of the story, the systems and techniques occupy the liminal space between onstage and offstage. They are part of the mise-en-scène as well as the infrastructure that supports and enables the production. To some extent, it may even be argued that the technologies created for the production constitute a step towards the advanced fictional technologies they portray.

When Simon Powers enters The System, the stage becomes the main character. Onstage, we see three large periaktoi that resemble bookshelves,

each 4.5 metres tall. In the first scene of the opera, they are still and inert, giving the appearance of a static set. However, once Simon is absorbed within his technological realm, these walls become the primary manifestation of Simon in The System. Each periaktos has a robotic drive system enabling it to move freely about the stage and rotate on its axis. The spine of each book forms an LED video display that spans four of the nine bookshelves, illuminating to represent Simon's abstract form. The bookshelves, an allusion to knowledge and memory, embody the character by moving and illuminating in a manner consistent with the character in his corporeal state. The visual language of the illuminated walls relies on abstract, non-anthropomorphic imagery that changes from moment to moment to reflect the character's emotional state.

Another set piece, the Chandelier, is also first seen in an inert state. However, Simon in The System inhabits it from time to time, at which points it illuminates and is revealed to be a large stringed electronic instrument. In the fourth scene, Simon as the Chandelier descends and encloses Evvy, who proceeds to play the Chandelier. Her plucks and strums of the strings of this harp-like instrument are translated into percussive and pizzicato sounds as well as transformations in the timbre, polyphony and spatialization of Simon's singing voice.

The Prologue and Epilogue of the opera are acted by a chorus of robots (operabots, as we call them). The operabots themselves function as part of the set, pet-like assistants and interfaces throughout the inner scenes. Each of the twelve operabots can illuminate in numerous ways, as well as move freely about the stage using an omnidrive system that enables them to trans-
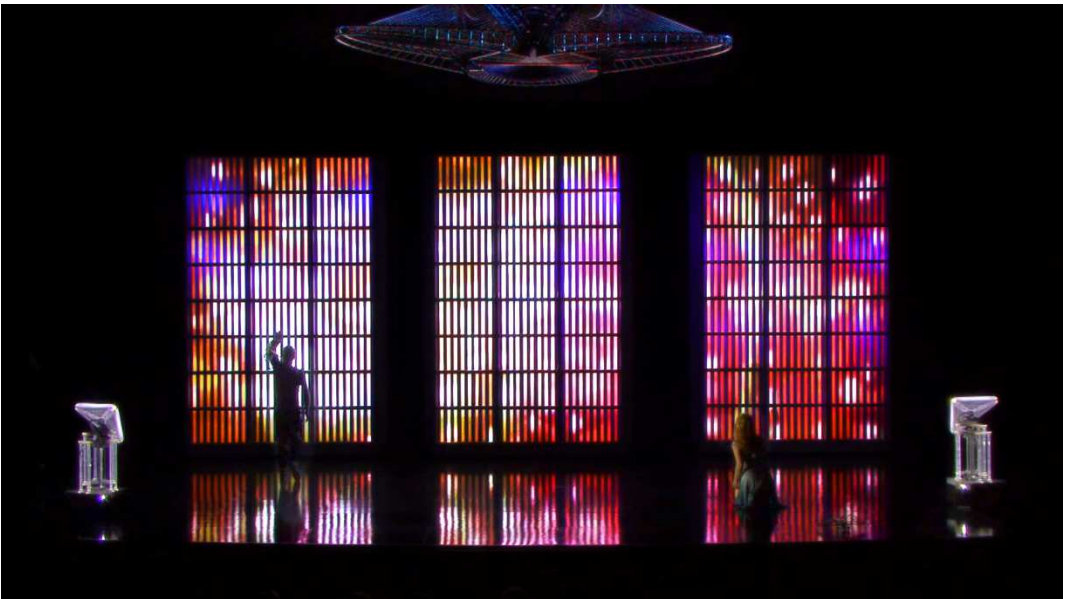

Figure 2: Bookshelf periaktoi and chandelier on the set of Death and the Powers, *Monaco performance. At this moment Simon Powers appears on the walls in a large, bright, fractured orb of light as the character asserts his confidence in his new identity for the first time after entering The System. Photo by Jonathan Williams.*
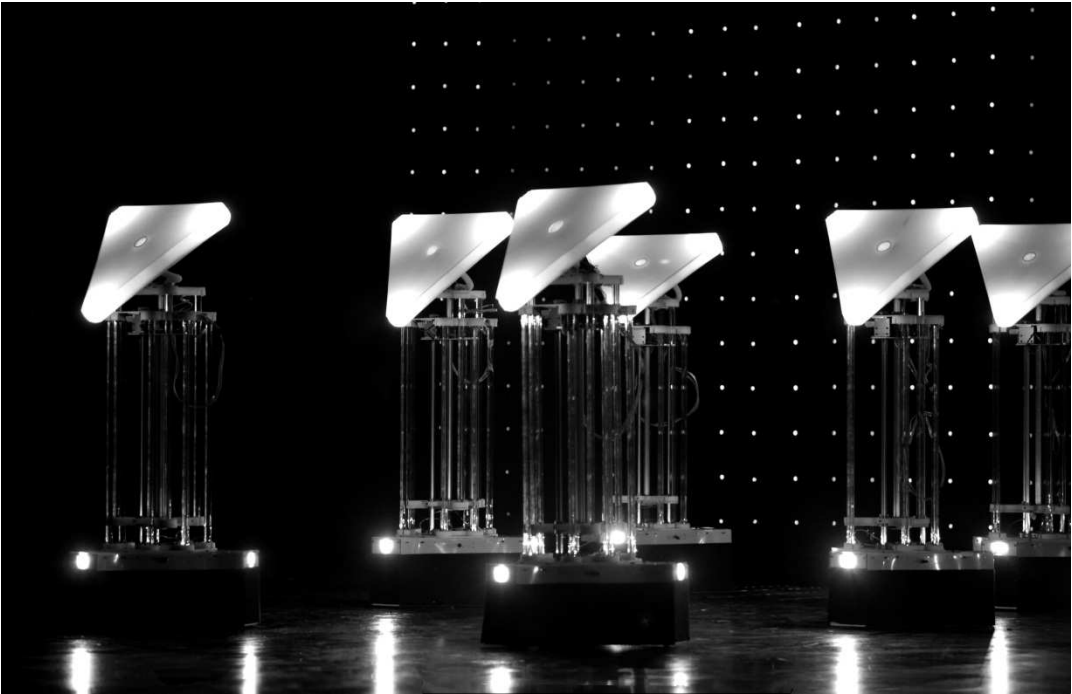
Figure 3: Operabots assembled for their ritual re-enactment in the prologue, Boston performance. Photo by Paula Aguilera.

late and rotate independently. Additionally, each can tilt its head and elevate from about one metre to over two metres in height.

Machover's compositions are well known for blending acoustic and electronic elements, and *Powers* is no exception. The orchestration calls for an acoustic pit ensemble of fifteen musicians along with layers of electronic sound and synthesized instruments. Consequently, the entire opera, including singers, is lightly amplified for balance with the electronics. Simon's voice, once inside the system, is also subject to manipulations that may distribute it in space and alter the timbral quality in response to performance data. At times, Simon's transformed voice may sound very delicate and localized. At others, it fractures into a multiplicity of voices that surround the audience in a display of the character's omnipotence or fills the space with an imposing, resonant, booming quality.

The production includes two formats of spatialized audio reproduction, which are used for musical effect as well as in the sound design and reinforcement. An ambisonic surround sound system consisting of numerous speakers placed throughout the auditorium allows for electronic sounds, the sound of the Chandelier and the voice of the omnipotent Simon to envelop the audience. A seven-metre long speaker array lies at the downstage edge of the stage and is used for a spatialization technique known as wave field synthesis (WFS). WFS creates the impression of a reproduced sound originating at a specific point in space. In *Powers*, this is used to associate sound reinforcement with objects and people onstage. This way, the onstage singers' reinforced voices still appear to originate from their respective bodies, providing a more natural vocal experience to the audience. It is also used for

voicing the operabots and other effects, such as when Simon Powers momentarily inhabits an object onstage.

Disembodied Performance

All of these animatronic, visual and sonic elements are used to represent Simon Powers in The System. As an omnipotent, omnipresent being, they all embody a principal character for the majority of the opera and, thus, must give a compelling and engaging performance. From the outset, The System was described as having characteristics identifiable as belonging to Simon Powers: traits and mannerisms that we would see in the human form of his character during the first scene. The motion of the set and visuals, as well as his voice and manner of speech, would be recognizable and consistent. As the manifestations of a single entity, all of the disparate set elements and modes of representation act in a coordinated fashion and need to feel convincingly alive and present in the moment.

In order to accomplish this, I developed a technique called Disembodied Performance. Rather than programming automation systems and creating pre-rendered motion graphics or video to represent Simon in The System, Disembodied Performance allows the multimedia representation to be shaped by a live performance. When offstage, the singer portraying Simon Powers is located in an isolation booth in the orchestra pit, with a view of the conductor. Inside, the singer is connected to a variety of wireless sensors that measure his gesture and breathing. Data from these sensors and the singer's voice are streamed to custom software for analysis and then used to drive and influence motion, illumination and visuals throughout the theatrical environment onstage that accompanies his amplified singing voice.

In his ethnographic reports of opera production, Paul Atkinson highlights the role of gesture in operatic performance (2006). Indeed, Atkinson notes the conflict between the singing body and the acting body. However, this conflict is resolved in an ideal case through gesture that can effectively communicate the experience of a character to an audience. He suggests that operatic gesture extends to the fusion of performance and music and space, with all gesture being embodied. Without the focus of an onstage body, as in the case of *Powers*, how then can the gestural performance remain communicative? The identification of sentic forms by Manfred Clynes suggests that the affective content of interest may be encoded and perceived across modalities (1978). The sentic forms were originally revealed as contours in human motion, specifically the pressing of a finger, in response to specific emotional prompts. Clynes went on to illustrate that the shape of these forms mirror contours in examples of visual arts and music intended to evoke similar emotional reactions. Mapping these expressive gestures from one domain into another effectively translates the perceived affective intent across modalities. The contours and qualities of movement are the communicative media and do not rely on a representation of the human body with a face or limbs in order to be understood and felt by an audience. The performative gestures are re-embodied in the non-anthropomorphic forms of the physical set and visuals.

In short, the objective of Disembodied Performance is to abstract an expressive performance away from the human body and into non-anthropomorphic representations throughout the environment. The actor still sings and performs offstage in the manner he normally would as if he were onstage. We sense this performance and map it to the new representa-

tions in a manner that preserves the expressive intent of the bodily gesture in the abstracted forms. In much the same way as the formal approach to mapping presence outlined by Chris Dodge, Disembodied Performance derives what Dodge calls salient vectors from live data and translates that known space of input into a known space of output (1997).

Two factors influence how the sensed performance data affects the extended onstage representation of the character. The first is that Disembodied Performance seeks to interpret the emotional journey of the character, rather than his literal movements. In selecting and analysing sensing modalities, the emphasis is on assessing the quality of movement, rather than classifying the gesture. In this way, the Disembodied Performance System is an expressive extension of the actor's performance and not a recreation of the body movements. As part of his technique for movement analysis, Rudolph Laban described a framework for articulating the dynamic qualities of gesture called effort comprised of a parametric space of four dimensions: weight, time, flow and space (1988: 169). The Disembodied Performance System implements an analysis of the weight, time and flow parameters as a means for assessing gestural quality. Experimenting with a variety of sensors on James Maddalena, the baritone portraying Simon Powers, and recording and analysing the data helped to select the types of sensors that best fit his particular gestural vocabulary and acting style (Torpey 2009: 119). Voice analysis and gestural sensors were deemed sufficient for capturing the expressive quality of Maddalena's performance. As expected, physiological sensors were not particularly useful, as they reflect the experience of the performer and not that of the character. The one exception to this is breath. Data from the singer's breathing are particularly effective for identifying musical phrasing and for imbuing output representations with an immediately recognizable sense of organic life, even when presented through mechanical and visual means.

The second consideration in Disembodied Performance is that the mappings from unprocessed sensor data to output representations are not one-to-one. Placing a human performer in control of a technological representation is not an uncommon practice in contemporary digital performance. The relationship between the performer and the results of their actions can be varied, but often subject to what Teresa Marrin Nakra refers to as the Disembodiment Problem (2000: 143). She asserts that there is an inherent disconnect between physical action and reaction in mediated, non-physical systems that fails to demonstrate causality to an audience. There is a necessary trade-off between the complexity of the mapping from stimulus to reaction and the expressive power of the mapping. Overly complex mappings obfuscate the causality while trivial mappings are limited in what they can convey. The abstraction of representation relied upon by Disembodied Performance would seem to suggest the potential for a similar lack of apparent causality. However, short time-scale adaptations and a careful attention to the semantics of mapping parameters to preserve intention help to maintain a sense of presence in the moment by allowing the output representations to respond with a causal immediacy to the performance. Furthermore, the actor performing through the system is offstage and not visible to the audience. Thus, the audience need not decipher the connection between the actor's movement and the changes in output. The causal link is then inferred from how the representations respond to the music, story movement and the other characters onstage with appropriate immediacy. In this way, the audience is invited to suspend its disbelief and accept the notion that the theatrical set has itself become the character.

Designing the visual language of Simon in The System that would be presented through the LED displays on the bookshelf walls was an important step in demonstrating how the Disembodied Performance would come to life onstage. The visuals representing Simon in The System needed to appear to be able to emote in response to performance data, interact with the human characters onstage and still be a plausible part of the overall scenography. In the design of the visuals, I wanted to maintain the sense of physicality that guided the initial production design proposed by Machover and McDowell and to reference the concept of the book as a unit of memory and sensation for the post-organic Simon. As Simon enters The System, we first see the displays illuminate as single full-height panels of monochrome light. Once Simon begins to adapt to his transformation, the granularity of the visual representation increases: next at the shelf level and then at a level at which each book is treated as a single pixel. Eventually, Simon turns his back completely on the material world and the physical structure of the books fade into full-resolution imagery.

The visual language spans a range of forms from books and diffuse mists to focused orbs, for example. It can assume a range of expressive stances varying from an active, slumbering representation that recedes at times when Simon is distant and the focus is on other onstage action, to a wide and full-stage presence on the room-sized display when Simon is intent on demonstrating his omnipotence. At other times, it is tightly focused, as if to directly address other characters, which provides some sort of eye contact between the abstract representation of Simon and the human characters. The look of each cue is constructed by blending procedural elements – noise, shapes, blurs and moving particles – from a library of dynamic visual primitives. Each element responds appropriately to performance data, thus the entire composition behaves accordingly.

A schema was developed to guide the creation of the imagery displayed on the walls. The first of three conceptual streams represents a mechanized version of biological life (essentially the autonomic responses of The System). The other two streams represent memory and desire, respectively. Each stream is defined by colour, form and type of imagery. The three streams blend in proportional correspondence with Simon's state at a particular moment in the scene through cuing and as influenced by the live performance data.

I strongly resisted the use of representational imagery on the displays in order to focus on abstraction and affective communication. Given Simon's insistence on the irrelevance of corporeal materiality, representational images of the body and the physical world are generally inappropriate. However, photographic video or iconic images are used sparingly at times to reflect Simon's memory of events, as a device for communicating emphatically (and often ironically) with the human characters or as a thread of nostalgia that occasionally surfaces.

DESIGN PRINCIPLES FOR DIGITAL PERFORMANCE SYSTEMS

The technological infrastructure for *Death and the Powers* consists of several interconnected control systems. In the following sections of this article, I will examine four of the control systems created for *Powers* and highlight the guiding principles that were incorporated into these systems that enable the production to have the dynamic, ephemeral quality that the story calls for.

This system architecture is important to create dynamic multimodal experiences that are performance-driven in real-time. This ability is essential in order to be able to adapt to the fluidity of time in a live theatrical performance, where the alternative of timed playback of events or sequences would unnecessarily restrict performance and give rise to asynchronicities that would undermine the sense of temporal immediacy and unified sense of presence across modalities. In much the way that an orchestra is desirable for live musical accompaniment over playback of recorded audio, the live performance data mapped to the theatrical environment can respond and dynamically modulate from moment to moment in time with other performers and aspects of the performance. Thus, as with any actor onstage, the performance of the offstage actor through the system can vary from show to show.

Common authoring and performance environment

I sought to create systems that could operate fluidly within a typical rehearsal environment by being able to rapidly adjust the look or behaviour of the technological components in the scene in response to changes being made onstage. From the start of the design process, we knew that we would want the Disembodied Performance System and robots to be able to take direction, as if they were playing a character. The real-time infrastructure and software control systems are essential for accomplishing this. There is no need for the time-consuming process of offline editing and re-rendering visual or audio content or rewriting computer code. In a rehearsal setting, actors, singers, dancers and musicians have the ability to take direction. The director can watch a scene, issue a note or suggestion and immediately rerun the scene, and the performer will react accordingly. This leads to an important iterative process.

The key to creating such systems is not to regard design, rehearsal and performance as independent, discrete states in a linear process. Rather, these three stages exist in a continuum of feedback and variability. Ultimately, in performance, the ideal is decided, but human variability, chance and feedback from an audience all influence the outcome onstage. In that light, it is reasonable that the tools for design, rehearsal and performance are one and the same. In *Death and the Powers*, the robotics, performance and visuals each use the same software application for authoring as they do for performance. Conventional practices, particularly for the creation of visual and motion graphics content cannot respond to real-time performance data, meaning that the imagery does not adapt to the ephemeral nuances of a particular performance. Furthermore, larger-scale changes using conventional tools would require a designer to use editing software to make modifications or to create new content, which then must be rendered or otherwise exported to the playback infrastructure. Contrastingly, the mapping and visual rendering software applications developed for *Powers* do not distinguish between an editing and a playback mode. Thus, changes may be made within a single software application in real-time, while receiving performance data, and the results can be viewed immediately onstage, as the content is being modified. Combined with a user interface intended to streamline manipulation of parameters of interest with intuitive semantic intents, the systems effectively take direction. The visuals and behaviours resulting from performance data can adapt to directorial input immediately and scenes could be rerun quickly with the changes.

A visualization of the output in these systems ensures their utility across the continuum from authoring to performance. In the authoring stages, being able to visualize the imagery on the walls or the movement of the robotics means that cues may be programmed offline, without needing to be in the theatre with the LED displays and robots connected to their respective computers. In performance situations, this visualization provides a method for verifying that the systems are behaving correctly. The robotics control system features a plan view and 3D model of the robots and walls onstage that continuously update with the playback of cues in the system. The 3D view enabled much of the robot choreography to be assembled offline and served to illustrate the current blocking during production meetings. During the performance, the plan view overlaid on an IR camera image from above the stage can be used to monitor and correct discrepancies between the actual position of a robot and where the control system thinks the robot is located. The software interface for the visual rendering system provides a simulation of what the output imagery will look like onstage. Using this system, I was able to create initial sketches of the looks for each cue prior to being in the theatre. Once in rehearsal and with James Maddalena performing as Simon Powers, I was able to refine each cue during the rehearsal performance to emphasize particular characteristics and the emotional timbre of the scene. For example, if Simon in The System needed to be more passive or more aggressive, director Diane Paulus could instruct Maddalena to tailor his performance accordingly while I could adjust the rendering parameters, if needed, to accommodate the change in performance. At one point, when Simon's visual representation may need to startle the human characters onstage (and the audience), a significant change to the visual look could be added within moments in the form of a new cue.

Cues, modes and triggers

We relied on the music to drive the states of events across systems. This was one technique used to synchronize events across various systems and to create an intimate, seamless connection between visual, physical and sonic gestures onstage. A second keyboard part was written as part of the orchestral score that contained specific notes for all music-driven cues for audio playback, transformations, changes in visual states or performance data mappings and some robot behaviours. This allowed the designers to work closely with the composer to orchestrate the entire scenography as a complement to the music. A keyboardist in the orchestra pit performed this part on a MIDI keyboard. The notes played do not directly produce sound, but the note event messages were routed throughout the various show systems to trigger cues. The various systems associated specific note numbers with cues relevant to that particular system in order to execute them. Thus, robot movements or visual elements can react in perfect synchrony with musical motifs that they reinforced while the music is being performed live. As the keyboardist plays a high-pitched cascading figure, the analogue in the visual language is also produced onstage. When the music follows a crescendo in Simon's intensity that culminates in an explosive display of light, the complex sequence of visual cues and playback of electronic sound happen precisely with the orchestra's build and crash. All the while, these visual changes are modulated by Simon's booming voice and given life through Maddalena's performance.

In our usage, cues may be of two types: triggers and modes. A trigger initiates a change in output, such as starting the playback of a time-based sequence. A mode puts a system into a configuration in which it is receptive to certain types of inputs and determines how the system responds to those inputs, such as a particular mapping of data or arming the ability to generate a subset of triggers. Cues in the audio and robotics systems more commonly serve as triggers, rather than modes, given the time-based nature of audio playback or the motion of a robot across the stage. A trigger can initiate a choreography of the chorus of operabots to undulate their heads in sequence for a specified time or until the next trigger, a technique used in the opera's prologue and epilogue to signify the robots' community, before and after they assume individual roles. For audio playback, triggers initiate the playback of a sound sample or ambisonic 'texture' that is encoded to move throughout the spatialized audio field. Modes expose certain parameters for control, such as changing mappings from performance input to visual representations, allowing spatialized sound sources, once playing, to be dynamically positioned or arming particular audio effects processing. All cues within the visual system are modes so that the imagery onstage can always be animated by Maddalena's offstage performance. The mode sets certain parameters for the look, but the quality of the movement is provided by the analysis of the gesture and voice to which the mode is receptive.

Interconnected systems

Each control system can easily exchange information with the other systems, allowing events and continuous gestures across modalities to be intimately
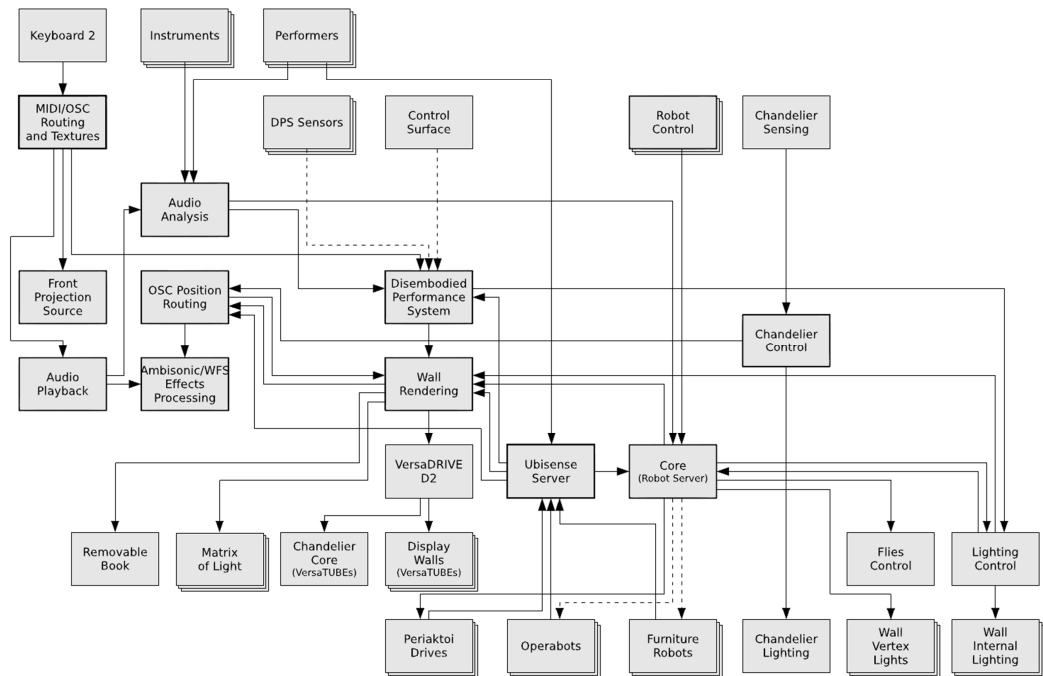

Figure 4: Flow diagram of Death and the Powers control systems depicting how information is shared among components.

coordinated. The mapping system analyses data from the sensors and voice analysis of the live performance by the singer portraying Simon Powers when he is offstage. These data can then be sent to the robot, audio or visual control systems in order to allow the human performance characteristically to influence each medium. Within the mapping system, cues allow the analysed data to be transformed as necessary to control the appropriate parameters of the other systems.

An absolute positioning system manufactured by Ubisense is deployed over the stage area providing real-time information about the position of robots and actors onstage. Because all of the control systems can communicate, they can each leverage this position data for their own needs. For example, the robot control system uses the position data of robots and walls as one form of closed-loop control, notifying robots of their actual position allowing the on-board robot systems to correct for discrepancies. Together with knowledge of the position of the human singers onstage, this allows robots to avoid collisions with singers and other robots. The position of the singers is used by the audio systems to localize the amplified audio of each singer to their person using the WFS spatialization described above. The visual rendering system uses position data of operabots and singers to localize visuals on the surface of the current position of the walls, in order to give the abstract representation of Simon Powers in The System the ability to directly address or react to the presence of other characters onstage. Simon, through his non-anthropomorphic visual representation, can reach out towards his wife Evvy as she passes by a wall. An operabot can follow Nicholas as he jaunts about the stage.

CONCLUSIONS AND IMPLICATIONS FOR DIGITAL OPERA

Death and the Powers demonstrates that the principles explained in this article can streamline the integration of new technologies, modes of performance representation and dynamic scenography within the framework of a digital opera. So as not to limit the palette of design possibilities or hinder creative expression in the development of a theatrical work, the systems must be responsive in real time to maintain a workflow that may be as close to improvisatory as possible. Systems that perform both as authoring tools and performance environments provide the ability to quickly alter and shape a multimedia performance through experimentation during rehearsal, allow an operator to make subtle adjustments during live performance and allow for live input during performance.

It should be noted that the incorporation of new technologies in theatrical performance furthers the need for communication across departments. As these technologies promote more conceptual interconnection between aspects of the production, aesthetically and through exchange of data, the greater the likelihood that a change in design by one department may have an (often-unanticipated) impact on another. Just as the colour palettes of costume, set and lighting must coordinate in service to the directorial interpretation of the story, so too must projection or visual components now integrate with these more traditional disciplines. For example, when modifying a scored part for triggering cues, as was used in *Death and the Powers*, the reuse, repositioning or deletion of a note for one system may affect another system relying on that note to initiate a cue.

This model also offers opportunities for audience participation. Performances using these techniques can readily incorporate input from a variety

of sources, so it follows that the audience may be one of these sources. This could be employed in order to allow the spectators to take an active role in shaping the existing narrative, for the audience actually to enter into the world of the narrative and have a role and agency in that capacity and even to allow the audience – either individually or collectively, remotely distributed or co-located – to create their own stories in the form of a digital opera to experience and share.

The systems presented above have satisfied the needs of *Death and the Powers* and will undergo further development for future performance projects at a variety of scales. Although they occupy much of the continuum between authoring or composing and final performance, future development will bridge the gap between the multimedia composition phase and realization. The interconnected, real-time protocols of the control systems can be transformed into something like a multimedia score, as well as serving as the fabric that allows the disparate systems to come together as a unified whole. The concept of a multimedia score was employed as a reference for collaboration and coordination across departments during the production of *Death and the Powers*. However, this visual tool did not interface directly with the show systems at the time. In future work, such an environment in which the elements, references, designs and parameters can all be scored in relation to the music or text can then become a compositional tool, a point of collaborative reference for various aspects of a show and the basis for the cues and choreographies used to run a performance.

REFERENCES

Atkinson, P. (2006), 'Opera and the embodiment of performance', in D. Waskul and P. Vannini (eds), *Body/Embodiment: Symbolic Interaction and the Sociology of the Body*, Farnham: Ashgate, pp. 95–107.

Auslander, P. (2008), *Liveness. Performance in a Mediatized Culture*, 2nd ed., London and New York: Routledge.

Causey, M. (2006), *Theatre and Performance in Digital Culture: From Simulation to Embeddedness*, Abingdon and New York: Routledge.

Clynes, M. (1978), *Sentics: The Touch of Emotions*, New York: Anchor Press/Doubleday.

Dodge, C. (1997), 'The abstraction, transmission, and reconstruction of presence: A proposed model for computer based interactive art', Master's thesis, Cambridge: Massachusetts Institute of Technology.

Duncan, M. (2004), 'The operatic scandal of the singing body: Voice, presence, performativity', *Cambridge Opera Journal*, 16:3, pp. 283–306.

Laban, R. ([1950] 1988), *Mastery of Movement*, London: Northcote House.

Marrin Nakra, T. A. (2000), 'Inside the conductor's jacket: Analysis, interpretation and musical synthesis of expressive gesture', Ph.D. thesis, Cambridge: Massachusetts Institute of Technology.

Pinsky, R. (2010), 'Death and the powers: A robot pageant', *Poetry*, July/August, pp. 285–327.

Torpey, P. (2009), 'Disembodied performance: Abstraction of representation in live theater', Master's thesis, Cambridge: Massachusetts Institute of Technology.

SUGGESTED CITATION

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