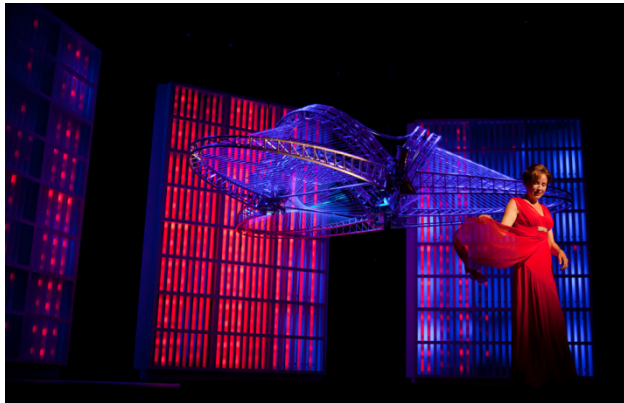


DEATH AND THE POWERS

New Technologies for Theatrical Performance

Death and the Powers, a new opera by composer Tod Machover, brings numerous artistic and technological innovations to the stage. The story is about Simon Powers, a wealthy inventor and entrepreneur, who uploads his consciousness and essence into The System, an elaborate mechanism he's developed throughout his home to preserve his agency in the world after he dies. Consequently, for much of the opera, the stage and the environment itself comes alive as the main character. Such a creative need brings with it a host of technical challenges and opportunities.

In this paper, we note a few of the core technologies and applications developed by the Opera of the Future research group at the MIT Media Lab for the production. Our interdisciplinary team sought to leverage existing technologies and practices from stagecraft and beyond where possible, and invent new ones as needed.



A Unified Control Architecture

All of the elements of the theatrical set—from the movement or robotic elements, spatialized sound,

lighting, and visuals—must act in synchrony to provide a consistent impression of a single expressive character. Gestures across media can respond in concert.

All show control systems are networked and can interact by sharing data and interfacing with traditional theatrical controls. Data is exchanged over a common IP-based network infrastructure using the OSC protocol so that any system can respond to input from any other.

Robots on Stage

Death and the Powers features two principal types of robots. The robots have multifaceted roles as setting, members of a Greek chorus for the action, and as a manifestation of Simon Powers. The main set pieces are three fifteen-foot tall wall structures, or periaktoi. The walls represent book shelves and each book spine forms and LED display surface. The structures can rotate and move freely about the stage. Nine smaller wireless Operabots were designed and fabricated at the Media Lab. These can extend up to seven feet in height, have articulated heads, and a holonomic omnidrive system that allows them to translate and rotate independently across the stage. Each is equipped with 11 channels of LED lighting. The computational core of each of these robots is the small, efficient, and inexpensive One Laptop per Child XO computer.

We developed a new type of automation and control system specifically for theatrical robotics. The system combines timeline playback and parameter curves, familiar from typical animation software programs, with cuing, autonomous operation, procedural behaviors, and

live control from a multitude of sources. This system has proven effective in choreographing the fast and complex Operabot movements and lighting, as well as the graceful repositioning of the three wall structures. Operators can assume control over any robot at any time, overriding any of its programmed behaviors. A 3D simulation module aids in live control monitoring and offline programming.

An ultra-wideband RFID absolute positioning system encompassing the stage communicates position information to each of the robots. This allows them to autonomously navigate along a predetermined trajectory and avoid each other and actors onstage, ensuring safe and robust operation. The nine Operabots may also be puppeteered as needed by operators situated above the stage, using commercially available video game controllers.

Disembodied Performance

The principal representation of Simon Powers in The System is the visual content displayed across the three walls of the set. The visual language for his expression evolves as Powers delves deeper into The System. The walls allow the character to emote and interact with others onstage.

To accomplish this, the actor portraying Simon Powers continues to sing and gesticulate offstage in the same



manner as if he were onstage. We've designed wireless wearable physiological and gestural sensors, as well as voice analysis algorithms to interpret the quality and emotive essence of the actor's performance, abstracted away from the human body.

These data are then mapped using custom software into a novel visual rendering system we've created. The rendering software is like a cue-based video compositing and animation environment. Cues put the system into specifically designed modes that allow the live data from the performer to procedurally shape the generation of graphics and image. An operator can then mix the visual influences using an Apple iPad during the performance. The result is a non-anthropomorphic manifestation of the actor's performance throughout the set.

Surround Audio

The production relies on a sonic transformation as well as visual transformations to locate Simon Powers in The System. The audio infrastructure to support him is quite extensive, utilizing two formats of surround sound, real-time performance control and several custom effects engines; all with the goal of achieving a smooth continuum ranging from completely acoustic to completely amplified textures. This is one of the unique

characteristics of *Powers*; while some sections are whisper quiet, some are positively massive. The large dynamic range in the audio system allows even the most basic characteristic of the sound to follow Simon's emotions very closely.

The heart of the *Powers* audio system is a DSP engine based on CoreAudio AudioUnits running inside Digital Performer 7. The majority of the system's 350 audio inputs and 250 audio outputs run through this system, which contains custom plug-ins to implement Ambisonics Surround Sound: an abstracted, permitter-based spatialization algorithm; and Wavefront Synthesis (WFS), a system for constructing a wave field to allow very precise localization inside the boundaries of the ambisonic system. Because surround sound is an essential part of the performance, it is critical for everyone in the audience to experience it. Each of the VIP boxes and balconies contains its own "mini" surround sound system; a superb application of the inherent scaling capability of ambisonics.

All told, the system contains 143 separate speaker outputs, each of which have their own DSP. These are managed intelligently by the DSP engine and controlled live using Apple iPads running TouchOSC. Finally each of the Duran Audio Axys loudspeakers in the main Left-Center-Right audio system runs additional DSP internally to manage crossovers and system-wide equalization.

A Vision of the Future Stage

We strive toward employing technology onstage that is both essential and seamless, incorporating new techniques into the theatrical tradition to tell stories that couldn't be told otherwise.

While many of the technologies developed for *Death and the Powers* were motivated by the particular needs of this story, we in the Opera of the Future group are

passionate about continuing to explore these innovations in order to redefine and extend the power of opera, theater, and performance experiences.



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For more information on *Death and the Powers*, visit:
<http://powers.media.mit.edu/>

