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Robot Opera: Bridging the Anthropocentric and the Mechanized Eccentric

Abstract: The recent emergence of robot opera, in which robots and robotic entities have served polyvalent and at times ontologically ambiguous roles, has challenged the distinction made by Bauhaus artist László Moholy-Nagy between anthropocentric and mechanized eccentric theater, as is outlined in his 1924 essay "Theater, Circus, Variety." When incorporated into the context of music theater, is the robot dimension intended to replace human activities and modes of expression; to augment, disembody or dislocate them; or rather to absorb them, such that the robot becomes an ersatz human presence in and of itself? If the latter, does the robot adequately emulate human attributes of musical expression, or does it establish its own artificial expressive mode and set of performance techniques? With Moholy-Nagy's criteria for a so-called Theater of Totality and these leading questions in the background, salient robot opera examples of the past several years will be discussed. Repertoire examples include Tod Machover's pioneering *Death and the Powers* (2010), the Komische Oper Berlin production *My Square Lady* (2015), Keiichiro Shibuya's *Scary Beauty* (2018), and works emerging from the University of Sussex Centre for Research in Opera and Music Theatre Robot Opera Mini Symposium, held in 2017.

The history of musical automata dates back centuries (Collins 2007; Roads 1996). With significantly increased availability of data, processing speeds, storage capacities, and hardware improvements in recent years, musical projects across a diverse array of genres in which artificial intelligence (AI) and robotics figure prominently have received considerable attention from both research communities and mass media. In the research domain, a number of automatic accompaniment systems have been introduced, such as those developed by Roger Dannenberg and colleagues (Bloch and Dannenberg 1985) and more recently, the *Antescofo* score-following system, with versions for Max and Pure Data (Cont 2008). The Qosmo AI DJ Project represents the deployment of automatic beat tracking in an electronica context, in which an AI DJ continually assimilates to a human agent (online presentation at http://qosmo.jp/projects/2018/08/21/ai-dj-human-dj-b2b). The Qosmo system's main components are (1) a convolutional neural network for music classification and recommendation and (2) a reinforcement-learning algorithm for beat matching. Among notable artificial performing agents that activate conventional instruments are the Expressive Machine Musical Instruments collective (Kemper 2014) and the anthropomorphic Japanese robot band Z-Machines, which collabo-

rated with Squarepusher on the 2014 *Music for Robots* album (see Lanre Bakare's interview "Meet Z-Machines" in *The Guardian* 4 April 2014). The Vocaloid virtual singer Hatsune Miku, created and licensed by Crypton Future Media (https://ec.crypton.co.jp/pages/prod/vocaloid/cv01_us), has gained a substantial following, and the Vocaloid software has been featured in a variety of commercial and artistic events and products.

Since 2011, there has been a discernible trend in which creators of multimedia works that incorporate intelligent agents have labeled their pieces "robot operas." At first blush, this may seem something of a contradiction: How could opera, a genre that for many represents the epitome of human expressive communication, be co-opted by nonhuman entities? Although several of these examples have been dismissed as anodyne or mechanistic in nature, or have been perceived as viable substitutes for commodified, functional music that, when composed by humans, sounds anonymous and mass-produced, the encroachment of robots onto the domain of opera may be construed as a transgression, as an overextension of automation. Upon closer examination of works falling under this rubric, however, it becomes evident that robot opera lacks a strict definition. This is in part a product of the recent embracing of the term "opera" by contemporary composers and by sound and media artists. As will be addressed in the section "University of Sussex Robot Opera Mini Symposium," whereas previous generations sought to avoid classifying their output

as opera, composers at present tend to identify artworks spanning a broad range of media, durations, and performance contexts as operas. Such a phenomenon not only challenges conventional notions of the criteria for opera, but also places in high relief the manifold and at times ambiguous roles that a robot presence may play, the physical representations that it may take, and the modes by which artificial and human agents may interact within the framework of the opera. Such a perplexing situation prompts one to pose the question: what are we talking about, when we talk about robot opera?

The objective of this article is to investigate present-day questions pertaining to the ontological status of the robot, the nature of robot performance and expression, and robot–human interaction—whether the robot has been explicitly programmed or is trained on machine learning algorithms—all in the context of opera. To approach these topics, robot opera will be examined through the lens of Theater of Totality, a notion formulated by Bauhaus artist László Moholy-Nagy (1895–1946). Moholy-Nagy was among the first artists to propose a form of multimedia performance in which the human would not occupy a central role, but would be either entirely absent or placed on an equal plane with visual, auditory, spatial, and kinetic technological elements. Manifestations of Moholy-Nagy's concept, which he termed the *mechanische Exzentrik* (mechanized eccentric), have been evident in works of music theater and experimental media from the mid-20th century through to the early 21st century, including robot operas, as will discussed later in this article. At the same time, the numerous categories that a robot can occupy—as humanoid or machine; servant to or augmentation of human activity; and as embodied, environmentally situated agents or disembodied intelligence—contribute a layer of uncertainty as to the boundary between humancentricity and "technocentricity." It is precisely in this gray zone in which there lie opportunities for innovative exploration into new models of human–robot and robot–environment interaction, new performance practices, and, on a more philosophical level, what it means to be human.

Although both aesthetic and technical aspects of the operas will be addressed within the scope of the this study, the former will in general receive greater attention, as the relevant technical specifications for each work have been well documented in the cited publications and elsewhere, although at the time of writing the literature has not yet given a thoroughgoing consideration to the aesthetic and conceptual parallels and contrasts among robot operas. This study represents a comprehensive survey of works to date that have been referred to as robot operas by their creators, and in which a robot entity is actively involved in the production (i.e., not merely operas *about* robots, portrayed by humans).

Moholy-Nagy and the Theater of Totality

"There will arise an enhanced control over all formative media, unified in a harmonious effect and built into an organism of perfect equilibrium," claimed Moholy-Nagy (1925b) in his essay "Theater, Circus, Variety." As an early 20th century extension of Wagner's concept of the *Gesamtkunstwerk*, Moholy-Nagy suggests not only incorporating new technological means into staged works—an extension of Wagner's use of lighting effects and stage machinery at Bayreuth—but also, in contrast to Wagner, making a departure from human-centered drama, which all elements of theater serve to reinforce, to one in which the essential formal components of theater—space, composition, sound, light, and motion—are synthesized into an integrated, abstract whole.

Theater of Totality: Definition and Salient Features

To gain a clear understanding of the motivations for Moholy-Nagy's aesthetic objectives, it is worth considering the artistic milieu and zeitgeist in which he was operating in general, and the tenets of the Bauhaus school specifically. The early years of the 20th century witnessed rapid changes with respect to mechanical technologies. From the 1924 perspective, there was an abundance of transport,

communication, media (e.g., cinema), warfare, production, and domestic apparatus that had between introduced within a span of 20 to 30 years. Such an unprecedented flourishing in machine inventions, coupled with recent pivotal achievements and discoveries in mathematics, the sciences, and engineering, led to a firm and widely held sense of optimism regarding the progress of human civilization and the potential to gain a richer understanding of the complexities of the universe—a manifestation of Enlightenment aspirations and values, which would again resurface during the first decade of the current century. Artists and composers at this time would be profoundly influenced by the era's new models, theories, and machines, as well as the consequent and abrupt shifts in the density and speed of activity and the heterogeneity of the soundscape of their physical environments. Certain composers would embrace these shifts and write works that would avail themselves of or evoke emergent technologies. Such works include *Ballet mécanique* (1924), a Dadaist film directed by Fernand Léger, with a score by American composer George Antheil. The "ballet" does not entail the choreography of humans, but rather of player pianos, airplane propellers, and electric bells, integrated into a percussion ensemble. The music itself is dominated by mechanical repetitions. By the same token, *Ionisation* (1931) by Edgard Varése is scored for 13 percussionists, whose instrumentarium includes two sirens. The repeated rhythmic motives, layers of unrelated materials, sudden shifts between contrasting sections, and periodic outbursts could be construed as a vivid reflection of the New York cityscape that surrounded the composer. The dynamism of transport machinery is represented in pieces such as Arthur Honegger's symphonic poem *Pacific 231* (1923) and the Intonarumori and paintings of Italian Futurist Luigi Russolo (1885–1947).

At the same time, the negative (and at times devastating) impacts of technological progress on humanity brought about by the industrial revolution (as described, for instance, by Upton Sinclair in his 1906 novel *The Jungle*) and the First World War would render certain artists as either entirely resistant to mechanical innovations, given their potential to oppress and dehumanize members of society, or to devise means of applying these innovations in ways that would potentially improve living and working conditions. With increasing industrialization, artists associated with the Bauhaus movement observed a growing separation between art, on the one hand, and the facelessness of industrial manufacturing, on the other, as well as the diminishing status of handicraft. As such, there emerged an interdisciplinary movement rooted in the Art Nouveau, Arts and Crafts, Jugendstil, and Secession schools of the previous century that integrated expertise from visual art and sculpture, architecture, typography, photography and film, and functional design. In so doing, the traditional hierarchy among the arts, on the one hand, and between art and techne, on the other, would be destabilized. Art and design would be unified in service of societal improvement measures and problem solving in the age of mechanical reproduction. Rather than conceiving of machines as incompatible with, or even adversarial to humans, members of the Bauhaus strove for a human–machine integration ideal, such that mechanical means would be applied to the betterment of human material conditions.

Central to Bauhaus aesthetics are the maintenance of harmony, balance, and equilibrium; plasticity within a coherent form; the role of color and the play of light in defining form; and the fusion of media. Given the tendencies towards nonrepresentational art, and advances in research into visual perception during the 1910s and 1920s, artist such as Vassily Kandinsky, Paul Klee, Joseph Albers, and Johannes Itten would investigate the phenomenon of color, with respect both to its capacity to trigger particular emotional states and to the perceived internal logic of color relations. As was also the case for the Italian Futurists, there were claims to synesthetic experiences: Itten would associate colors with temperatures, and Kandinsky and Klee would connect colors to music. These color theories and the aforementioned aesthetic values would be applied to visual art and architecture (e.g., Walter Gropius's buildings), as well as to furniture, product design, graphic design, typography, costume and set design for theater, and other disciplines that were previously considered merely artisanal. The Bauhaus itself opened in 1920 in Weimar, and

would become a center of both research and development and of pedagogy. When the Bauhaus was closed by the Nazis in 1933 and its members fled Germany, Bauhaus principles were introduced to artists and architects in other countries, such as the United States, the UK, the Netherlands, and Israel. Moholy-Nagy himself taught industrial design and photography at the Bauhaus between 1923 and 1928. He worked as a set, book, and graphic designer, as well as a filmmaker in Germany and the Netherlands. During the interwar period, Moholy-Nagy gained a reputation for his imaginative stage designs for opera productions, including a production of *The Tales of Hoffmann* at Berlin's Kroll Opera House (Gropius 1961). It was thus through his engagement with the mechanics of theater, and his professional experience in a range of media that his vision of the Theater of Totality would develop.

When he proposed this new multimedia practice, in keeping with Bauhaus aesthetics, Moholy-Nagy emphasized that the relations among the dimensions of theater should be logical and organic, without reducing the complexities inherent in each dimension.

> The contemporary painting exhibits a multiplicity of color and surface interrelationships, which gain their effect on the one hand, from their conscious and logical statement of problems, and on the other, from the unanalyzable intangibles of creative intuition. In the same way, the Theater of Totality with its multifarious complexities of light, space, form, motion, sound, man—and with all the possibilities for varying and combining these elements—must be an *organism* (Moholy-Nagy 1925b, pp. 21–22).

This ideal work of the Theater of Totality, with its emphasis on logic and coherence, may thus be differentiated from the Futurist and Surrealist integrated media pieces of roughly the same time period, in which the relationships among media elements are often intended to be provocative or arbitrary. As Marinetti states, the Futurist cinema "will be painting, architecture, sculpture, words-in-freedom, music of colors, lines, and forms, a jumble of objects and reality thrown together at random" (Marinetti

et al. 1916, p. 13). Moholy-Nagy's critical assessment of the contemporaneous radical developments in Futurist and Dadaist artwork is addressed in the following section.

Erzählungsdrama, Aktionsdrama, Theater of Surprises

An evolution of theater is traced by Moholy-Nagy with respect to the relative importance of narrative and the literary on the one hand, and the nonverbal dimensions of theater—sound, light, motion, space, and form (of humans and objects)—on the other. The first phase in this historical process is so-called *Erzählungsdrama* (epic drama), in which nonverbal dimensions were used as mere illustration, subordinated to story narration or propaganda. Wagner's concept of *Gesamtkunstwerk*, in which all art forms integral to a production would operate in service of the drama, would exemplify this notion of *Erzählungsdrama*. In *Aktionsdrama*, associated with commedia dell'arte, circus performance, as well as experimental theater of improvisation of the early 20th century, the focus shifts from narration and onto physical gesture as bearer of meaning, such that "dynamic-dramatic movement begins to crystallize." With Futurism, Dadaism, and *Merz* (i.e., Kurt Schwitters) comes what Moholy-Nagy describes as the "Theater of Surprises," in which the word and phonetic content would function as raw material for the sonic and visual collages, rather than as a vessel of the "logical-linear content of a work of literature" (Moholy-Nagy 1925b).

In exploiting the then-nascent medium of cinema, the Futurists proclaimed:

> We shall set in motion the words-in-freedom that smash the boundaries of the literary as they march towards painting, noise-art, and throw a marvelous bridge between the word and the real object (Marinetti et al. 1916, p. 13).

Despite the alienation of word from semantic content and linear narrative, "man, who until then had been the sole representative of logical, causal action and of vital mental activities, still dominated"

Figure 1. Moholy-Nagy's Lichtrequisit *[light prop]. (Photo: The J. Paul Getty Museum, Los Angeles. Laszlo Moholy-Nagy, aus* dem Lichtspielfilm schwarz-weiss-grau, *1930, gelatin silver print, 11 x 16.5 cm)*
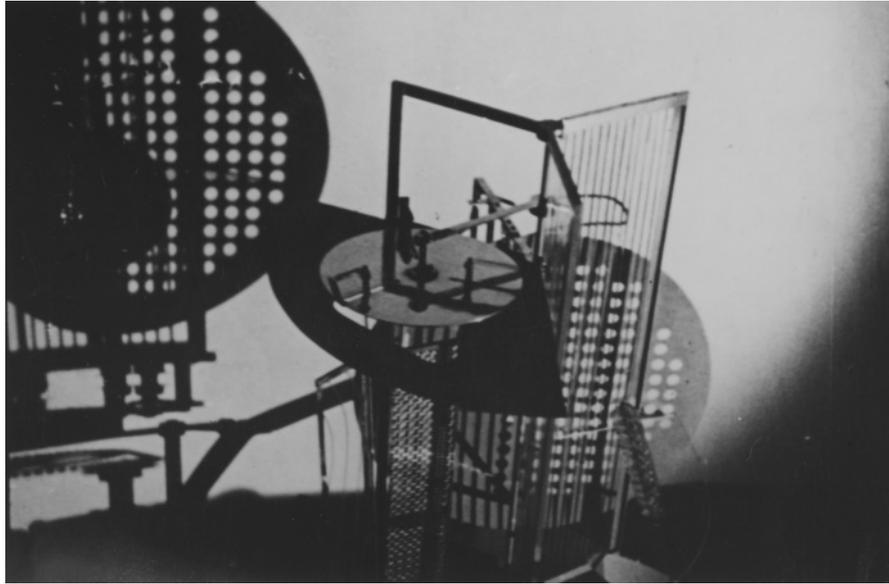
(Moholy-Nagy 1925b). ("Logical" in this instance refers not to coherent relationships within or among media, but rather to the word "logos": the centrality of text-based linear narrative.)

The Mechanized Eccentric

Distancing the work not only from linear narrative and the literary, but also from the centricity of the *Gestaltung* (configuration) of the human body—resulting in the elevation of the other crucial dimensions of theater—would require for Moholy-Nagy "the concentration of stage action in its purest form," that form being the *mechanische Exzentrik* (mechanized eccentric). This term refers to the offset of a rotating object from a fixed point (i.e., eccentric in a physical, as opposed to behavioral sense).

> The inadequacy of "human" *Exzentrik* led to the demand for a precise and fully controlled organization of form and motion, intended to be a synthesis of dynamically contrasting phenomena (space, motion, form, sound, and light) (Moholy-Nagy 1925b, p. 20).

Visual, auditory, spatial, and kinetic elements—including the *Körpermechanik* of the human body—

would be tightly choreographed to form multimodal, morphing geometries. As such, the focus on the orbital behaviors and speeds of collections of motor-driven objects and surfaces evident in Moholy-Nagy's iconic *Lichtrequisit* ("light prop"), a metal-and-glass kinetic sculpture used for creating and projecting complex light displays, depicted in Figure 1, would be amplified and extended to the coordination of all principal elements of a theatrical production.

That is not to say that the human presence would be eliminated entirely. Rather, humans would operate "on equal footing" with other "formative media," standing in a causal, functional relationship to them. Although the idiosyncrasies of a given actor's *Körpermechanik* would remain important—just as would individual characteristics of an object of any medium—the actor would avoid representing a character, and instead seek out "that which is common to all men." Consequently, the human and other media would be integrated into a complex organism, and the roles of nonhuman elements of a production would be elevated.

On stage a total stage action would unfold, consisting of "simultaneous interpenetrating sets of contrasting relationships." Moholy-Nagy further proposes that "simultaneous, synoptical, and

synacoustic reproductions of thought" (i.e, machine representations of human mental states or processes), could be brought about via the available technologies. He gives the example of gearwheels as a stand-in for the human production of thoughts (Moholy-Nagy 1925b). Such human–machine exchanges resemble a proposal of "cinematic analogies" made in the Futurist Cinema manifesto:

> Example: If we should want to express the anguished state of one of our protagonists, instead of describing it in its various phases of suffering, we would give an equivalent impression with the sight of a jagged and cavernous mountain (Marinetti et al. 1916, p. 13).

(The parallel is not surprising, given the emphasis on cross-modal relationships common to both the Futurist and the Bauhaus movements.)

With respect to audience participation, a collapsing of the artificial "fourth wall" separating stage from public would no longer be hindered by the need for a character- or narrative-driven scene, which would normally require distance, full attention, and reverent silence from spectators. The Theater of Totality would "no longer permit the masses to be silent spectators," who would "fuse with the action at the point of cathartic ecstasy" (Moholy-Nagy 1925b, p. 25). In the 1870s, Wagner attempted to heighten engagement of spectators at his custom-designed Bayreuth opera house using a democratic seating arrangement and placing the orchestra beneath the stage, to avoid distraction from the unfolding drama. Moholy-Nagy thus proposes taking Wagner's ideal of audience immersion a radical step further.

More concretely, by what means could one arrive at the mechanized eccentric ideal in a staged production? Moholy-Nagy is explicit in this regard, suggesting deriving "material from our daily living," falling into the following categories:

1. Sound effects produced by "acoustical equipment driven electronically or by some other mechanical means . . . issuing from unexpected sources—for example, a speaking or singing arc lamp, loudspeakers under the seats or beneath the floor of the auditorium, the use of new amplifying systems"
2. Color (light), including films "projected on various surfaces" and "actions of light."
3. Complex apparatus, "such as films, automobiles, elevators, airplanes . . . as well as optical instruments, reflecting instruments and so on." One such optical instrument example is the *Lichtrequisit*, described earlier in this article.
4. Architectural elements for the stage, such as suspension bridges and drawbridges, "running horizontally, diagonally, and vertically within the space of the theater," connecting moveable planes on various levels.
5. "Precision-made metallic masks and costumes . . . designed to emphasize function," along the lines of the Bauhaus costumes featured in Oskar Schlemmer and Paul Hindemith's *Triadisches Ballett* (1922).

The Mechanized Eccentric in Staged and Intermedia Works

In the 1920s, Walter Gropius designed a Total Theater, based upon Moholy-Nagy's specifications—as Moholy-Nagy had indicated textually in "Theater, Circus, Variety" and graphically in his "Partiturskizze zu einer mechanischen Exzentrik" from the same year Moholy-Nagy (1925a). Gropius was forced to abandon the project because of the collapse of the German economy preceding Hitler's rise to power. Furthermore, the Bauhaus itself was shut down in 1933 (Gropius 1961). Moholy-Nagy would move to Holland, to London, and eventually to Chicago in 1937. As such, Moholy-Nagy had neither the opportunity nor the resources to stage original works representative of Theater of Totality principles.

These principles have, however, articulated themselves to varying degrees in several seminal staged and (to borrow Fluxus pioneer Dick Higgins's term) "intermedia" works over the past fifty years or so. It would be instructive to examine a few of these works, aspects of which have influenced the recent

robot operas that will be discussed subsequently. John Cage's *Variations* V (1965), produced in collaboration with the Merce Cunningham Dance Company, exists not as a narrative-bound piece, but rather as a dynamic, interactive system, in which "actuators" (i.e., dancers), sensors, sound, visuals, and the movements both of humans and of sounds among the loudspeakers. This project was realized in the midst of the heightened interest and investment in interdisciplinary arts and engineering initiatives that typified the Cold War period in the United States, when the cybernetics principles of Norbert Wiener and information-theory models of Claude Shannon and others were gaining attention in both the scientific and artistic communities. The Experiments in Art and Technology in New York, which brought together Bell Telephone Laboratories researchers such as Billy Klüver and Max Mathews, with artists such as Cage, Robert Rauschenberg, and David Tudor, exemplified this trend. On the surface level, the performance, according to Gordon Mumma, came across as a "multiringed circus." (One important parallel between Moholy-Nagy and Cage is the reference made by both to the circus as a model for the performance event, as is evident in the "Musicircus" presentations of Cage's music.) Beneath this surface, there is an intricate set of feedback loops among the deployed technologies. Dancers activate two arrays of sensor systems: photocells, sensitive to changes in light intensity, and antennae, responsive to the distance between dancers, proximity of dancers to antennae, and the number of dancers on stage. These systems transmit control signals triggering sound spatialization and trajectories. As Mumma recounts from his experience as a sound operator during the performance, "further activities compound this counterpoint [between dancers' movements on the stage and the sound movements in the auditorium]: an elaborate lighting system, including film and slide projections designed by Stan Vanderbeek, and on-stage props, which are wired for direct sound by special mikes" (Nyman 1999, p. 98). Besides the organic, cybernetic connections between human *Körpermechanik* and the media technologies, there is a resemblance between the list of "ingredients" in Moholy-Nagy's recipe for a Theater of Totality performance

and those incorporated into the *Variations V* scenario.

Heiner Goebbels describes his work *Stifters Dinge* (2007) as "a composition for five pianos without a pianist, a play with no actors, a performance without performers" (quoted in Anthony Tommasini's review, *New York Times*, 17 December 2009), and as a "performative installation" in which objects serve as protagonists (Birringer 2012). Figure 2 gives a view of a performance of the work. The work is based upon the works and ideas of the Austrian writer and artist Adalbert Stifter, whose "Eisgeschichte" [Ice Tale] is recited by a recorded voice towards the middle of the 80-minute piece. Projected sounds include field recordings made in 1905 by Austrian ethnographer Rudolf Pöch of songs and stories from Papua New Guinea (Birringer 2012), a traditional Greek lament, and the voices of Claude Lévi-Strauss, Willliam S. Burroughs, and Malcolm X. These disembodied voices are "accompanied" by the automated, computer-triggered pianos. The stage architecture, pianos, and three onstage pools are precisely controlled and coordinated with the sounding elements. Although *Stifters Dinge* is thematically humancentric, and replete with literary content, the absence of human performers, coupled with the fusion of media and the foregrounding of the stage set, machinery, and objects are salient mechanized eccentric properties. Moreover, the invitation of audience members to the stage to experience the installation first-hand is a means of "breaking down the fourth wall," an aesthetic objective of Moholy-Nagy.

Another, more recent, example falling at the boundary between music theater and installation is Taro Yasuno's "zombie opera" *Danse Macabre* (2015). As in *Stifters Dinge*, Yasuno's opera makes use of automaton instruments (in this case, clarinets, recorders, and other winds, activated by servomotor-controlled artificial fingers and a pressure pump) that are distributed across a multilayered stage set, as depicted in Figure 3. Although human participants are present on stage (including the composer), it is the software-triggered instruments, stage architecture, and lighting with projected visuals that are placed in high relief. Fittingly, the

Figure 2. Heiner
Goebbels's "performative
installation" Stifters
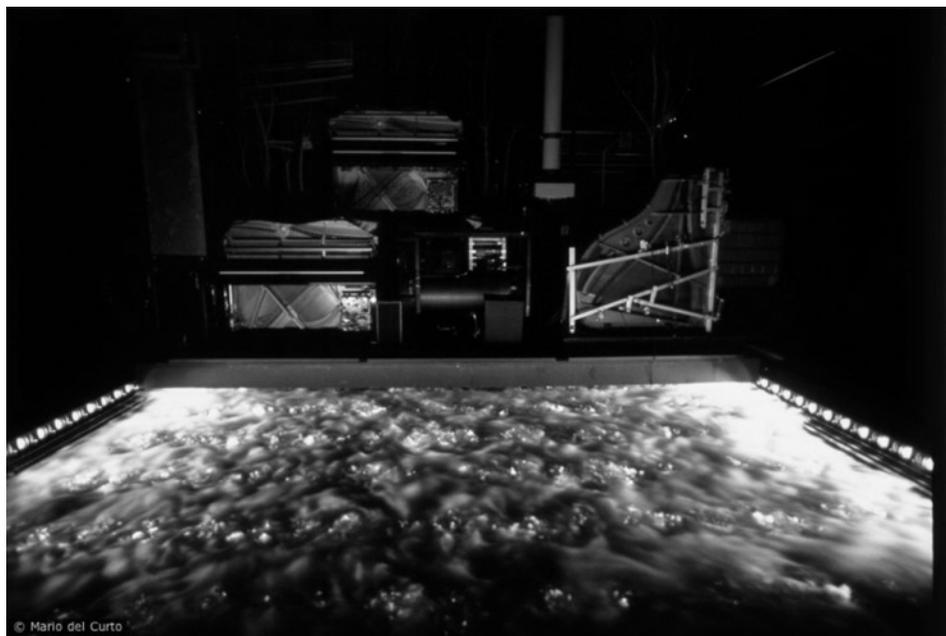Dinge. (Photo: Mario del
Curto / Théâtre Vidy,
Lausanne.)

Figure 3. Performance
photo from Taro Yasuno's
"zombie opera" Danse
Macabre. (Photo by
Kazuyuki Matsumoto.)

Figure 2

Figure 3

actors quite literally play the role of servants to the machines. (Please see https://www.artscouncil-tokyo.jp/en/events/8801/ for production details.)

Defining Robot and Robotic

The Goebbels and Yasuno examples both deal with the automation of instrumental performance via an invisible control center, which may be described as a "robotic" attribute of the works. Explicitly programmed actions are but a subset of behaviors of which robots are capable, however. Indeed, the term "robot" conjures a wide range of associations, including:

1. an android entity, emulating human behaviors and responses; manifesting "reembodied cognition" and interacting with the environment and other agents;
2. an auxiliary, serving humanity, performing specific tasks;
3. an augmentation of humanity, as "disembodied and expanded cognition";
4. a dynamic, cybernetic system, an evolving network of relations; and
5. an alien entity and object of fantasy.

One could position these robot definitions along a gradient, ranging from dehumanized and mechanical automaton (and perhaps a threat to humankind?) on one end, to anthropomorphic stand-in for humankind on the other. (If one consults the *Merriam-Webster* definition of "robot," these extremes of the continuum are both represented.) According to Moholy-Nagy's formulation, would a robot presence in a theater production signify the introduction of a novel technology to a *Gestaltung*, or just the opposite: contribute human-centered and "literary" qualities to the production? As will be discussed in the following examples of robot opera, given the multiple characterizations of robots—sometimes within the same piece—the boundary between anthropocentricity and technocentricity becomes fuzzy. Furthermore, the extent to which robots are merely imitating conventions of human expressivity versus developing their own modes of expression is at times unclear.

Death and the Powers: Disembodied Consciousness and Human–Robot Interfaces

Composed by Tod Machover, in conjunction his Opera of the Future research group at the MIT Media Lab, *Death and the Powers* (2010) deals with themes of embodiment versus disembodiment, modes of interaction with the environment and agents within that environment, and possible posthuman futures. Following the synopsis by Jessop, Torpey, and Bloomberg (2011), the protagonist of the opera, Simon Powers, is a wealthy inventor who, when learning of his immanent demise,

> seeks to extend his life, legacy, and ability to interact with the world by uploading his consciousness, memories, and essence into a computer system built into his house.

Once this is achieved—at the end of the first scene of this one-act, evening-length production—his uploaded contents are downloaded into the bookcases of the house (represented on stage as *periaktoi*, i.e., rotating triangular prisms that enable rapid set changes). His family and research assistant

> try to relate to Simon in his new form. They question whether he is still alive and still the same person, and finally decide whether they wish to come join him in the "System."

Effectively, Powers himself becomes a System.

From this synopsis, it is clear that the opera follows a linear storyline, as conveyed through the libretto by former United States Poet Laureate Robert Pinsky. The lead actors become the focus of an essentially human drama, which unfolds following operatic conventions (aria and recitative-like passages, accompanied by a 15-piece orchestra). Rather than serving as a mere backdrop to dramatic events, however, the media technologies utilized in the production become active participants—and indeed, the set becomes the main character, and vice versa.

Robots "have multifaceted roles as set pieces, lighting elements, individual characters, and part of the manifestation of Simon Powers" (Jessop, Torpey, and Bloomberg 2011). One trio of robots,

Figure 4. Scene from Tod Machover's Death and the Powers*: Chorus of Operabots. (Photo: Jill Steinberg.)*

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assuming the form of three bookcase *periaktoi* on stage, receive analyzed and processed vocal and motion sensor data from the performer. The multimodal mapping between input data and visual, auditory, and kinetic output constitutes the "disembodied performance system," whose objective is to capture and transmit the affective content of the vocalizations and gestures of the singer portraying Simon Powers as sensitively as possible.

Nine so-called Operabots constitute a chorus (as shown in Figure 4), which is integrated into the scenes and comments on events. They are situated both along the timeline in which the drama takes place, and in a posthuman future in which they periodically retell or perform the story of Simon Powers to gain insights on the nature of suffering and death in the Organic Age, as is explained in the opera's prologue. Although vaguely anthropomorphic in design—each robot has a triangular "head" and adjustable, columnar "body"—the Operabots are more reminiscent of LED-illuminated digital devices than androids. In performance, the Operabots are precisely choreographed, in conjunction with with the movements of humans and the stage architecture.

To attain sufficient flexibility and adaptability of the robots, a cue-based playback system was developed that would enable the robots to behave autonomously, while permitting preprogrammed procedures to be overridden in real time by the robot control operators (Jessop, Torpey, and Bloomberg 2011). Although receiving input signals and commands from human performers, robot interaction with humans is a merely staged phenomenon. That is to say, the robots are governed neither by generative nor machine-learning algorithms that would contribute not only a layer of unpredictability to the performance, but also a certain freedom for the robots.

The "Chandelier" serves as an antipode to the control dynamic of an offstage human versus onstage technology, exemplified by the bookcase *periaktoi* and the Operabots, and as a means for Simon Powers's wife to retain a level of haptic contact with her "uploaded" husband. This object, presented in Figure 5, functions simultaneously as a lighting element and a new interface for musical expression. When the teflon strings are activated, complex voice-sample-based and string-like sounds are emitted (Jessop, Torpey, and Bloomberg 2011).

Figure 5. Scene from Death and the Powers*: Simon Powers's wife Evvy (played by Patricia Risley), interacting with the "Chandelier." (Photo: Jill Steinberg.)*

In an abstract sense, this object represents the reembodiment of a human presence, recast as a musical instrument, but it is ultimately a weak compromise between organic life-form and the System.

Consistent with Moholy-Nagy's mechanized eccentric concept is the coherent choreography of all media and objects employed in the production, albeit making use of precision-engineered objects emerging from the MIT Media Lab, as opposed to objects from daily life. It is obvious that such a prototypical *Erzählungsdrama* runs counter to Bauhaus aesthetic ideals. But to what extent do the robots and stage set diminish the human element by dominating the proceedings, and to what extent do they intensify it, through the diffusion of human input data and images across the stage scenery and Operabot chorus? This ambiguous divide between affective and digital, and the degree to which an ageless, disembodied manifestation of a human could be equated with its carbon-based counterpart, lie at the core of *Death and the Powers*.

The Body Electric: Marynowsky and Knowles's *Robot Opera* and Gob Squad's *My Square Lady*

In 2015, two notable and highly contrasting robot operas were realized. In Australia, the artist Wade Marynowsky and the composer and sound designer Julian Knowles created their *Robot Opera* (described at www.julianknowles.net/in_development/robot-opera-development). In Germany, the Komische Oper Berlin produced *My Square Lady* with the performance group Gob Squad.

The eight connected but independent robot "performers" designed by Marynowsky and creative performance team Branch Nebula each project sounds and display symbols via DMX512 (digital-multiplex) and LED-array lighting systems. They bear little or no resemblance to human performers, and thus can be seen as a kind of cross between Machover's modified stage set bookcases and his Operabots. In fact, in a manner contrary to the design principles used by MIT Media Lab's Opera of the Future group, the internal components of these constructions are entirely exposed, minimizing any association with android or automaton stereotypes. Like the *Death and the Powers* robots, they are tightly choreographed via a wireless network. The "opera" by Marynowsky and Knowles, however, assumes the form of an interactive installation, in which audience members' facial expressions and proximity to the robots—captured by infrared cameras and Kinect depth sensors—influence the visual and audio output of the robots.

As in the Machover work, the robots can operate according to preprogrammed algorithms ("autonomous" mode) or can receive live input from the artists ("manual" mode). There is also,

however, a "follow" mode, in which the robots track audience members' current positions, and approach them (see Stephen Jones's review in *Real Time Arts* December–January 2016). In contrast to *Death and the Powers*, the robots modify their behaviors based upon their interactions with the environment. Audience members' movements are, in turn, influenced by the changing states of the robots. At the same time, each robot's input is fed to a pair of central computers, thereby contributing to a cybernetic system (as opposed to remaining completely autonomous). Furthermore, the "driver" of the system shifts from preprogrammed robot to artist intermittently during the performance. Therefore, these robots are between categories: embodied without adopting human characteristics, but also nonautonomous and networked. Given the absence of a libretto or of literary themes, human-like vocalization, and a "fourth wall," among other attributes of the project, the affinities between Moholy-Nagy's Theater of Totality and *Robot Opera* are self-evident. The notion of "opera" here expands beyond the conventions by which *Death and the Powers* is bound. It is the synthesis and synchronization of a plurality of resources (light, sound, space, and movement), scale, and the resulting spectacle that imbue the work with operatic qualities. One could go so far as to claim that a sense of drama (or at least tension) emerges from the interactions among robots, the artists, and the public.

Gob Squad's *My Square Lady* follows a similar premise to *Death and the Powers*: A robot tries to understand opera and human emotion—in particular, empathy. In this case, however, there is a single child-sized humanoid, learning directly from scientists, musicians, and stagehands in the present, as opposed to a future reenacting of a specific human drama. The learning process is genuine (via the deployment of neural-network algorithms in real time), as opposed to the fictional and extended robot-learning scenario in Machover's opera. Just as Henry Higgins in *My Fair Lady* attempts to train cockney flower girl Eliza Doolittle in high-society mores and discourse, such that she could be mistaken for being of heightened social status, the AI researchers, Gob Squad members, and Komische Oper Berlin chorus and instrumentalists in *My Square Lady* attempt

to train the robot on an eclectic array of Western music, from Purcell to the present, such that it could come across as human with respect to music appreciation and skills (Hild et al. 2012).

Rather than a robot designed specifically for this production, or for use in artistic contexts in general, the protagonist in this case was the Myon robot, developed at the Neurorobotics Research Laboratory at the Humboldt University Berlin by Manfred Hild and colleagues. Furthermore, Hild himself appears in *My Square Lady*, where he trains the robot and even sings to it. Designed for the generation of artificial language, Myon robots acquire names for physical postures and gestures through engaging in training with other robots or with humans. (For a brief demonstration and explanation see https://youtu.be/UV8dDFDDVds.) Myon effectively trains first on itself, using its body as a model for physical movements of other agents. This proprioceptive awareness, coupled with sensorimotor feedback (between sensors and actuators), and greater elasticity (more degrees of freedom in the components' movements) imbue Myon with greater organic qualities than are typical for humanoid robots. Complementing the structural plasticity of the robot are the distributed local processing nodes, which permit autonomous processing and control of individual anatomical components. As such, there is no central processing unit to speak of. The camera-mounted head of the robot is largely responsible for image processing (Hild et al. 2012). Thus, Myon represents an extreme case of embodied cognition: Not only do interactions with and sensory feedback from the environment that utilize the various "body parts" of the robot shape its knowledge base and enable it to adapt to shifting conditions, but the input data processing also occurs inside the individual components.

Contrary to *Death and the Powers* and *Robot Opera*, the Myon robot exists as a fully autonomous entity in *My Square Lady*, with the capacity to emulate human behaviors (to a limited extent) and to acquire knowledge through engaging with the external world. Although the intent of *My Square Lady* is similar to that of *Death and the Powers*—to fold back upon the human experience and determine what it ultimately means to be human—the former

Figure 6. A pair of the Nao robots used in the University of Sussex Mini Symposium on Robot Opera. (Photo: University of Sussex Media Centre.)

treats humans and humanoids as categorically distinct, while a continuum between the human and posthuman is established is the latter. Given the intention on the part of the scientists and musicians to extend or transform the robot, as opposed to harnessing technology to extend or transform themselves, it is conveyed that timeless human themes are placed in the foreground, and technological features in the background—the inverse of the mechanized eccentric ideal.

Given that *Robot Opera* has neither literary reference nor human cast, consists of nonanthropomorphic robots, and is staged as an interactive installation where there is no border between audience and stage, the work exemplifies the mechanized eccentric ideal. Conversely, *My Square Lady* is narrative in nature, and features actors and musicians interacting with a humanoid robot. As such, it tends towards the humancentric. With respect to robot properties, Myon robots, who receive continuous environmental input and feedback, demonstrate a higher degree of autonomy than the models used in the Marynowski production, which are selectively autonomous and interact selectively with the physical environment. In both cases—and in contrast to *Death and the Powers*—robots are conceived purely as embodied entities.
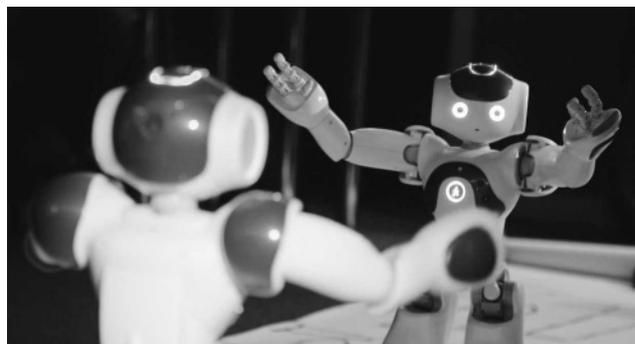
University of Sussex Robot Opera Mini Symposium

In 2017, Evelyn Ficarra, assistant director of the Centre for Research in Opera and Music Theatre (CROMT) at the University of Sussex, launched an interdisciplinary project dedicated to the creation of robot operas, in collaboration with Ron Chrisley, director of Sussex's Centre for Cognitive Science (COGS). A symposium consisting of performances, presentations, and discussions "about the philosophy and potential impact of artificial intelligence and the arts" (Hakner 2017) was held at Sussex as a culmination of the project.

Robot Opera Project Background: The Nao Robot

As was the case for *My Square Lady*, the Sussex team repurposed a model of humanoid robot not originally intended for musical contexts. In this instance, Nao robots, originally developed by Aldebaran Robotics (later acquired by Softbank Robotics) were utilized, as shown in Figure 6. Unlike Myon, the Nao robot is programmed to speak in multiple natural languages. Whereas Myons are trained to recognize and imitate physical gestures and poses, Nao robots are equipped with facial recognition abilities. Most significantly, these systems are fully programmable in a number of programming languages and environments, thereby rendering the robot adaptable to a broad range of applications. To date, Nao robots have primarily been used in educational, clinical, and research contexts, but, as the CROMT project demonstrates, they are by no means limited to these domains. (For further information on Nao robots, see https://www.brainaryinteractive.com/nao-robot).

As Ficarra explains:

> If, in the near future, we are expecting to see robots used as care workers or teaching assistants, we need to teach them to understand and respond appropriately to humans. The virtues of the musician—listening, cooperation, group creativity—are transferable skills that could apply in all kinds of human situations. Opera requires all of these, plus vocal expression, acting skills, movement, and the ability to respond to other performers. So, in addition to being a fascinating exploration of "posthuman" performance, the work could have interesting implications for research in artificial intelligence and social robots (Hakner 2017).

Figure 7. Rehearsal of Ed Hughes's robot opera Opposite of Familiarity *at Sussex in 2017. (Photo: University of Sussex Media Centre.)*

The Operas and Collaborative Process

To initiate the project, project director Evelyn Ficarra and Sussex composition professor Ed Hughes each composed a 5-minute work for two vocalizing Nao robots and cello, with intimate, minimal staging (see Figure 7). As in the examples of robot opera discussed above, the robots were programmed according to a cue-based score, requiring the occasional intervention of the composers to signal a shift to the next cue.

In Ficarra's *O, One*, the robots commence with uttering binary code, which morphs into natural language. In so doing, the text, in English, is of a self-reflective nature, consisting of statements such as "I am not a robot." Hughes's *Opposite of Familiarity* sets a libretto by Eleanor Knight. For both operas, the composers decided (in conjunction with Ron Chrisley, who was responsible for the robot programming) that rather than simply having the robots play back recorded human voices, they would perform using their own synthetic voices. This required a process of mutual adaptation: The composers would operate under the constraints of the Nao's vocal algorithms, and the robots would be programmed to produce pitches, rhythms, and musical gestures. The idiosyncrasies of the Nao speech engine, as explored and exploited by

Chrisley, Ficarra, and Hughes, resulted in unusual vocal output (Hakner 2017).

Symposium Themes: Anthropophony, (Dis-) Embodiment, and Robot Performance

The operas challenged project collaborators, symposium presenters, and audience members alike to consider a number of essential questions, such as: What does it mean for a robot to sing, to listen, and to express human themes? Are the discrepancies between human and robot modes of vocal expression to be viewed as a limitation on the part of the Nao speech engine, or as the introduction of a new type of performance practice? These topics, among others, were addressed over the course of the symposium. Besides Ficarra, Hughes, and Chrisley, participants included researcher Thanos Polymeneas-Liontiris and Chris Kiefer, lecturer in music technology (all affiliated with the University of Sussex). Video documentation of the symposium presentations and the performances of the Ficarra and Hughes operas can be found at https://youtu.be/bV-seLR0OP0.

In the symposium proceedings, Ficarra provides an aesthetic and historical perspective on the project, while Chrisley draws not only upon his experience on the technical side of the project, as

well as his cognitive science training in general, but also on his background in philosophy. In her introduction, Ficarra remarks upon the recent resurgence in popularity of labeling compositions as "opera," even in the absence of musical performers. An opera may be composed entirely for amplified objects, or be considered an opera simply due to the participation of a single singer. From the postwar period, composers typically preferred labels such as "music theater," "interdisciplinary work," or "performance-installation," given the historical trappings of the term "opera." In light of this general regravitation towards opera as a genre, coupled with rapid developments in AI and robotics of the past few years, this project has been of particular relevance.

Once distinguishing between, on the one hand, operas about robots or directed by robots and, on the other, operas with robots as singing performers, Chrisley narrowly defines robot singing as musical sounds, with the possibility of carrying speech elements, produced in real time by an artificial agent without the direct control of humans. In terms of behaviors directed towards performance, he emphasizes the distinction between programming specifications and the realities of how they are translated into physical actions—loosely comparable to the relationship between the ideals of the composer reflected in a score and the interpretation and realization of the score by human performers. Also prioritized is the ability of robots to become sensitive listeners, applying aesthetic judgments to their own performances. Although composed for disembodied performers (i.e., virtual instruments and Vocaloid-driven robotic voices), Polymeneas-Liontiris's work *A Magnificent Crossbreeding of Protein and Tinplate* addresses issues of anthropomorphy versus anthropophony (i.e., human-like sound), which are central not only to the operas by Ficarra and by Hughes, but more generally to working with embodied robots in a musical context.

Thus far, the only example of applying machine-learning algorithms (as opposed to generative or purely deterministic ones) to the productions of robot opera cited in this article has been *My Square Lady*. In the case of the Myon robot, however, the learning process was a central focus of the

storyline, occurring largely within the time frame of the performance, and limited in scope, as opposed to being fully integrated into the rehearsal and preparation process. Kiefer, who has a history of designing controllers and interactive systems responding to arrays of data larger or more complex than a human could feasibly manipulate, addresses not only crucial concerns pertaining to human–AI interaction in performance, but also the optimal rehearsal conditions. Kiefer first characterizes training on a set of labeled input data as rehearsal, and predictions on new input as performance. These predictions not only assume the form of output motor commands, but may also be represented by "imagining" responses to a given visual, auditory, or tactile input from sensors. Effective training requires a precise choreography between human and robot agents, especially in the case of dealing with a large number of features. Needless to say, as in the traditional rehearsal process for humans, patient and disciplined repetition is a necessity. For a classifier to make predictions, it is necessary for the AI to exhibit neither high bias (i.e., underfitting with the resultant overgeneralizing across the data) nor high variance (overfitting the data, thereby substantially limiting the AI's capacity to generalize over previously unseen data). In terms of the nature of the input, Kiefer provides an earlier example of a hand-recognition program, which functions largely using lower- and mid-level image processing. But there is also the possibility for an AI to be responsive to more complex input, such as specific facial expressions and vocal passages, or customizing an AI to react to a particular human agent. He then considers the issue of embodiment: not only the importance of the AI in adapting to a given environment, but also in adapting the environment to an artificial agent, rendering it conducive to the processing of the data therein (see https://youtu.be/bV-seLR0OP0).

The symposium participants thus draw attention to and analyze a number of salient theoretical and practical considerations with respect to robot opera, the relevance of these topics extending well beyond the pieces premiered within the framework of the symposium. As was the case for *Death and the Powers*, the divide between anthropocentric and technocentric is an uncertain one for the Ficarra and

Hughes operas, but for exactly the opposite reasons. Whereas Machover and his research group were dealing with the disembodiment of the human, and the indirect mapping of human vocalizations and physical gestures to nonhumanoid robot agents, *O, One* and *Opposite of Familiarity* were composed for the vocalizations and gestures unique to an embodied, autonomous humanoid.

Shibuya's *Scary Beauty*

Premiered in July 2018 in Tokyo, and following upon the success of Keiichiro Shibuya's 2013 opera *The End*, featuring vocaloid Hatsune Miku (http://atak.jp/en/project/the_end), *Scary Beauty* is scored for a human orchestra and a robot that sings and conducts. *The End* features an anthropomorphic but virtual (i.e., disembodied) protagonist. In *Scary Beauty*, an embodied, three-dimensional android takes center stage. The robot, called Alter 2, was designed by Hiroshi Ishiguro, director of the Intelligent Robotics Laboratory at Osaka University. Alter 2's software was developed by University of Tokyo artificial life researcher Takashi Ikegami. Fatalistic in tone, the texts that constitute "The Seven Last Texts of Human" that are recited by the android are derived from a subversive love song by provocative French novelist Michel Houellebecq, Yukio Mishima's disturbing final novel *Sun and Steel*, cut-up narratives by W. S. Burroughs, and passages of Wittgenstein's last book *On Certainty*. Fragments of the texts are converted into three-dimensional vectorized representations (or "embeddings") using a Word2Vec model (Mikolov et al. 2013). These embeddings are not used to capture semantic relationships among input words or phrases (e.g., in the context of encoder–decoder machine translation, summarization, or query-matching tasks). Instead, the three dimensions of a given vector are mapped in real time onto pitch, duration, and sound level, respectively. As such, the texts are both projected and utilized as raw compositional material. Given the variations in text input selection, each performance is unique. At present, the android is not responsible for selecting the text excerpts to be vectorized, but that behavior is planned for the future.

Further information on the opera may be found at http://scarybeauty.com/index-en.html.

As in *My Square Lady*, a humanoid robot engages in musical performance. Alter 2 is specially designed, however, with respect to both software and hardware, not only to perform but also to make interpretation decisions. As such, it is "learning" from the input texts, rather than from the external environment or its peers. Similar to Marynowski's *Robot Opera* and the Sussex works, the term "opera" is loosely applied. It is really an orchestral song cycle in the tradition of Mahler and Richard Strauss, and there is no explicit staging to speak of. The spectacle of the android's gestures and utterances occupy the foreground, however, and the coupling of the robot's decision-making process with the human musicians' responses arguably creates dramatic tension. In contrast to all other projects addressed in this article, it is the text, rather than a set of cues or changes in the physical environment, that bears a direct influence on the actions of the robot. Although far from embodying the mechanized eccentric ideal, the relationships between text and music established in this piece do, in a sense, reflect Moholy-Nagy's interest in representing human thoughts via nontextual media.

Conclusion and Future Directions

When making precise comparisons among works falling under the rubric of "robot opera," and examining the range of design, hardware, and software specifications distinguishing the various types of robots used from each other, it becomes evident that this is not a mere gimmick or subgenre, but rather an expanded field of possibilities. Furthermore, it is instructive to use staged works and performance installations of the past several decades in which human presence is reduced, or entirely absent, and in which media technologies are placed in the foreground, as reference points for constructing a continuum between conventional human-centered drama, into which robots have been inserted, and Moholy-Nagy's mechanized eccentric ideal. Along this continuum, one may situate extant and future works classified as "robot opera."

For the future, it is therefore impossible (and indeed futile) to trace a single trajectory for robot, or more broadly, "posthuman" opera. The potentials for disembodiment, whether through the mapping of human sounds and gestures to stage objects (as in the case of *Death and the Powers*) or through the use of virtual performers (such as the Vocaloid-driven works mentioned earlier) could be just as effective in a music theater context as the programming of environmentally sensitive embodied agents. With respect to the development and implementation of an artificial agent performance practice, the Sussex robot opera symposium has laid a promising foundation for subsequent research on the part of scientists and composers. As the domains of AI and robotics continue to evolve, it would be of great interest to witness the innovative integration of machine-learning algorithms in multiple dimensions of staged productions: from the composition and performance to lighting and visual design.

Acknowledgments

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