Research Report

Robot Opera: The Mechanized Eccentric, or the Eccentric Mechanism?

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Abstract

In his 1924 essay "Theater, Circus, Variety," Bauhaus artist László Moholy-Nagy (1895-1946) unfolds his vision of a "Theater of Totality," in which the essential formal components of theater—space, composition, sound, light, and motion—are synthesized into an integrated, abstract whole. In this context, he introduces the notion of the *mechanische Exzentrik* [mechanized eccentric] to express a state of theater in its purest form, in which the human subjective presence is no longer the focus of a linear-logical dramatic narrative (*Erzählungsdrama*) or non-verbal *Aktionsdrama*, but rather the human configuration (*Gestaltung*) stands in functional relationship to the coordinated movements of machines and media. While Moholy-Nagy was not able to fully realize the aims of the theater of totality in his lifetime, there are a number of examples of classic and more recently produced staged works in which the mechanized eccentric concept has been reflected.

The emergence of the robot opera in recent years has challenged Moholy-Nagy's distinction between anthropocentric and mechanized eccentric theater, due to the polyvalent and at times ontologically ambiguous roles that robotic entities have served. When incorporated into the music theater context, is the robot dimension intended to replace human activities and modes of expression, to augment and/or 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 theater of totality and the leading questions in the background, salient robot opera examples of the past several years will be discussed. In so doing, cybernetics principles and embodied cognition issues pertinent to musical performance are also addressed. Repertoire examples include Tod Machovers pioneering *Death and the Powers* (2010), the Komische Oper Berlin production *My Square Lady* (2015), and works emerging from the University of Sussex Centre for Research in Opera and Music Theatre (CROMT) Robot Opera Mini Symposium (2017).

1. Introduction and Motivation: Bauhaus, Robots, Opera?

With advances in robotics and artificial intelligence across multiple domains, the perennial question has become: which fields/occupations will resist automation, and which will be jeopardized by it? A typical response rests on the assumption that menial, repetitive, and easily learned tasks that require little interaction with humans, such as transport, factory assembly line work, crop harvesting, retail transactions, and low-level computer programming will be most at risk, while those that are more complex in nature and/or require a deeper understanding of human psychology, communication, and expression would exceed the capacities of robot agents. However, with the emergence of robot operas in the past few years, this basic distinction becomes blurry. If opera singing, a practice that for many represents the epitome of human expressive communication, may be co-opted by intelligent machines, then can one safely claim that the performing arts will remain solely the province of humanity?

The objective of this paper is not to speculate on future job security and automation in the arts, but rather 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 the robot has been explicitly programmed or is trained on machine learning algorithms—in the opera context. In order to approach these topics, robot opera will be examined through the lens of Bauhaus artist László Moholy-Nagy's notion of a Theater of Totality. Moholy-Nagy was amongst the first artists to propose a form of multimedia performance in which the human would not occupy a central role, but would either be absent entirely, or placed on an equal plane with visual, auditory, spatial, and kinetic technological elements. Manifestations of Moholy-Nagy's concept of the *mechanische Exzentrik* [mechanized eccentric], have been evident in music theatre/experimental media works of the mid-late twentieth and early twenty-first centuries, including robot operas, as is discussed below. At the same time, the numerous categories that a robot can occupy—as humanoid or machine, servant to or augmentation of human activity, embodied, environmentally-situated agents and disembodied intelligence—contribute a layer of uncertainty as to the boundary between human-centricity ends and techno-centricity. It is precisely in

this grey zone in which there lie opportunities for innovative exploration into both new modes of human-robot and robot-environment interaction, and on a more philosophical level, what it means to be human.

2. Moholy-Nagy and the Theater of Totality

2.1. Theater of Totality: Definition and Defining Features

"There will arise an enhanced *control* over all formative media, unified in a harmonious effect and built into an organism of perfect equilibrium" (1). So claimed László Moholy-Nagy (1895-1946) in his 1924 essay "Theater, Circus, Variety." As an early twentieth century riposte to 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 theatre—space, composition, sound, light, and motion—are synthesized into an integrated, abstract whole.

In proposing this new multimedia practice, Moholy-Nagy, in keeping with Bauhaus aesthetics, emphasizes that the relations amongst the dimensions of theater should be logical and organic, without reducing out 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" (1). This (ideal) work of the Theater of Totality may thus be differentiated from the Futurist and Surrealist integrated media pieces of roughly the same time period, in which the relationships amongst media elements are often intended to be provocative and/or arbitrary. As Marinetti states, the Futurist cinema "will be painting, architecture, sculpture, words-in-freedom, music of colours, lines, and forms, a jumble of objects and reality thrown together at random" (2). Moholy-Nagy's critical assessment of the recent (from the 1924 perspective) radical developments in Futurist and Dadaist artwork is addressed below.

2.2. 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 non-verbal 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 non-verbal dimensions were employed as mere illustration, subordinated to story narration and/or propaganda. In *Aktionsdrama*, associated with *commedia dell'arte*, circus performance, as well as experimental theater of improvisation of the early twentieth 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" (1).

In exploiting the (at the time) nascent medium of cinema, [1] the Futurists proclaimed that "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" (2). 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" (1).

2.3. The Mechanized Eccentric

Distancing the work not only from the linear-logical and the literary, but also from the centricity of the *Gestaltung* (configuration) of the human body and an 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]. "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)" (1). Visual, auditory, spatial, and kinetic elements—including the *Körpermechanik* of the human body—would be tightly choreographed to form multimodal, morphing geometries.

More concretely, by what means could one arrive at the mechanized eccentric ideal in a staged production? Moholy-Nagy suggests deriving "material from our daily living," falling into the following categories (1):

1. **Sound effects** produced by "acoustical equipment driven electronically or by some other mechanical meansissuing from unexpected sources—for example, a speaking or singing arc lamp loudspeakers under the seats or beneath the floor of the auditorium."

2. **Color** (light), including "films...projected on various surfaces" and "actions of light."

[1] One of the few remaining examples of Futurist cinema is the film *Thaïs* (1917), which may be viewed here: `https://www.youtube.com/watch?v=6G01_2zhulg&pbjreload=10` (accessed 05 February 2018).

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 Moholy-Nagy's *Lichtrequisit* [Light-Space Modulator], a metal-and-glass kinetic sculpture used for creating and projecting complex light displays (depicted in Figure 1). [2]

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. **Costumes** "designed to emphasize function." [3]

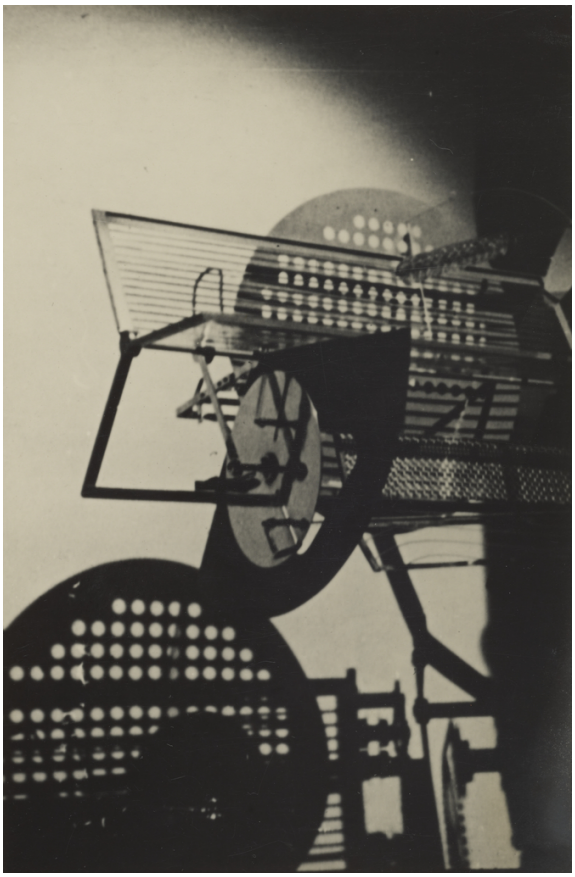

Figure 1. Moholy-Nagy's *Lichtrequisit* [Light-Space Modulator].

[2] One may view the Light-Space Modulator in action, under varied lighting conditions here: `https://www.youtube.com/watch?v=hAXBL8bDyr0` (accessed 05 February 2018).

[3] Along the lines of the Bauhaus costumes featured in this production of Oskar Schlemmer's *Triadisches Ballett* (1922): `https://www.youtube.com/watch?v=r4pJlj_bteQ` (accessed 05 February 2018).

3. The Mechanized Eccentric in Twentieth and Twenty-First Century Staged and Intermedia Works

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. In the preceding decade, Walter Gropius designed a Total Theater, based upon Moholy-Nagy's specifications, but was forced to abandon the project due to the collapse of the German economy preceding Hitler's rise to power. Furthermore, the Bauhaus itself was shut down in 1933 (3). As such, Moholy-Nagy had neither the opportunity nor the resources to stage original works representative of Theater of Totality principles.

However, these principles have been applied to several seminal staged and (to borrow Dick Higgins' term) intermedia works over the past fifty years or so. 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 (dancers), sensors, sound, visuals, and both human and sound movement (amongst loudspeakers) are placed in functional relationships with each other. This project was realized in the midst of the heightened interest and investment in interdisciplinary arts/engineering initiatives [4] that typefied 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. On the surface level, the performance, according to Gordon Mumma, came across as a "multi-ringed circus." [5] Beneath this surface, there is an intricate set of feedback loops amongst the deployed technologies. Dancers activate two sensor system arrays: 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, "'[f]urther 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...'"(4). Besides the organic, cybernetic connections between human *Körpermechanik* and the media technologies, there is an explicit resemblance to the list of "ingredients" in Moholy-Nagy's recipe for a Theater of Totality performance, and those incorpo-

[4] Exemplified by the Experiments in Art and Technology (E.A.T.) in New York, which brought together Bell Telephone Laboratories researchers such as Billy Klüver and Max Mathews, and artists such as Cage, Robert Rauschenberg, and David Tudor.

[5] 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.

rated into the *Variations V* scenario. [6]

Figure 2. Cage's *Variations V* performance configuration.

Described by the composer as "a composition for five pianos without a pianist, a play with no actors, a performance without performers,"(5) and as a "performative installation", in which objects serve as protagonists (6), Heiner Goebbels' 2007 work *Stifters Dinge* [7] 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. In addition, 1905 field recordings made by Austrian ethnographer Rudolf Pöch of songs and stories from Papua New Guinea (6), a traditional Greek lament, and the voices of Claude Lévi-Strauss, Willliam S. Burroughs, and Malcolm X are projected. 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 (5). Although *Stifters Dinge* is thematically human-centered, and replete with literary content, the absence of human performers, coupled with the fusion of media and 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.

Other more recent examples of notable works falling at the boundary music theater and installation are Icelandic composer David Brynjar Franzson's *Longitude* (2014) [8] and Taro Yasuno's "zombie opera" *Danse Macabre* (2015). In *Longitude*, "a monodrama for one performer, two stagehands, and five instruments" (7), the text (by Canadian writer Angela Rawlings) is not explicitly recited, but rather is used to sculpt the sounds produced by the instruments. The staging consists primarily of video and shadows, projection-mapped to screens. As in *Stifters Dinge*, Yasuno's opera makes use of automata instruments (in this case, clarinets, recorders, and other winds, activated by servo-motor-controlled

[6] A clip of the *Variations V* premiere may be viewed here: `https://www.youtube.com/watch?v=EqXM-EU1ncw` (accessed 06 February 2018).

[7] Excerpts of which may be viewed here: `https://www.youtube.com/watch?v=NKmaFLuELZo` (accessed 06 February 2018).

[8] From the 2014 Transart Festival: `https://www.youtube.com/watch?v=jE7qyHwPwcc` (accessed 06 February 2018).

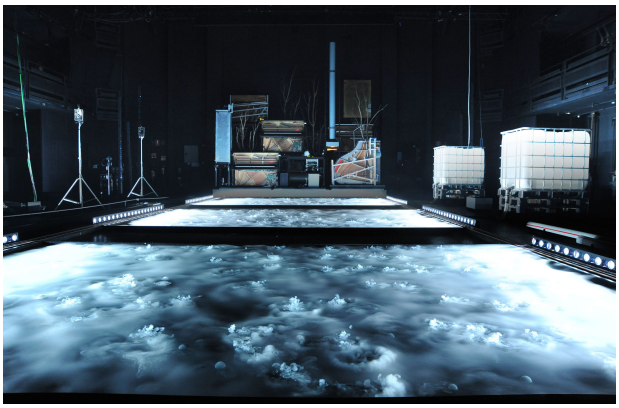

Figure 3. Heiner Goebbels' "performative installation" *Stifters Dinge*.

artificial fingers and a pressure-pump) [9] are distributed across a multi-layered stage set, as depicted in Figure 4 (8). Although human participants are present on stage (including the composer), it is the software-triggered instruments, stage architecture, and lighting/projected visuals that are placed in high relief. Fittingly, the actors quite literally play the role of servants to the machines. [10]

Figure 4. From Taro Yasuno's zombie opera *Danse Macabre*.

4. Defining Robot(ic)

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

[9] Demonstrated in this video: `https://www.youtube.com/watch?v=DMokRJ4Io4Y&t=5s` (accessed 06 February 2018).

[10] Several of these observations are based on the author's attendance of a performance of the opera in 2015.

- an android entity, emulating human behaviors and responses; manifesting *re-embodied cognition*, interacting with environment and other agents;
- an auxiliary, serving humanity, performing specific tasks;
- an augmentation of humanity; as *disembodied and expanded cognition*;
- a dynamic, cybernetic system; an evolving network of relations; and
- an alien entity/object of fantasy.

One could position these robot definitions along a gradient, ranging from dehumanized and mechanical automaton (and possible threat to humankind?) on one end, to anthropomorphic stand-in for humankind on the other. [11] 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 shall be discussed in the below examples of robot opera, given the multiple characterizations of robots—sometimes within the same piece—the boundary between anthropocentricity and techno-centricity becomes fuzzy. Furthermore, the extent to which robots are merely *imitating* conventions of human expressivity vs. developing their *own* modes of expression is at times unclear.

5. 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 Massachusetts Institute of Technology (MIT) Media Lab, *Death and the Powers* (2010) deals with themes of embodiment vs. disembodiment, modes of interaction with the environment and agents within that environment, and possible post-human futures. Simon Powers, the protagonist of the opera, 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. 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 (9; 10).

From the above synopsis, it is clear that the opera follows a linear storyline, as conveyed through former US Poet Laureate Robert Pinsky's libretto. 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). However, rather than serving as a mere backdrop to dramatic events, the media technologies employed 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" (9). One trio of bots, 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 [12] as sensitively as possible.

Nine so-called Operabots constitute a chorus (as shown in Figure 5), 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 post-human future in which they periodically re-tell/perform the story of Simon Powers, in order to gain insights on the nature of suffering and death in the Organic Age. [13] 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. In order 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 pre-programmed procedures to be overridden in real time by the robot control operators (9). While receiving input signals and commands from human performers, robot *interaction* with humans is a merely staged phenomenon. That is to say, they are governed neither by generative nor machine learning algorithms that would contribute a layer of unpredictability to the performance, and freedom for the robots.

The Chandelier serves as an antipode to the offstage human-onstage technology control dynamic exemplified by the bookcase periaktoi and the Operabots, and as a means for the Simon Powers' wife to retain a level of haptic contact with her "uploaded" husband. This object, presented in Figure 6, functions simultaneously as a lighting element and a NIME (new interface for musical expression). When the Teflon strings are activated, complex voice-sample-based and string-like sounds are emitted (9). In an abstract sense, this object represents the re-embodiment of a human presence, re-cast as a musical

[11] If one consults the Merriam-Webster definition of "robot," these extremes of the continuum are both represented.

[12] James Maddalena, in the original production

[13] As is explained in the Prologue: `https://www.youtube.com/watch?v=Myd2DdSxUEk` (accessed 08 February 2018).

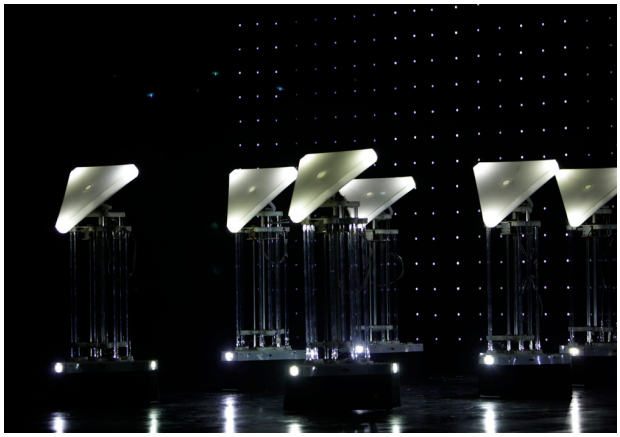

Figure 5. *Death and the Powers* chorus of Operabots.

instrument...but is ultimately a weak compromise between organic life-form and System.

Figure 6. Simon Powers' wife Evvy (played by Patricia Risley), interacting with the Chandelier.

Consistent with Moholy-Nagy's mechanized eccentric concept is the coherent choreography of all media and objects employed in the production. [14] 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 actually *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*.

[14] Albeit making use of precision-engineered objects emerging from the MIT Media Lab, as opposed to objects from daily life.

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

In 2015, two notable and highly contrasting robot operas were realized: Australian artist Wade Marynowsky and composer/sound designer Julian Knowles' *Robot Opera*, and the Komische Oper Berlin production *My Square Lady*.

As a kind of cross between Machover's modified stage set bookcases and Operabots, the eight connected but independent robot "performers" designed by Marynowsky and creative performance team Branch Nebula each project sounds and display symbols via DMX and LED-array lighting systems, bearing little or no resemblance to human performers (see Figure 7). [15] In fact, in a manner anathema to MIT Media Lab Opera of the Future design principles, the internal components of these constructions are entirely exposed, minimizing any association with android/automaton stereotypes. Like the *Death and the Powers* robots, they are tightly choreographed via a wireless network. However, the Marynowsky/Knowles' "opera" 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, there are two modes of robot control: either they operate according to pre-programmed algorithms("autonomous mode") or receive live input from the artists ("manual mode") (11; 12). There is also a "Follow" mode, in which the robots track audience members' current positions, and approach them (12). [16]

In contrast to *Death and the Powers*, the robots modify their behaviors based upon their interactions with the environment. In turn, audience members' movements are 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 pre-programmed robot to artist intermittently during the performance. Therefore, these robots are between categories: embodied without adapting human characteristics, but also non-autonomous and networked. Given both the absence of libretto (or literary themes) and the absence of a "fourth wall," amongst other attributes of the project, the affinities between Moholy-Nagy's theater of totality and *Robot Opera* are self-evident.

Gob Squad's *My Square Lady* follows a similar premise to *Death and the Powers*: a robot tries to understand opera and human emotion (empathy in particular). In this case, however, there is a single child-sized humanoid, learning 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 deploying neural network algorithms in real time),

[15] Arguably, the metallic voices in the audio are the most explicit reference to classic androids.

[16] Excerpts of the opera, with audience participation: `https://www.youtube.com/watch?v=eOgKzrsgb2s` (accessed 08 February 2018).

Figure 7. Wade Marynowsky's robots.

as opposed to the fictional and extended robot learning scenario in the Machover. 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 (14). [17]

Figure 8. Myon robot learning to conduct in *My Square Lady*.

Rather than using 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 of Humboldt University in Berlin by Manfred Hild and colleagues. [18] Designed for artificial language generation, Myon robots acquire names for physical postures and gestures through engaging in training with other robots or with humans. [19] Myon effectively trains first on itself, uses 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/degrees of freedom of components 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 (14). 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 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.

7. Hear and Nao: The 2017 University of Sussex CROMT Robot Opera Mini Symposium

7.1. Robot Opera Project Background: The Nao Robot

Last year, Evelyn Ficarra, Assistant Director of the Centre for Research in Opera and Music Theatre (CROMT) at the University of Sussex, launched an interdisciplinary robot opera creation project, in collaboration with Ron Chrisley, Director of Sussex's Centre for Cognitive Science (COGS). As was the case for *My Square Lady*, the Sussex team re-purposed a model of humanoid robot not originally intended for musical contexts. In this instance, Nao robots, originally developed by Aldebaran Robotics, [20] were utilized. In June 2017, a symposium consisting of performances, presentations, and discussions "about the

[17] Excerpts may be viewed here: `https://www.youtube.com/watch?v=49rJMgJY1CU` The rehearsal process and collaborator backgrounds: `https://www.youtube.com/watch?v=EaFq85aGSPs` (accessed 09 February 2018).

[18] Hild appears in the *My Square Lady*, where he trains the robot, and even sings to it.

[19] As is demonstrated in this video: `https://www.youtube.com/watch?v=Qh2yT-AL1V8` (accessed 09 February 2018).

[20] Later acquired by Softbank Robotics.

philosophy and potential impact of artificial intelligence and the arts" (15) was held at Sussex.

In contrast to 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 has primarily been employed in educational, clinical, and research contexts, but, as the CROMT project demonstrates, are by no means limited to these domains (16).

As Ficarra explains: "'If, in the near future, we are expecting to see robots used as care workers or teaching assistants, then we need to teach them to understand and respond appropriately to humans. The virtues of the musician—listening, co-operation, 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 post human performance, the work could have interesting implications for research in artificial intelligence and social robots"' (17).

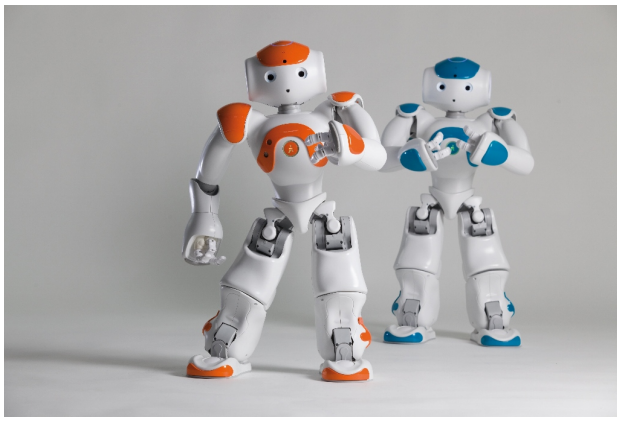

Figure 9. A pair of Nao robots.

7.2. The Operas and Collaborative Process

To initiate the project, project director Evelyn Ficarra and Sussex Composition professor Ed Hughes each composed a five-minute work for two Nao robots and cello, with intimate, minimal staging (see Figure 10). 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 (English) text is of a self-reflective nature, consisting of statements such as "I am not a robot." Hughes'

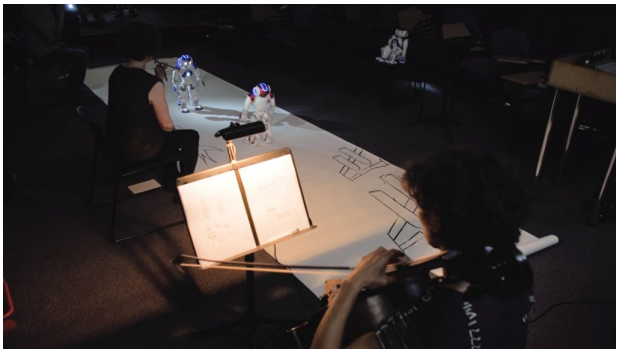

Figure 10. Nao robots in performance at Sussex.

Opposite of Familiarity sets a libretto by Eleanor Knight. [21] For both operas, it was decided by the composers, 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 (17). These outcomes spurred of the fundamental questions surrounding the project: what does it mean for a robot to sing, listen, and 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? This topic, amongst others, was addressed over the course of the mini-symposium.

7.3. Robot Opera Symposium Themes: Anthropophony, (Dis)embodiment, and Robot Performance

The paper session component of the symposium consisted of an introduction by Evelyn Ficarra, followed by presentations by Ron Chrisley, PhD Researcher Thanos Polymeneas-Liontiris, and Chris Kiefer, Lecturer in Music Technology. Ficarra summarized the motivations for the project, and remarked upon the recent resurgence in popularity of labeling compositions as "operas," even in the absence of musical performers. From the post-war 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 re-gravitation towards opera as a genre, coupled with rapid developments in artificial intelligence and

[21] The performances in their entirety of the Hughes and Ficarra operas (respectively) may be found at the beginning and end (from 1:05:53) of the video embedded in the Robot Symposium documentation: `http://www.sussex.ac.uk/cromt/archive/documentation` (accessed 11 February 2018).

robotics of the past few years, this project has been of particular relevance.

In his talk "What would it be for a robot to sing?," Chrisley draws upon not only 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. After distinguishing between operas *about* robots or directed by robots [22] and operas *with* robots as singing performers, he 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 in 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.

Polymeneas-Liontiris discusses his work *A Magnificent Crossbreeding of Protein and Tinplate*, scored for virtual instruments and Vocaloid-driven "robotic" voices. [23] Unlike the robot operas of Ficarra and Hughes, this piece is scored for disembodied, virtual performers. Nonetheless, the use of generative algorithms, and considerations of anthropomorphy vs. anthropophony (human-like sound), which the composer addresses, are also central 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 robot opera productions has been *My Square Lady*. However, in the case of the Myon robot, 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/preparation process. Chris Kiefer, who has a history of designing controllers and interactive systems responding to too large or complex an array of data than a user 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 do not only assume the form of output motor commands, but many also be represented by "imagining" responses to a given visual, auditory, or tactile (sensor) input. 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 is the rehearsal process, 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., under-fitting/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. However, there exists 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 (18).

The symposium participants thus drew attention to and analyzed 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 anthropocentric/techno-centric divide is an uncertain one for the Ficarra and Hughes operas, but for exactly the opposite reasons. While the Machover and his research group were dealing with the *disembodiment* of the human, and the (indirect) mapping of human vocalizations and physical gestures to non-humanoid robot agents, *O, One* and *Opposite of Familiarity* were composed for the vocalizations and gestures unique to an embodied, autonomous humanoid.

8. Conclusion and Future Directions

When making precise comparisons amongst works falling under the rubric of "robot opera," and examining the range of design, hardware, and software specifications distinguishing the various types of robots employed from each other, it becomes evident that this is not a mere gimmick or sub-genre, but rather an expanded field of possibilities. Furthermore, using staged/performance-installation works of the past several several decades in which human presence is reduced (or entirely absent), and media technologies are placed in the foreground as reference points is instructive for the purposes of 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/"post-human" 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 (as in the case of *A Magnificent Crossbreeding of Protein and Tinplate*) could be just as effective in a music theater context as the programming

[22] E.g.: `https://www.youtube.com/watch?v=HYfWRQDHYlM` (accessed 11 February 2018).

[23] Similar to the Vocaloid model behind Japanese virtual singer Hatsune Miku: `https://www.youtube.com/watch?v=jhl5afLEKdo` (accessed 11 February 2018).

of environmentally-sensitive embodied agents. As the domains of AI and robotics continue to evolve, it would be of great interest to witness the innovative integration of machine learning in multiple dimensions of staged productions, and/or to connect the use of machine learning algorithms in the compositional and performance processes. 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.

9. Acknowledgements

The author wishes to thank Dr. Evelyn Ficarra for her valuable insights on the University of Sussex CROMT Robot Opera Mini Symposium.

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10. Author's Profile

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Alexander Sigman's award-winning instrumental, electroacoustic, multimedia, and installation works have been featured on major international festivals, exhibitions, institutions, and venues across Europe, Asia, Australia, and North America. He has been awarded residency fellowships by the Akademie Schloss Solitude (Stuttgart, Germany), the Djerassi Foundation, the Paul Dresher Ensemble Artists Residency Center, and Gullkistan (Laugarvatn, Iceland). In 2013-2014, he undertook a musical research residency at IRCAM. Recent festival and conference performances have included the 2017 International Computer Music Conference (Shanghai), the 2016 Sound and Music Computing Conference (Hamburg), the NWEAMO Festival (Tokyo and San Diego), and Dark Music Days (Reykjavik). His two-disc recording of audiovisual works entitled *fcremap* was released in November 2017 on New Focus Recordings. He is currently Associate Professor and Chair of the Music program at the International College of Liberal Arts (iCLA) of Yamanashi Gakuin University in Kofu, Japan.

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