DEUS EX MACHINA

Towards an Aesthetics of Autonomous and Semi-Autonomous Machines

by

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Robots and puppets are linked by a common human impulse: the desire to give life to nonliving objects through the animation of material forms. Like puppets, robots are technological objects capable of revealing aspects of the human experience and have demonstrated the ability to provoke the suspension of disbelief and evoke agency. While the role of puppets and automata in theatre history is well established (Segel 1995, Jurkowski 1996, Reilly 2011), the study of robots in theatre performance is largely unexamined. Citing the presence of autonomous and semi-autonomous machines in live performance and technological developments that result in increasingly responsive and interactive robots, I argue that these technological players warrant critical investigation and study of their methods of representation.

Given their ontological link, I use puppetry to construct a phenomenological understanding of robots by considering the following questions: "Does robotic performance constitute a creative act?" and "Can engineers use puppetry to develop robots that better exhibit behaviors are identified with creative performance?" Using States' concept of "binocular vision" and Dennett's concept of "intentional systems," I propose that robots evoke agency by demonstrating expressive and responsive behaviors. Contrary to the imitative approach which uses realism and life-like features as a starting point, I suggest that engineers adopt the method of puppetry which utilizes movement as the primary means of expression. This approach results in machines that produce motions that appear less rigid and mechanical and are more likely to avoid the Uncanny Valley (Mori 1970).

Citing recent theatrical productions (*How to Train Your Dragon*, *King Kong*), and my contributions to a robotic marionette system (*Pygmalion Project*), I outline how entertainment robotics can use puppetry-inspired choices to create intuitive interfaces for designing and operating robots. I advocate for an approach that acknowledges binocular vision and minimizes the role of mechanical reproduction in favor of essential and abstracted movements. For tele-operated machines, I propose a gesture-based control system that more tightly couples the interaction of the operator's motions with those of the puppet. I anticipate that these methods will lead to robots that are more dynamic and more likely to evoke agency.

For Ravenna & Saar

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Art lies halfway between scientific knowledge and mythical or magical thought.

-Claude Lévi-Strauss

CHAPTER I

INTRODUCTION

In *Theatre, Performance, and Technology* Christopher Baugh traces the important links between scientific discoveries, technical developments, and their presentation throughout theatre history by calling attention to the profound ways in which science and technology have contributed to evolving modes of narrative and representation:

> Our thinking, our philosophies, and modes of expression and understanding of humanity have been frequently governed by current technology and the capabilities of machinery. […] Inevitably, therefore, technologies used in theatre and performance cannot exist in isolation from the larger issues of natural philosophy and science that, since Copernicus and Galileo, have attempted to explain the existence of the world, the behavior of materials and objects, and of humanity. (Baugh 8)

Technological innovation and theatrical representation have been linked since the beginning of theatre history: from the use of *mechane* and *deus ex machina* on classical Greek stages to the staging of humanoid robots in contemporary productions, the use of emerging technologies in live performance reflects the shifting complexities of human values and beliefs concerning scientific discovery and technological innovation. In theatre and performance studies scholarship, technology has traditionally been studied as a tool or embellishment that modifies the materiality of the human performer or conditions of the performance space, but has rarely been considered as the subject or originator of performance.[1]

In this study, I expand the definition of performance to include performances by robots and machines, and I develop an aesthetic framework for considering autonomous and semi-autonomous machines used in live performance. In particular, I call attention to the methods through which robots can evoke agency and generate performances that emulate the fundamental characteristics of live performance. As emerging technologies lead to more expressive and responsive machines, robotic performances challenge the way we have hitherto considered the aesthetics of inanimate objects, raising questions about agency and a machine's ability to generate a work of art. Understanding how theatre artists have historically envisioned and employed machines onstage and how engineers have sought to imitate life through mechanical means reveals much about our evolving and complex relationship to technology and the human proclivity for creating artificial life. The study of autonomous and semi-autonomous machines also raises important questions concerning human agency, intentionality, and aesthetics.

One of the key questions that robotic performers provoke is agency. If machines are to convincingly emulate aspects of human performance without appearing rote or perfunctory, they must demonstrate an ability to think and act independently in the world. In other words, inanimate objects must be designed so that they are perceived as intentional systems. Artificial Intelligence philosopher

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[1]See Baugh 2005; Bay-Cheng 2010; and Salter 2010.

D.C. Dennett defines "intentional systems" as those "whose behavior can be (at least sometimes) explained and predicted by relying on ascriptions to the system of beliefs and desires" (Dennett 87). Dennett proposes that a system can be designated intentional when it provokes the spectator to adopt an intentional stance toward the object. The intentional stance is essential to an object's ability to evoke agency and be perceived as autonomous, which in turn promotes and sustains human-machine interaction. Applying Dennett's concept of intentional systems to autonomous and semi-autonomous machines used in theatre performance, I propose that inanimate objects evoke agency through a dialectical process that depends on the object's kinetic behaviors and the spectator's strategies to understand and predict the behavior of the performing object. Viewed this way, we might say that all robots inherently perform an "act" of autonomy: unlike automata, robots are designed to move and operate in the world independently from a human operator. The degree to which a robot signals agency depends on the spectator's strategy to understand and predict its behavior and the degree to which the engineer's role is foregrounded or hidden. If robots are to engage live audiences the way that human performers do, they must be designed and animated so that they are perceived as intentional systems.

Until recently, robots used in live performances have not been considered intentional systems because their behaviors have not been sufficiently expressive or responsive. As such, performances by autonomous and semi-autonomous machines have largely been overlooked in theatre scholarship, except when cited as visual symbols that explore humanity's relationship to technology (Kang 2011; Reilly 2011) or as metaphors to explain the cultural and gendered politics of technology (Huyssen 1986; Haraway 2010; Parker-Starbuck 2011). As a result, the majority of scholarly research on performing machines is generated and discussed in the fields of engineering and computer science.[2] Because of the institutional structures that distance these fields from theatre and performance scholarship (research on autonomous machines generally appears in technical journals and conference proceedings that target engineering audiences), significant developments in robotics, automation, and animation often go unnoticed by theatre scholars and the study of performance aesthetics. Often, it is only after a new technology or device has been appropriated by an artist that scholars begin to analyze the technology and its effects on performance. This retroactive approach prevents thoughtful interrogation of the machine as performer. By examining how theatre artists have historically envisioned machines onstage and how engineers have approached the task of automating human and animal motions, I hope to recast autonomous and semi-autonomous machines as subjects of theatrical performances worthy of scholarly attention and philosophical insight.

[2] The field of music is a notable exception. There are numerous research programs that combine computer science and engineering with music (such as Stanford University's Center for Computer Research in Music and Acoustics and Berkeley's Center for New Media and Acoustic Technologies), and the Computer Music Journal (MIT Press) is an established resource for musicians, composers, engineers, and computer scientists. While it is possible to argue that the United States Institute for Theatre Technology (USITT) and the International Organization of Scenographers, Theatre Architects, and Technicians (OISTAT) are important sites for research in theatre and engineering developments, the reach of this work generally does not extend to scholarly consideration of performance aesthetics.

Because of the overwhelming similarities that puppets and robots share, I use puppetry as a lens for interpreting performances by autonomous and semi-autonomous machines. Citing my contributions to the *Pygmalion Project*, a collaboration with Northwestern University and Disney Research to develop an automated marionette platform, and other robotic performances, I offer a theory for designing entertainment robots that are more expressive and responsive than traditional animatronics and therefore more likely to provoke the intentional stance and evoke agency. I propose that the use of puppetry-based approaches for designing and controlling robots may result in more dynamic and interactive machines. While scholars might be reluctant to identify these machines as creative, they do begin to overcome some of the challenges that have hitherto plagued traditional entertainment robots. I outline some methods for how engineers might use puppetry-inspired design choices to create autonomous and semi-autonomous machines that are more likely to be perceived as intentional systems.

Through the artful imitation of human and animal motions—using either the techniques of traditional puppetry (inanimate objects operated through direct human manipulation) or automated motion (inanimate objects that move autonomously)—inanimate objects create compelling illusions of life because of the phenomenological stance that theatre provokes. Theatre scholar Bert States refers to this stance as "binocular vision" where the spectator may "hold in mind two categories—that of the real and that of the imaginary—that are fused into a single phenomenon" (States 1985:169). Binocular vision is what enables an audience to perceive at once the simultaneous and complex realities of the human actor and the character being portrayed without experiencing uncertainty with regards to the real and the imagined worlds. States' concept of binocular vision is not dissimilar to Dennett's idea of intentional systems: for Dennett, a system can be described as intentional only if it provokes the spectator to adopt an intentional stance, where the spectator construes the behavior of an object to be intentional and motivated by the object's own belief or acting according to its own desire (87). The intentional stance and binocular vision both rely on the strategies of the spectator to actively seek to understand and predict the behavior of the object of interest. Binocular vision is particularly pronounced in puppetry and productions that feature robot actors; however the nature of the theatrical illusion is problematized because, unlike human actors, puppets and robots are inanimate material objects that simultaneously occlude and expose their artificiality (Ghedini and Bergamasco 2010). This paradox presents a challenge for puppets and for entertainment robots in particular: they either risk appearing frightful or uncanny because of their uncertain status (animate/inanimate), or they are dismissed as dull and perfunctory because they fail to interact with the world in a meaningful way.

While a human actor never has to prove their "liveness" to a spectator, robots and puppets hover in a liminal space between the animate and the inanimate and must therefore work differently than human actors to provoke binocular vision. In marionette puppetry, puppeteers create the illusion of life by directing the dynamic swing motions of the marionette to generate motions that indicate human and animal motions but do not copy them. Conversely, robots and other animatronics have typically eschewed dynamic motions in favor of ultra-realistic design, which results in objects that look realistic but have a limited range of motion. This approach raises expectations about how believably and convincingly the object should be able to perform, challenging the spectator's binocular vision by presenting an illusion of life that can sometimes appear frightful or uncanny.

Thus, the designers of entertainment robots face two significant challenges: 1) overcoming uncertainty about the liveness of an object and 2) generating behavior that is both expressive and responsive. Puppets are not only metaphors for thinking about how to imitate expressive and responsive behaviors, they provide a rigorous method for designing and testing these behaviors. Puppets are physical objects onto which we can map our own emotional experiences and responses, and the semiotic study of puppetry provides an established conceptual framework for understanding how inanimate objects function aesthetically in performance (Proschan 1983; Jurkowski 1983). As such, puppets make an ideal test-bed for exploring relevant questions in robotics, and may inspire new approaches to the design of entertainment robots. Engineers might learn from puppetry how to create compelling theatrical illusions that avoid appearing uncanny or dull and provoke the intentional stance. Once we have defined which behaviors are essential to creative performance and identified which techniques best demonstrate these behaviors, we can then approach the question of whether or not something like creativity can emerge from artificial systems.

Traditional puppets— which puppet scholar Henryk Jurkowski defines as an acting subject that makes temporal use of motor and rumoristic (sound) sources of power that are outside it (Jurkowski 1988, 55)— avoid appearing uncanny because of the implied presence of a human operator and an aesthetic that privileges abstraction over physical realism and verisimilitude. In other words, because puppets are controlled by outside agents and are rarely mistaken for actual human beings, they usually do not provoke strong feelings of the uncanny.

Freud defined the uncanny as the emotional response of fear or dread that arises from an encounter with a person or object that provokes doubt about its liveness (Freud 1919). Recognizing the implication for robotics, Masahiro Mori coined the term "Uncanny Valley" to define this problem for engineers: we delight in the illusion of inanimate objects that appear to be alive, such as dolls and puppets, but if a performing object reaches a remarkable likeness without actually achieving liveness, the illusion is no longer pleasurable but disturbing (Figure 1). Unlike robots, traditional puppets can avoid the Uncanny Valley in part because they are controlled by a separate agent. Because a puppet never has to convince a spectator of its autonomy—the puppeteer's presence is implied even when unseen by the audience—we can enjoy the illusion without experiencing uncertainty about the puppet's liveness. The puppet is always a passive, inanimate object controlled by a human operator, and we usually do not experience cognitive dissonance when face with a puppet.

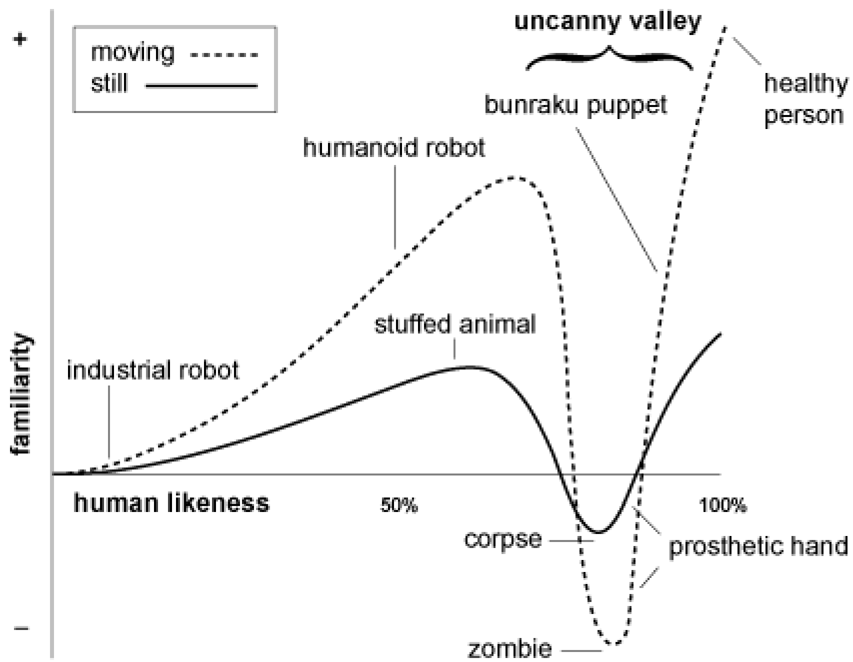

Figure 1. The Uncanny Valley. Mori illustrated the paradox of realistic-looking robots: if as a lifelike robot becomes more realistic without actually achieving "liveness," the object becomes too frightening to appear relatable or be enjoyed.

The illusion of artificial life in puppetry therefore relies on binocular vision that simultaneously affirms the inanimate nature of the objet (the puppet announces its puppet-ness), enabling it to bypass the Uncanny Valley problem. In this way, puppets evoke agency by encouraging the spectator to adopt an intentional stance towards the inanimate object in spite of its artificial or inanimate status. A robotic actor, however, always risks appearing uncanny because it is designed to perform independently from its human programmer. Even when we know a robot is controlled by a human operator (for example via remote-control), its ontological status as a machine purposefully designed to function autonomously in the real world forces the spectator to adopt a more critical stance towards the object. For robots, binocular vision is still present, but the threshold for proving liveness is much higher. Puppeteer Basil Jones has suggested that a puppet's struggle for life is the "Ur-narrative" that underlies all puppetry (Jones in Taylor 2010, 263). We might extend this metaphor to robots by suggesting that the Ur-narrative of autonomous robots is the struggle to demonstrate autonomy and prove their liveness.

On stage, a robot actor must work differently than a puppet to encourage spectators to adopt the intentional stance. Robots that are designed to realistically resemble living creatures are more likely to appear uncanny because their physical verisimilitude raises high expectations about how believably and convincingly the object should perform. The ultra-realistic humanoid robot *Geminoid F*, developed by Hiroshi Ishiguro at Osaka University physically resembles a real human being but its mechanical and jerky movements stand contrast with the ultra-realistic, "lifelike" appearance. The artificial quality of the movements disrupts the visual experience of the object, making it difficult for the object to sustain the illusion of life that its physical appearance provokes. The combination of realistic appearance with unrealistic motions disrupts the spectator's experience of the object because of the uncertainty surrounding the object's status. In order to create compelling theatrical illusions and sociable robots that promote human-robot interaction, engineers must design robots that are aesthetically interesting, interactive, and avoid the Uncanny Valley. Historically, this challenge has been discussed in terms of mimesis, or whether or not to build robots that realistically resemble human beings. But mimesis is not the only factor that contributes to a robot's uncanniness or an automated machine's ability to create compelling theatrical illusions.

Theatre is rooted in mimesis, but it is also a kinetic art. The physical movement of actors—whether human or mechanical—is central to the act of mimesis. In both puppetry and robotics, expressive movement is integral to the theatrical illusion, influencing how deftly the illusion of life is created and sustained. Citing the significance of dance in contemporary performance and scholarship, Joseph Roach has observed that "expressive movement is becoming a lingua franca, the basis of a newly experienced affective cognition and corporal empathy. Mimesis, rooted in drama, imitates action; kinesis embodies it," (Roach 2). Recognizing the importance of expressive movement to theatrical illusions, we might extend the metaphor of movement as a "lingua franca" for communication and interaction between humans and robots, and in particular for robotic actors tasked with mechanically imitating life.

A robot (or any autonomous or semi-autonomous machine used in performance) has two components: the physical design (the materials of construction, its outward appearance, and how it physically moves in the world) and how it is animated (what actions it performs, how it behaves). When designing entertainment robots, engineers must make decisions about how the robot should look and what functions to privilege. As in puppetry, the form and function of robots are tightly bound. Just as the theatrical illusion succeeds in part because of the audience's willingness to "suspend our belief in the empirical world and attend to a half-reality already 'reduced' by the premeditations and manipulations of a series of prior and present artists" (States 2007, 29), so must a robot performance engage the imagination to provoke binocular vision and the intentional stance. In theatre, reality and theatrical illusion are co-present, and in this space spectators are inclined *a priori* to project psychology and emotions onto inanimate objects, granting fictive life to characters or objects based on their behaviors and the performance setting. For a robot to appear expressive and responsive, it must be designed and animated in such a way that engages binocular vision and provokes a similar phenomenological stance.

Spectators have specific criteria for human performers and often measure human-shaped robots according to similar benchmarks. A successful theatrical illusion relies on the actor's ability to behave in accordance with the script and production (irrespective the genre) and in accordance with the evolving condition of the live event. In Chapter Two, I use Fisher-Lichte's description of theatre as a feedback loop that involves both the actors and the spectators to describe this interaction: the theatrical illusion is created mutually and shaped in part by the audience's expectations of the performer. When a robot takes the place of a human actor, the spectator places similar expectations on the inanimate object as for the human actor: the spectator expects the robot to be expressive and responsive to the environment, to the other characters, and to the audience. These behaviors—expressivity and responsiveness—are ultimately more significant to provoking the intentional stance than whether the object physically resembles the living creature it aims to represent. In other words, kinesis is the new mimesis.

Mimicking these two vital aspects of human performance is an extraordinarily difficult task, and robots have typically not done a good job at it. It should not then come as a surprise that theatre scholarship has largely ignored performances by machines and robots, leaving these technologies to be explored in other areas where they are more creatively and successfully employed—among them visual art, music, and engineering (Burnham 1968; Roads 1989; Kac 2005). However, the field of puppetry has a rich history of varied approaches to creating movement that suggests the illusion of life. Through creative movement, puppets have continually demonstrated the reliable ability to provoke the intentional stance and even evoke agency.

From the perspective of movement, puppets are interesting because they partly resist a puppeteer's attempts to direct them: to create the illusion of life puppeteers are forced to reach a compromise with the puppet. This tension was explored in Heinrich von Kleist's 1810 essay "Über das Marionettentheater," here summarized by Kenneth Gross:

> The puppeteer knows he cannot control each limb separately, and thereby imitate in perfect detail the natural movements of human bodies. Rather, the manipulator learns to yield himself to the specific weight, the pendular motion and momentum of that thing suspended from strings. That's where the puppet's soul is found, in its merely physical center of gravity, which is the line of its spirit. (Gross 63)

The puppet's power of artistic expression is not determined by how well it mimics human behavior, but rather by its ability to abstract the human experience and throw it into a type of relief, offering an artistic projection of a recognizable world from which we are partly or wholly free. For marionettes, puppeteers have developed approaches that enable them to balance the dynamics of the puppet against the need to execute expressive choreography that convincingly imitates—but does not replicate—human and animal motion. This approach has led to dynamic and expressive movements that create remarkable illusions of life, prompting some theatre scholars to celebrate the marionette as an ideal model for human actors (Kleist 1890; Craig 1911). These theories are considered more fully in Chapters Two and Three. Despite some praise for the mechanical qualities of puppets, robots and animatronics are usually perceived as perfunctory and soulless. How might one account for this discrepancy? Puppets and robots both use realism as their starting point, but unlike automata and robotics, puppets do not aim at precise mimicry or imitation. They are therefore capable of creating the illusion of life (or a different kind of life) in ways that pure mechanical replication cannot. For this reason, I anticipate that entertainment robots will benefit from incorporating puppet-inspired design choices.

Traditionally, engineers have approached the task of imitating movement through mechanization, powering the motions of robotic limbs through individual motors or hydraulics located inside the puppet.[3] Because of the tremendous difficulty of reproducing complex movements such as walking or dancing, robots designed for entertainment are usually heavily stabilized and equipped with a

[3]Puppet scholar Hans Richard Puschke has speculated that the puppets of ancient Greece were originally mechanical or partly mechanical figures that moved through invisible threads hidden within the puppets (Jurkowski 1996, 1:43). This argument is more fully considered in the next chapter.

limited set of pre-programmed gestures or animations. These animations can be performed by direct control (sometimes called direct-driven, where a human operator tele-operates the machine remotely with a joystick, keyboard, or through other sensing technologies) or they can be fully scripted (according to a program that runs using a computer). The reliance on a reduced set of behaviors ensures that the robotic actors are reliable and stable, but the mechanisms involved with replicating the motions make the robots heavy and difficult to work with. Robots designed to mimic realistic motions requires separate motors and controls for each motion, and this often requires more than one puppeteer to control them. Because of the mechanics involved, attempts to realistically mimic facial expressions and refined gestures result in jerky, mechanical-looking motions that appear uncanny or inartistic. Engineers who wish to develop mechanical performers that are better able to imitate the human experience can learn to create the illusion of life through other means. The initial findings of the *Pygmalion Project* (presented in Chapter Four) suggest that one way to achieve this is through dynamic motion that does not aim at precise mimicry. In the project, we use puppetry as a model for creating expressive automated robots that avoid the limitations of conventionally automated figures.

I have suggested that robots used in performance incur high expectations from human audiences. In addition to being both expressive and responsive, entertainment robots should be safe, stable, and reliable. These are necessary conditions for any robot used in a performance setting, particularly if the robots come into close proximity with other actors or audiences. However, these traits can sometimes be at odds with one another, forcing engineers to make decisions about how best to design systems that create and sustain compelling theatrical illusions while considering safety and reproducibility. These decisions usually involve some sort of trade-off for designing physically robust systems with less dynamic behaviors, or relying on a reduced set of expressive behaviors such as facial gestures or speech rather than more dynamic and expressive motions. Not surprisingly, robots on stage rarely capture our imaginations or compel us to suspend our disbelief in the ways that human actors do. This is partly because of the high expectations we place on them, and partly because the reduced set of behaviors fail to convincingly imitate life or provoke the intentional stance. Thus, the physical and technical limitations of robots loom large in any encounter that asks us to conceive of entertainment robots as autonomous, and results in what I refer to as a "kinematic version of the Uncanny Valley" where the kinematic[4] motions of the robot and the attending rigidity disrupt our experience of the robot as an intentional system. Put simply, robots designed for entertainment must work harder and work *differently* than humans or puppets to create compelling theatrical illusions and evoke agency.

This study is chiefly concerned with efforts to create expressive and responsive behaviors in entertainment robots designed for aesthetic and mimetic experiences, and not household robots or other types of utilitarian machines. However, given the

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[4] Kinematics is the branch of mechanics that studies the motion of a body or system of bodies without consideration given to its mass or the forces acting on it. Kinematic motion is used to describe the motions of systems comprised of jointed parts, and is distinguished from dynamic motion.

ubiquity of (and our subsequent familiarity with) robots in non-performance settings, it is useful to consider how to define expressive and responsive behaviors in inanimate objects, especially in light of the human tendency to anthropomorphize moving objects (Demers and Horakava 2008). In general, we associate responsiveness with interactive and spontaneous behaviors, which can be achieved by embedding a robot with sensors to trigger specific actions based on input from a human user or the environment. Typically, we do not expect (or even wish!) for our blender to be expressive or spontaneous; however we do want it to responsive to our input, for example, when we press the "on" switch. We also know from experience that sophisticated sensing technologies do not necessarily correspond to inherently expressive or artistic behavior: the use of motion sensors to automate lights in our living room is probably not enough to sustain aesthetic interest.

For an art object to be compelling, it must offer an artistic projection that corresponds in some way to a recognizable life (or, like puppets, a different kind of life). Regardless of whether it is intentional or unconscious, this artistic projection must prompt some sort of critical reflection with regards to the overall aesthetic of the object or the experience, which is precisely that which distinguishes a machine's aesthetic function from its utilitarian function. Susanne Langer's definition of art provides a useful way of distinguishing aesthetic function from utilitarian function: in *Feeling and Form* she defines art as "the creation of forms symbolic of human feeling," and suggests that a work of art contains within it a certain creative principle that distinguishes it from other forms. This issue is considered more fully in Chapter Two. The distinction I want to make here is between robots designed with an impulse towards evoking this creative principle and those that evoke a utilitarian principle. In order to be perceived as intentional, the object (actor, puppet, or robot) must create the illusion that the observed behavior is somehow related to the object's beliefs, desires, or ability to act in the world. The combination of binocular vision and intentional stance is what promotes a sustained interaction between spectator and the inanimate object, and enables that object to be perceived as creative.

When engineers use realism as a starting point for designing robots, they often consider the potential uncanniness of the object, which we have defined as the spectator's momentary uncertainty about the liveness of the object. This uncertainty can provoke fear or anxiety, disrupting the spectator's experience and influencing their interaction with the object. (Mori uses the examples of a zombie or an ultra-realistic prosthetic hand to illustrate this point). However, there is another aspect to uncanniness that has nothing to do with how realistic a thing looks, but with whether or not the object is perceived as intentional. Consider the example of the household blender: if the device were to suddenly switch on while the spectator/user is seated on the other side of the room, one might describe the object as having "a life of its own."[5] When we are unable to determine the source of power, or figure out a causal relationship between a moving object and the forces that

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[5] Turkle *et al*. cite the 1960 study by Swiss psychologist Jean Piaget, *The Child's Conception of the World*, to explain this anthropomorphizing tendency in children: "…Piaget studied how children reasoned about the question of aliveness, he found that they gradually came to define life in terms of autonomous physical motion. Things that moved on their own accord were alive. Gradually, children refined the notion of "moving of one's own accord" to mean the 'life motions' of breathing and metabolism" (Turkle et al. 322).

animate it, we become afraid and this impacts our willingness to interact with the object. In the study of human-machine interaction, a human user's willingness to interact with a machine or computer is known as compliance. The uncanny-factor increases when the object is realistic-looking and visually approaches human or animal likeness, as for example, a realistic looking prosthetic hand that appears to move spontaneously. Once we ascertain that the seemingly spontaneous movement is triggered by a sensor or a timer, we cease to be afraid or uncertain and can instead delight in the moving object and the "appearance" of autonomy. However, we are no longer willing (or perhaps even able) to perceive the object as an intentional system: the robot's behavior can no longer be presumed to be based on its beliefs, desires, or ability to act in the world.

The situation changes slightly when an inanimate object is truly autonomous, that is, designed to respond to external inputs (rather than run a pre-determined script) in a way that demonstrates what robotics expert Rodney Brooks calls "emergent behavior" where "the intelligence of the system emerges from the system's interactions with the world and from sometimes indirect interactions between its components" (Steels and Brooks 29). How do we intellectually and emotionally reconcile the behavior of autonomous and semi-autonomous machines moving and performing in our world? Let us imagine (following Brooks' example) a team of small autonomous robots tasked with cleaning a room: when we observe these machines operating independently and moving simultaneously throughout a space to execute a shared task, we might adopt the intentional stance towards the objects and perceive them as intentional systems. We may even project personality or character traits onto the swarm or individual units, for example, if a single robot is "left behind" or becomes separated from the swarm.[6] In this example, the robots evoke agency because of two factors: the robot's ability to independently navigate the environment and the intentional stance the spectator adopts when perceiving the objects in motion.

The point I am trying to make is that the theatrical double vision is provoked whenever a spectator encounters autonomous or semi-autonomous objects, and even in non-artistic settings: the spectator simultaneously recognizes the materiality of the object (a bunch of metal, wires, and silicon chip) and the symbol of what that thing might represent—which may momentarily extend beyond its utilitarian function. The nature of this double vision means that while we may know intellectually the object in front of us is not sentient, it appears as such because of the way it interacts with the world and the feelings/emotions/ideas that we project on to it. Even objects that are not realistic-looking or remotely anthropomorphic provoke this response because of the atmosphere that surrounds the object and the expectations that the spectator brings to the interaction. We might refer to this as the object's "situatedness." In performance, a combination of binocular vision and the intentional stance results in whether or not the object is perceived as alive. While engineers must consider the Uncanny Valley when creating realistic looking devices, they must also consider another type of uncanniness—how readily the physical movements of inanimate objects provoke the intentional stance.

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[6] This effect was observed in spectator's interacting with William Grey Walter's "turtle" shaped robots during the 1940's. The robots were equipped with simple sensor devices to avoid obstacles and to return docking station to recharge their batteries. See Brooks 2002.

In order for a robot to be considered autonomous, it must have some system for perceiving the world and interacting in it accordingly. In Artificial Intelligence (AI) research these traits are referred to as situatedness and embodiment and are the traits which distinguish robots from other mechanical devices and automata. Building a robot with a full perceptual model that approximates a human being's perception of the world is still a very challenging computational task. The task is further complicated by the enormous challenge of understanding the physical and mental process involved with human vision. The human eye perceives visual information in a way wholly different than that of a camera lens: when humans look at a vase of flowers on top of a table, we perceive those objects in relationship to one another and to ourselves, making certain assumptions based on our prior experience and understanding of the world. Humans don't merely see objects in front of us, they perceive them. Looking at the vase of flowers, we can see where the physical edges of the objects meet, and can make assumptions about the weight and quality of the materials, and intuit how to move the vase without disrupting the overall stability of the arrangement. Designing robots with "vision" capabilities is not at all the same thing as building robots that emulate human perception. For robots to demonstrate autonomy, they must be equipped with some perceptual model of the word and use this model to direct their actions towards some goal. While machines that have full perceptual models of the world do not yet exist, there are robots that are able to partially perceive the world around them and make independent decisions about how to behave in the changing circumstances of the real world.

In some cases, perceptual models of the world include inputs of physical information such as light, sound, and physical obstacles. In other cases, robots are equipped with perceptual models based on emotion-based systems, basing their reaction on prosody of a human voice, or the emotional reaction of a human being with whom it is interacting. This is known as affective computing, and one of the best known models for affective visual attention system was developed by Cynthia Breazeal for the sociable robot Kismet, developed at the MIT Media Lab (Breazeal 2002) and discussed in Chapter Four.

The technologies described above have resulted in robots that are capable of increasingly autonomous behaviors which are context-dependent and directly related to input from the environment. In short, robots are becoming more expressive and responsive, and these behaviors inevitably raise questions about how humans relate to these types of machines and new ideas concerning agency and consciousness. Just as earlier attempts to mechanically imitate life dangerously "trespassed on ground that was thought, insistently, to be the exclusive province of the living" (Woods 63), so do contemporary robots prompt similar discussions in the about a machine's ability to learn, grow, and acquire human social characteristics.

What happens when sophisticated robots engage in tasks that are not deliberately utilitarian, but rather involve some creative or artistic goal, such as performing a dance, composing a piece of music, or generating a painting? My aim is to consider situated, embodied robots in the context of live performance, and determine which conditions are necessary for these artificial creatures to be perceived as intentional systems capable of creative acts. Thus, I begin by considering two interrelated questions concerning entertainment robotics: 1) Does robotic performance constitute a creative act?, and 2) How can engineers use puppetry to develop robots that better exhibit behaviors that are identified with creative performance? My purpose is not to prove that robots are creative in the same way that human beings are creative, but rather to articulate the challenges of designing robotic actors that do not appear routine or boring and to identify possible solutions for designing robots that are more dynamic and aesthetically interesting.

While automata and robots have captured the imagination of playwrights and theatre artists, theatre history is scant on productions that feature autonomous or semi-autonomous acting machines doing anything remotely interesting (from an acting perspective) or complex (from an engineering perspective). In general, robot "actors" in theatre history can be divided into two categories: human beings that behave like robots and ready-made robots inserted into theatrical settings. In the former case, the situatedness and embodiment of the "robot" depends entirely on the human actor's ability to perceive and respond to their world. Fittingly, these productions (such as *R.U.R.*) have been considered in terms of dramatic representations of machines and technology and rarely in an engineering context.[7] Concerning the latter category, I have not yet located a single instance of a robot that is fully autonomous— that is independently able to perceive and navigate its environment— used in a theatre performance in a way that meaningfully contributes to the overall aesthetic composition (Hoffman's aforementioned play

[7] Karl Capek's *R.U.R* presented a vision of robots emoting and reacting to their environment, but the use of robots was only a conceit for presenting a dystopian vision of technology's threat to humanity.

relied on a human operator to control the robot directly). In short, there are not many examples of truly autonomous robots capable of expressive and responsive behaviors in theatrical productions.

While theatre scholars may be reluctant to consider robotic actors, there are many examples of engineers who have attempted to use theatre to design robots that appear creative. Guy Hoffman's 2006 study *Ensemble: Fluency and Embodiment for Robots Acting with Humans* uses acting theory to develop cognitive mechanisms for robots that enable them to "overcome the stop and go rigidity" of human-robot interaction (2007). Hoffman identifies features of Stanislavski-based acting theory—psycho-physical unity, the mechanism of mutual responsiveness, and the continuous inner monologue—as behaviors that are analogous to the staging of Artificial Intelligence: "like researchers in AI, actors construct minds by systematic investigations of intentions, actions, and motor processes with the proclaimed goal of artificially recreating human-like behavior." Hoffman's work with *AUR*, a non-anthropomorphic robotic desk lamp, is particularly relevant to the present study because he tests the program in a live theatre production and describes the control system almost exclusively in puppetry terms (Hoffman 2008). The play, *Talking with Vegetables* (which premiered in 2008 at MIT) is a rare example of a robot used on onstage in a live performance alongside other actors.

More recently, the 2010 opera *Death and the Powers* by Tod Machover (which premiered in Monaco with subsequent performances at the American Repertory Theatre and Chicago Opera Theatre) premiered a new technique called "Disembodied Performance," which relies on gestural, physiological, and vocal sensors to control robots and other moving set pieces (Topey 2009). The goal of "Disembodied Performance" is to use a human actor to control non-anthropomorphic machines in a live performance, using technology to mediate the actor's expressive body. Essentially, the actor is a puppeteer directing the movement of the object's from off stage using only physical gestures and voice. Because the onstage machines do not physically resemble a human shape, we can think of them as non-anthropomorphic avatars. The opera tells the story of Simon Powers, a successful business man who, preoccupied with his legacy and the desire to live forever, invents "The System," a method for downloading his persona into the environment. The goal of the production is to tell a story through the animation of inanimate objects, or to tell a story *through* technology (as opposed to using technology to only enhance the physical presence of an actor).

The production features a chorus of "Operabots" designed to move in choreographic phrases and function like a Greek chorus, while three large bookshelf *periaktoi*, and several interactive "hyperinstruments" that the actors manipulated and controlled during the performance. While the technology innovations are impressive, the machines themselves are not capable of generating an original performance: the robotic behaviors mediate the sound and gesture of the human actors and the resulting motions are meant to be interpreted as those of the character. Rather than evoking agency, the conceit of the drama demands that we constantly read the robot's behaviors as extensions of the human performer. While the objects may be viscerally engaging and provoke binocular vision, they do not ask to be perceived as intentional systems that are independent from the human agent controlling them. The play ends with all the robot characters transforming into humans (coincidentally not unlike Capek's *R.U.R.*), suggesting that the robots are gradual learning how to become more like humans. At present, the technology required to generate "Disembodied Performance" is still tied inextricably to the human performer.

When autonomous machines have appeared as actors on theatre stages, they are often discussed in historical terms by scholars that overlook their use in contemporary performance. Kara Reilly's *Automata and Mimesis on the Stage of Theatre History* (2011) examines the influence of automata on theatre and intellectual history from the Renaissance through the end of the First World War, and Minsoo Kang's 2011 *Sublime Dreams of Living Machines* traces the Western fascination with automata from antiquity through the Industrial Age. Both studies end prior to the advent of digital computing, cybernetics, and Artificial Intelligence research. In other words, the research on robots and theatre ends just as robots are becoming more interesting—that is, capable of expressive and responsive behaviors with greater verisimilitude and complex programming that leads to emergence.

Just because there are not yet examples of autonomous machines performing onstage does not mean that there aren't robots that are equipped with some of these capabilities. Semi-autonomous robots are machines that can be direct-driven but are equipped with sensing technologies (such as vision or speech) and able to generate motions and behaviors algorithmically based on some input from the environment (context-dependent). We might think of these robots as a hybrid form of traditional puppetry and animatronics. Hoffman's *AUR* is an example of a semi-autonomous machine which can be direct-driven, but could potentially be automated to perform without a human operator. Given the available technologies and the longstanding interest in creating machines that reproduce human performances, it is not difficult to imagine the presence of more dynamic and interactive machines on performance stages in the near future. This presents the occasion to reconsider the parameters of live performance and the aesthetics of autonomous and semi-autonomous machines, and engage in a discussion of what types of design and kinetic behaviors are more likely to result in systems that are perceived as intentional.

In the 1950's and 60's industrial robotics were quickly appropriated for animatronics—plastic shaped figures were placed over mechanical arms with limited degrees of freedom, and this quick implementation resulted in what I have already described as a kinetic version of the Uncanny Valley and the broad conception of animatronics as dull and predictable (Moravec 25). Interactive robots that are equipped with sensing technologies and programming based on affective behavior and perception modeling are changing the way that humans interact with machines. There is also evidence that these technologies are resulting in more interactive animatronics: the dinosaur robots in *Walking with the Dinosaurs* are equipped with infrared sensors that trigger certain behaviors based on conditions of the live event (Millar, P. 2013). This is a unique moment to consider how these new types of robots can (and should) be designed to provoke the intentional stance and evoke agency before such objects are used in performance. Puppets provide a powerful framework for this discussion.

The 2012 edition of the magazine *Robotics and Automation* did not feature a robot on its cover, but rather a picture of a traditional Japanese *bunraku* puppet framed by the title "Manipulation and Imitation." The cover story was the Uncanny Valley, and included an interview with Mori on the enduring appeal of his 1970 essay. Originally published in the little-known journal *Energy*, the essay received almost no attention when it was initially published, but has since gained greater significance. It has become an increasingly cited paper that describes the problem of creating robotics that approach—but fail to attain—lifelike appearance. Mori called the effect "bukimi no tani," and the term was translated as Uncanny Valley into English. His essay prompted debate about how best to deal with this dilemma in the design of new robots that were increasing capable of more lifelike behaviors, and robots that mimic the functional anatomy of humans by closely mimicking human sensory and motor capabilities. As the 2011 reprinting of the essay suggests, the debate is a pressing one for robotic engineers. The editor's decision to use an image of a puppet rather than a robot to demonstrate this question belies something intrinsic about the relationship between puppets and robots, and hints at the implied relationship between robots and theatre. Mimesis is central to theatre, and it is central to robotics. Puppetry is a system of mimesis that combines artful interpretation with representations of physical and motor processes.

At the same time that *Robotics and Automation* issue was published*, the New York Times* published an article on robotic performances that describes recent attempts by engineers and theatre artists to create more lively and interactive performances:

> The emerging intersection of drama and robotics is creating rich opportunities for collaboration while also revealing the challenges of bridging disciplines that have traditionally shared little common ground. Working with robotics engineers forces dramatists to frame their stage directions in highly precise terms. Roboticists, meanwhile, must learn to cultivate a humanistic understanding of how gesture and movement combine to create emotional responses in audiences. (Wright 2012)

Wright cites a handful of experiments researchers who use robots in theatrical settings. With few exceptions, the projects that were discussed were limited to experiments in engineering labs that combined ready-made robots into theatrical settings, such as the Nao developed by Aldebaran Robotics, and the DARwIn-OP, manufactured by ROBOTIS. Both machines are commercially available autonomous, programmable humanoid robots, and researchers from Carnegie Mellon University and Georgia Institute for Technology author software and algorithms that personalize the generic robots to create personalities and behaviors suited to performance (McKnight 2012). Drawing on such various acting techniques as Michal Checkov's psychological gesture, *commedia dell'arte*, and Suzuki acting method, these experiments explore the challenges of incorporating tele-operated and automated robots into live performance settings. The outcome of this research may contribute to a greater understanding of the mechanics of movement and how gesture can evoke emotional responses. However, because these works rely on ready-made robots which were not designed with theatre or performance they are *a priori* constrained by their mechanical design and subject to the kinematic version of the Uncanny Valley. As such, these experiments are not likely to lead to new ideas about how to design more dynamic robotic actors. Given these examples, it is hard to conceive of robotic actors as anything more than technological embellishment and gadgetry.

One instance of robotic actors that stands apart is *Heddatron* by Elizabeth Merriweather and produced by Les Freres Corbusier at the HERE Arts Center in New York in 2006. In this production, the use of robots illustrates the challenge of creating artistically compelling machines, but also suggests strategies for designing non-mimetic robots that provoke the intentional stance and evoke agency. Unlike ready-made humanoid robots programmed to execute a pre-determined script, the robots were conceived according to their physical tasks onstage. In the play, the robots play the roles of "alien robots" that kidnap a suburban housewife while she reads Ibsen's "Hedda Gabler." Two life-sized aluminum robots force the wife to play the part of Hedda as other robots act out the supporting roles in Ibsen's drama. Apart from the kinetic motions of the life-sized humanoid robots, the production features a parade of less anthropomorphic robots: "a scurrying black suitcase-like creature there in a white wig (for Ibsen's Judge Brack); a balletic walking broom (as the maid, Berta); a silver two-sided daguerreotype figure (as Auntie Julie); and […] a creeping cluster of vine leaves" (Brantley 2006). The humanoid robots are fixed to platforms that wheel around the stage via remote control and do not gesture. For Brantley, the illusion of life that the robots create does not stem from their autonomy (they have none) or their ability to realistically mimic human emotions and expressions (they can not). Rather, the robots are artistically compelling because of their ability to arouse and exploit the audience's imagination. The robots bypass the Uncanny Valley because of their crude, non-naturalistic aesthetic (verisimilitude is not even remotely the goal). However, Brantley still manages to perceive the robots as intentional systems, praising one robot's comic timing: "Auntie Julie announces that she won't sit down, per Ibsen's script, just after the robot bumps blindly into a chair." The robots evoke agency because they are conceived in relation to the work, and their mechanical construction acknowledges their technical limitations (no biped locomotion, no vision). Rather than try to replicate human physiognomy, the artists choose to exploit the limited movements of the robots and made artistic decisions about how to communicate the idea and mood of the piece within these constraints. In short, they learned how to work differently with robotic actors to create a compelling theatrical illusion. While the use of robots in *Heddatron* may not shift the paradigm for robotic actors, it signals something more than mere technological embellishment. The approach to design and control emulates puppetry methods and enables the robots to provoke the intentional stance by creating the illusion of expressive and responsive behaviors.

The above examples suggest that developing behaviors that are expressive and responsive may ultimately be more crucial to provoking the intentional stance than accurate physical representation. However, this does not necessarily mean that robots that are realistic-looking or shaped like humans cannot also evoke agency. Engineers at Disney Research are interested in developing robots for more interactive experiences that allow visitors to their theme parks to interact with robots at a closer distance than has hitherto been allowed. They are currently experimenting with a humanoid robot that is capable of playing a game of throw and catch with human participants (Ackerman 2012). While the robot is shaped like a human, the metal skeleton and exposed wiring and motors announce the robot's mechanistic character. At first glance, the robot is limited in many of the ways that we have already identified as preventing the object from being perceived as expressive: the robot is stabilized, uses pneumatics (forced air), does not locomote and uses only on a limited set of pre-programmed gestures. However, a video of the robot interacting with human subjects highlights two unique features: the robot uses an onboard tracking system to reliably catch the ball most of the time, and uses clever animation sequences that acknowledge its failed attempts.[8] These animated behaviors amount to a performance that aims to convince the spectator of the robot's autonomy and sentience. Despite its physical limitations, the robot's expressive and responsive behaviors provoke the intentional stance. Like the *Heddatron* robots, the robot provokes the suspension of disbelief, exploiting binary vision and provoking the intentional stance principally through creative movement.

Since engineers have successfully sent a semi-autonomous humanoid robot into outer space to aid human astronauts (the Robonaut was delivered to the International Space Station in February 2011), it is not too difficult to imagine that sometime in the near future we might see robots onstage and in theatrical settings

[8] Video available at http://spectrum.ieee.org/automaton/robotics/artificial-intelligence/video-monday-rat-heart-robots-cheap-uavs-and-disneys-humanoid

that are independently navigating their surroundings, interacting with human actors in front of human audiences. It would be useful to have systems in place for understanding how non-humanoid robots challenge our conception of liveness and agency in performance. This study proposes puppetry as a model for establishing a conceptual framework for autonomous and semi-autonomous machines in performance.

ARRANGEMENT OF THE THESIS

To establish an aesthetic framework for autonomous and semi-autonomous machines, I begin by asking if robotic performance constitutes a creative act, and how engineers might use puppetry to develop robots that better exhibit behaviors that are identified with creative performance. My purpose is not to prove that robots are creative in the same way that human beings are creative, but rather to articulate the challenges of designing robotic actors that do not appear routine or boring and to identify possible solutions for building robots that are more dynamic and aesthetically interesting. Using the framework of phenomenology of performance (States) and the intentional stance (Dennett) as points of reference, the next chapter identifies binocular vision as constitutive of the perceptual act that undergirds all theatre performance. Given the semiotic study of puppets and performing objects (which includes robots), binocular vision is particularly pronounced in puppet theatre where the objects paradoxically both occlude and expose their artificiality (Bergamasco and Ghedini 2010). Adapting the framework introduced by Alan Turing to identify machine intelligence (Turing 1950) and Dennett's concept of intentional systems, I develop a theory for identifying the creative principle in robots in performance. Using Fischer-Lichte's concept of theatre-performance as a feedback loop, I propose that robots can provoke the intentional stance by exhibiting expressive and responsive behaviors. These features are dependent on how the object is animated and designed to move. If the robot provokes the intentional stance (rather than the *physical stance* or *design stance*) it is perceived as intentional and more likely to create the illusion of a creative performance. Because a machine's expressive and responsive behaviors are rooted in movement, I suggest that designers of entertainment robots can use puppet-centered approaches to create objects that appear more interactive. These design choices affect the aesthetics of the robots as well as the system for controlling them, and influences new methods of representation and approaches to automated movement.

Using the conceptual framework for machine aesthetics in Chapter Two, Chapter Three considers the historical avant-garde as instances of proto-robotic performance. Artists like Enrico Prampolini, Fortunato Depero, and Oskar Schlemmer all drew on puppetry-inspired design choices and approaches to movement to generate representations of autonomous and semi-autonomous machines. Although the productions did not feature robots *per se* (they were limited by the technical capabilities of the time), the approaches represent an impulse towards the creation of purely mechanical forms and the urge to replace humans with machines as the subjects of performance. Reading these "proto-robotic" performances alongside Umberto Boccioni's influential essay on dynamism, we recognize movement as an essential characteristic of autonomous art objects. Futurists and the Bauhaus artists combined principles of puppetry with technological innovations of the period to imagine machines that moved autonomously and created the illusion of intentionality. In these productions, movement emerges as a major factor in the object's creative function. How an object moves—the range and quality of the movement and also the source of power which automates the movement— is a central concern.

Once I have established movement as the central criterion for an object's ability to create convincing and compelling performances in a human-free environment, in Chapters Four and Five I examine how engineers have traditionally approached the task of imitating and automating the motions and behaviors of human and animal figures. In these chapters, I use puppetry to identify new methods and approaches to movement that combine robotics with puppet-inspired deign choices. The urge to create artificial figures in our own human likeness has occupied humans since antiquity. Chapter Four considers some implications of this tendency by examining human-inspired robots used in entertainment settings, demonstrating how the traditional approach to movement modeled on functional anatomy leads to a kinematic version of the Uncanny Valley. Because automated and tele-operated humanoid robotics use realism as their starting point, and approach movement in kinematic terms (where movement is replicated by geometrically mimicking the functional anatomy of humans), these robots appear rigid and perfunctory. As performers, they are limited because their mechanical design impedes their ability to communicate any truths other than mechanical ones. To avoid kinematic uncanniness, I discuss a third approach to automated motion based on the principals of marionette puppetry, which is part of my work on the *Pygmalion Project*.

In the *Pygmalion Project*, the robots do not replace puppets but act as the agents that operate the puppets from above. This arrangement emulates the process of human puppeteers, and introduces the possibility of automated puppets that are capable of dynamic movement like jumping and flying—motions that are typically beyond the range of traditional animatronics because they are heavy and unstable. Using the natural dynamics of marionettes, where puppets create the illusion of life through the art of indication rather than precise mechanical reproduction, I anticipate that the robotic marionette platform will allow for more artistic, automated motions. Rooted in puppetry, these robot-controlled puppets have a wide range of physical expression and are capable of interacting more fluidly with human operators and spectators than traditional animatronics.

The development of an automated robotic platform for controlling marionettes uses the principle of abstraction native to puppetry, which relies on movement that is suggestive rather than mechanically faithful to human functional anatomy. In other words, a puppet doesn't use its legs to walk, rather legs indicate the act of walking. This allows the movement to appear more artful because the illusion relies on binocular vision—the spectator's perception and ability to "fill in the blanks." Secondly, the design of collaborative, autonomous robots capable of sensing and responding to their environment emulate aspects of human-powered puppetry such as collaboration, intuition, and control. I suggest that these features amount to a level of emergence that influence the robot's ability to imitate interactive and spontaneous behaviors—traits that we typically associate with creative performance. While we might be reluctant to say that robots are "creative" or "perform" in the same way that human puppeteers do, the performance appears more dynamic than a purely automated animatronic performance.

Contemporary robotics research has benefitted from observing behaviors and movements of animals in the wild.[9] In Chapter Five, I argue that engineers might also benefit from puppet-inspired design choices in the design and control of animal-inspired robots and animatronics. Citing the recent trend of animal-inspired robots in theatre productions (Global Creature's 2010 *Walking with the Dinosaurs* and the forthcoming musical *King Kong*; Dreamworks Theatrical's stage adaptation of the animated film *How to Train Your Dragon*), the entertainment industry's interest in developing interactive technologies and more dynamic animatronic figures for theme parks, and other animal-inspired robots for domestic and rehabilitative use, I demonstrate how these robots challenge our conception of liveness and agency in performance. Extending my hypothesis for human-inspired robots to include animal-inspired robots, I suggest that puppet-inspired choices can lead to more expressive automated movement that is not constrained by mimicry-based

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[9] Swarm robotics is one particular outgrowth of this research, and the field of biomimetics uses the structure and function of biological systems found in nature as models for the design and engineering of materials and machines.

approaches. I propose a more sensor-oriented control system modeled after traditional puppetry techniques (such as haptic or tactile feedback and gesture-based control systems) that would enable operators to direct robots more fluidly, and I anticipate that such a system will lead to more compelling stage figures.

The scant number of theatre productions that feature fully autonomous or semi-autonomous machines does not prevent us from constructing a framework for understanding how these objects function aesthetically and evoke agency. The fact that engineers have not yet developed a fully interactive and autonomous social robot has not prevented important research on the fundamental aspects of social intelligence and important design issues. My research on this subject was motivated by my work with a robotics lab at Northwestern University, and a grant from the National Science Foundation to develop a platform for automating traditional string marionettes (discussed in Chapter Four). This work has directed my attention to a field of research and scientific inquiry that is approaching a watershed moment. It is undoubtedly an exciting time to be a researcher in this field: the topics of uncanniness, autonomy, and emergence are discussed with great fervor at the release of every new prototype, and the fields of computer science, affective computing, and sociable robotics are increasingly interested in adopting the methods of theatre to inform their work (Wright 2012).

Even as I write, I am aware that the contemporary works which I here discuss as examples of “cutting-edge” research may soon look as primitive as eighteenth century automata which, although considered incredibly realistic at the time, now strike us now as intricate mechanical devices part of a historical legacy but not suitable enough for an engaging live performance. While I cannot write with any certainty whether or not robots will feature (or be absent from) live theatrical performances one year from now or twelve years from now, I can point with confidence to exciting new possibilities for performance afforded by autonomous and semi-autonomous acting machines.

CHAPTER II

MACHINE AESTHETICS

Puppets challenge the audience's understanding of object and life, and question a complex relation with acting, non-living beings. This issue is crucial to our technology-oriented society. Indeed, studies demonstrate that our relationship with machines is both natural and social, and our brain mechanisms evoke empathy, trust, uncanniness, etc., towards an assembly of circuits or mechanical pieces. A technological object can suspend our disbelief, just as would a literary character, or indeed a puppet; moreover, we project our feelings and attachment more and more on virtual worlds, and we became operators of many online puppets that represent ourselves or others in the digital realm. Robots, like puppets, are an example of the ontological paradox that can take place in our technology saturated environment, as entities simultaneously "occluding" and exposing their artificiality.

-Ghedini and Bergamasco

Not until a machine can write a sonnet or compose a concerto because of thoughts and emotions felt, and not by the chance fall of symbols, could we agree that machine equals brain—that is, not only write about it but know that it had written it. No mechanism could feel (and not merely artificially signal, an easy contrivance) pleasure at its successes, grief when its valves fuse, be warmed by flattery, be made miserable by its mistakes, be charmed by sex, be angry or miserable when it cannot get what it wants.

-Lister Oration on *The Mind of Mechanical Man*, by Sir G. Jefferson

CHAPTER OVERVIEW

Robots and puppets are linked by a common human impulse: the desire to give life to nonliving objects through the creation and animation of material objects. Like puppets, entertainment robots are technological objects capable of revealing aspects of humanity and have the potential to suspend our disbelief so that we perceive the objects as alive. While the study of puppets and classical automata is well established, there is considerable less research on the aesthetics of semi-autonomous and autonomous robots used in live performance. To understand how robots can convincingly provoke the suspension of disbelief and evoke agency requires that we establish an aesthetics for robotic performance; puppetry is the conceptual framework that I use to construct this criteria.

I begin by considering two interrelated questions concerning entertainment robotics: 1) Does robotic performance constitute a creative act?, and 2) How can engineers use puppet-inspired choices to develop robots that better exhibit behaviors that are identified with creative performance? My purpose is not to prove that robots are creative in the same way that human beings are creative, but rather to articulate the challenges of designing robotic actors that do not appear routine or boring, and to identify possible solutions for building robots that are more dynamic and aesthetically interesting. Drawing on theories of theatre performance (States 1985; Fisher-Lichte 2008), puppetry (Kleist 1890; Jurkowski 1996; Proschan 1983), and artificial intelligence (Turing 1950; Dennett 1971; Brooks 2002), I argue that robots evoke agency and appear creative by exhibiting two features: expressivity and responsiveness. These features create the illusion of a unique performance and can be achieved through the art of movement. For entertainment robots, the question is not whether a robot is conscious of the creative act, but if the spectator perceives the performance as creative. In other words, creativity is in the eye of the beholder. Because creativity cannot be instilled and must be evoked, it is important to understand how robots can be designed to better demonstrate expressive and responsive behaviors.

The second part of my hypothesis suggests that engineers might use puppetry-inspired methods to design and construct robots that are more likely to be perceived as creative. In puppetry, the "movement must be more persuasive than the form" (Millar, M. 2007), and it is through movement that puppets create compelling illusions of life. For this reason, I propose that movement may ultimately prove more significant in provoking the intentional stance than physical resemblance or verisimilitude. In short, kinesis is the new mimesis. Understanding how theatre artists have historically envisioned and employed machines onstage and how engineers have sought to imitate life through mechanical means helps to identify the challenges of creating robots that appear creative, and suggests which techniques for design and control are most likely to result in compelling theatrical illusions. Such methods include aesthetic choices that acknowledge binocular vision and design and control mechanisms modeled after techniques of traditional puppetry.

REVIEW OF THE LITERATURE

A Theory of Performance

Before constructing a theory for autonomous and semi-autonomous machines in performance, we must first define performance by identifying its constitutive elements and the relationships between them. Setting aside for the moment discussions of genre and the various media that theatre encompasses, I focus on what I consider the central paradigm of theatre performance: the relationship between that which occurs on stage and the audience. Theatre studies scholar Erika Fisher-Lichte defines the theatrical event as a genuine act of creation where "the very process of performing involves all participants and thus generates the performance in its specific materiality" (Fischer-Lichte 36). For Fisher-Lichte, theatre performance can be understood as a "self-referential, autopoietic feedback system" where actors and spectators influence one another in performance. The Oxford English Dictionary defines autopoiesis as "the self-maintenance of an organized entity through its own internal processes." Fischer-Lichte recognizes theatre as autopoietic because of its self-maintaining and self-regulating functions, where the "organized entity" is defined as that which emerges from the interaction between performer and spectator:

> In short, whatever the actors do elicits a response from the spectators, which impacts the entire performance. In this sense, performances are generated and determined by a self-referential and ever-changing feedback loop. Hence, performance remains unpredictable and spontaneous to a certain degree. (Fischer-Lichte 38)

In theatre history, staging strategies have sought to strengthen the sphere of influence of one side of this system or the other: at the *Bayreuth Festspielhaus*, Wagner aimed to control and guide the responses of the spectators, while Richard Schechner's experiments with the Performance Group during the 1960's and 70's sought to strengthen the role of the spectator through role reversals that prompted spectators to become actors (Fischer-Lichte 41). Whatever staging strategies are evoked, in the autopoietic model the pivotal role of the audience is not a pre-condition for performance, but rather a necessary and explicit element of performance. The concept of theatre performance as an autopoietic system serves two functions: it highlights the role of the spectator's strategies to see and understand what occurs on stage, and it underscores the spontaneous nature of live performance. We might illustrate the relationship between the artist and the spectator thus:

ARTIST $\rightleftarrows$ SPECTATOR

Framing theatre performance as a feedback loop allows us to set aside distinctions between performances that feature human actors, puppets, or robots as well as the attending distinctions of style and genre that can obfuscate discussion of this essential aspect of performance. This definition enables us to concentrate on the nature of performance as an interactive process between artist and spectator. In such a system, the events of the performance are not pre-determined but rather arise from the unique (and not reproducible) exchanges between actors and spectators. The negotiation between these agents is active and hinges on behaviors that are expressive (the thought, image, or idea that is communicated) and responsive (either to the conditions of the real world or the imagined world of the play). In this dialectical process, both agents demonstrate these behaviors: the actors express the thought or idea through modes of representation and respond to the evolving conditions of the live event, while the spectators demonstrate expressive and responsive behaviors through their mental and physical strategies to see and understand what happens on stage and their engagement with the performance. This process produces an exchange that is, to a certain degree, spontaneous and unpredictable.

For the spectator, understanding what happens on stage is not merely an act of seeing, but a perceptual act that involves imaginative and metaphoric integration. This is what is known as the willing suspension of disbelief. Actors also rely on imaginative and metaphoric integration, a processes that Stanislavski referred to as the "Magic-If." Building on the concept of theatre as an autopoietic system, I offer the following definition: theatre performance is an interactive process between artist and spectator which involves imaginative and metaphoric integration, where both the artist and spectator react to the conditions of the live event through expressive and responsive behaviors.

The notion of the pivotal role of the spectator in the generation of meaning of a work of art is well established, and has been long used to articulate philosophical notions of the creative process and works of art. Russian formalist Victor Shklovsky famously defined art as "a way of experiencing the artfulness of an object; the object is not important" (Shklovsky 21). In visual art, the notion of art as a phenomenal experience shifted the site of interest from the art object to the nature of perception and how the object is perceived (this is known as phenomenological aesthetics). For Marcel Duchamp, this meant recognizing the authorial role of the spectator in a work of art:

> Art is a dynamic process between two poles represented by the artist and spectator, where the creative act is not performed by the artist alone; the spectator brings the work in contact with the external world by deciphering and interpreting its inner qualification and thus adds his contribution to the creative act. (Duchamp 140)

Duchamp's reading of the creative act as a dialectical process is echoed in art historian Wolfgang Kemp's essay "The Work of Art and Its Beholder," which argues that the function of beholding is incorporated *a priori* into the work itself. Kemp relates this idea to the study of perception psychology, which proposes that

> [T]he work of art is based upon active completion by its beholder […] that is to say that a dialogue occurs between the partners. […] It almost goes without saying that the work of art and the situation of reception make many more specific offers to the beholder than would arise through formal articulation. And the beholder, of course, brings more than his or her open eyes to the perception/reception of the work of art. (Kemp 181)

Kemp's language stresses the influential role of the "beholder," making the act of beholding not a passive behavior but an active one. In this way, Kemp reaffirms Shklovsky's conception of art as way of seeing that strengthens the authorial role of the spectator. Shklovsky, Duchamp, and Kemp's avowal of the pivotal role of the spectator is given fuller consideration in Nelson Goodman's *Ways of Worldmaking*, wherein the author claims that the conditions of reception are fundamental to understanding how a work of art functions. For Goodman, a necessary condition for art is its "situatedness," or how the object is presented. Goodman rephrases the problematic question "What is art?" with the more agile question "When is art?" This maneuver establishes a method for identifying and understanding the active strategies of the spectator to see and understand a work of art, calling attention to art's semiotic function: "How an object or event functions as a work explains how, through certain modes of reference, what so functions may contribute to a vision of—and to the making of— a world" (Goodman 70). Goodman essentially redefines art not as an object but rather as a phenomenological experience that acknowledges the object's semiotic function:

> A salient feature of symbolization…is that it may come and go. An object may symbolize different things at different times, and nothing at other times. An inert or purely utilitarian object may come to function as art, and a work of art may come to function as an inert or purely utilitarian object. Perhaps, rather than art being long and life short, both are transient. (70)

Goodman's concept of the art object's situatedness and process of symbolization has implications for visual art as well as theatre performance and the semiotic study of puppets and robots. Phenomenological aesthetics primarily considers inanimate objects as their objects of study: a painting, sculpture, or art installation. Goodman, Duchamp, Shklovsky and Kemp's notion of the phenomenological experience opens up a space for the art object to communicate certain artistic truths independently from the artist that created it. In this way, the art object achieves a type of autonomy irrespective of its inanimate nature. In other words, an art object does not have to be sentient, intelligent, or alive to communicate artistic truths that speak to the human condition.

The emergence of phenomenological aesthetics is sometimes referred to as the "performative turn" (Fried 1967; Fischer-Lichte 2008) which not only acknowledges but actively provokes the audience into participation. The performative turn did not meet with universal enthusiasm. In "Art and Objecthood," Michael Fried emphatically declares that "Art degenerates as it approaches the condition of the theatre" (163). He critiques literalist (or minimalist) art's theatricality, suggesting that a hidden interest in anthropomorphism lies at the core of its theory and practice. Citing works by Robert Morris, Robert Grosvenor, Carl Andre, and Tony Smith (157), Fried argues that "the literalist espousal of objecthood amounts to nothing other than a plea for a new genre of theatre; and theatre is now the negation of art." In other words, when a work of art is predicated on the sensibility and experience of the beholder, the object is robbed of its own unique semiotic function. Fried takes aim at the "situatedness" of literalist art and how it extorts the complicity of the spectator and alters the experience of time:

> There is nothing within his field of vision—nothing that he takes note of in any way—that declares it's irrelevant to the situation, and therefore to the experience, in question. On the contrary, for something to be perceived at all is to for it to be perceived as part of the situation. Everything counts—not as part of the object, but as part of the situation in which its objecthood is established and on which that objecthood at least partly depends. (155)

> The literalist preoccupation with time—more precisely, with the *duration of the experience*—is, I suggest, paradigmatically theatrical, as though theatre confronts the beholder, and thereby isolates him, with the endlessness not just of objecthood but of *time*; or as though the sense which, at bottom, theater addresses is a sense of temporality, of time both passing and to come, *simultaneously approaching and receding*, as if apprehended in an infinite perspective.

.

Despite Fried's negative view of theatre performance and assertion that the survival of the arts depends "on their ability to defeat theatre," this essay is relevant to the present study for two reasons. First, it highlights the paradigmatic shift in visual art that occurred in the 1960's as result of minimalist art. The "performative turn" in the visual arts foregrounds the authorial role of the spectator, which in turn shapes the field of phenomenological aesthetics. The notion of theatre as an autopoietic, feedback loop grows from this understanding. Secondly, Fried's argument emphasizes the role of the art object's situatedness and the conditions of reception, which include presence and duration of the experience. As we will soon see, the concept of situatedness is essential to understanding how robots function and how their behaviors are understood and interpreted in performance.

Building on Goodman's conception of art as a phenomenological perspective, theatre scholar Bert O. States examines the symbols of the theatrical stage to describe the unique phenomenological experience of theatre performance. Following

Goodman, States defines art not as a symbol but rather as a "certain perspective on a substance" (38), noting that this perspective has specific consequences for theatre performance. During the theatrical event the audience is engaged in a mode of seeing that makes the performance a collaboration between the stage and the spectator (similar to Duchamp's "poles of creation" and Fisher-Lichte's autopoietic system). States uses the term "binocular vision" to describe this mode of seeing where "one eye enables us to see the world phenomenally; the other eye enables us to see it significatively" (States 8). In theatre, binocular vision enables the spectator to "hold in mind two categories—that of the real and that of the imaginary—that are fused into a single phenomenon" (States 169). In the theatre of human performers, this means the ability (either conscious or unconscious) to perceive simultaneously the actor and the character, acknowledging the fiction of the drama while granting liveliness to the fictional character. Thus, the character assumes a kind of life, and this life is evoked through the active strategies of the spectator to see and understand what happens on stage. As I will demonstrate, the process of double vision is especially pronounced in puppet theatre, and is further complicated in performances that feature robotic performers.

The Aesthetics of Puppets

There is a vast amount of literature on the history of puppets. Perhaps the most comprehensive source on western puppetry traditions is Henryk Jurkowski's two-volume *A History of European Puppetry*, which covers the history of puppetry and puppet theatre from antiquity through the twentieth century. Jurkowski traces the lineage of puppets from the use of dolls, idols, and fetishes used in social and religious functions in Asia, Africa, and the West through the emergence of puppet theatre as a specific genre of theatre art. He defines puppet theatre as that "in which a puppet (or several puppets) in the function of a stage character, acts in a scenic space through the manipulation and speech of at least one hidden player, presenting the unfolding of a dramatic action" (1996, 1:11). Jurkwoski's decision to distinguish puppetry from puppet theatre is meant to delineate the separate theatrical phenomenon of performances that utilize puppetry and puppet techniques from that of a "homogenous" theatre, which is subject to its own aesthetics and codes of performance. Both puppetry and puppet theatre are given equal consideration in his study.

Jurkowski illustrates the transition of the puppet from ritual figure to theatrical figure, highlighting the development of classical mechanics that facilitated the development of more complex devices "which led to the birth of automata, individual or groups of figures in mechanical motion" (1996, 1:38). He cites works by Philo of Byzantium (end of the third century BC) and Hero of Alexandria (second century BC) as the progenitors of automata, which used automatic mechanisms to power kinetic scenes illustrating stories from Greek history and mythology (1996, 1:39). The Greek word for puppet is *nuerospaston*, a juxtaposition of two words: *nuero* (meaning nerve) and *spaston* (meaning involuntary movement). Some puppet scholars have speculated that classical puppets were originally mechanical or partly mechanical figures that moved through invisible threads hidden within the puppets (Jurkowski 1996, 1:43). Puppet scholar Hans Richard Puschke has suggested that *nuerospaton* did not originally require a human puppeteer but was originally a mechanical device; Puschke proposes that the puppet's transformation from ritual figure to theatrical puppet coincided with a movement away from mechanical movement towards manual movement powered directly by a human puppeteer (Jurkowski 1996 1:46). While it is impossible to wholly reject or accept Puschke's hypothesis, we can reasonably argue that the given understanding of puppetry refers to inanimate objects that rely on a human operator to animate it. For this reason, I use Jurkowski's definitions to define puppet and puppet theatre:

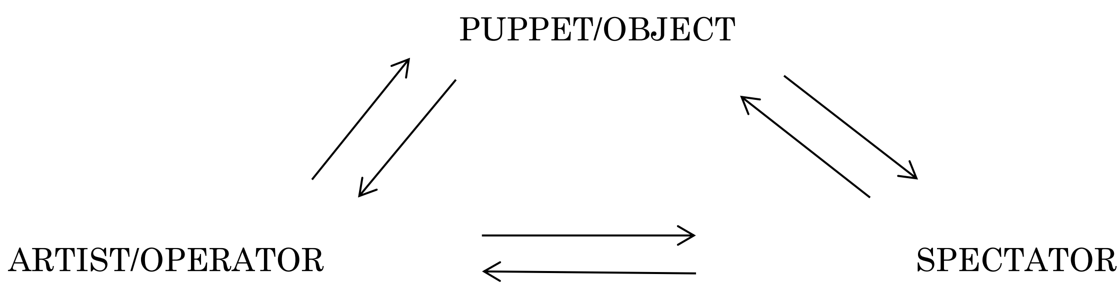
> Puppet theatre is a theatre art distinguished from the theatre of live performers by its most fundamental feature, namely that the speaking, acting subject makes temporal use of vocal and motor sources of power which are outside it, which are not its own attributes. The relationships between the subject and its power sources are constantly changing, and this variation has essential semiological and aesthetic significance. (Jurkowski 1988, 55)

Furthermore, Jurkowski calls specific attention to the relationship between the operator and the performing object as the essential characteristic of puppetry:

> Whatever form it takes, realistic or highly stylized, puppet theatre makes use of the variable relationships between its means of expression and their driving forces. These variations are even demonstrated in the choice of the technique—string or glove, say—meaning that tradition still underpins the style of contemporary puppet theatre and that any new relationships between the means of expression and the power sources arise from the characteristics of the whole genre. (1988, 55)

Given these definitions, we recognize that the art of puppetry hinges on a feedback loop between the puppet (expression) and the operator (the driving forces). While the relationship between puppet and operator may vary according to style or genre, the essential aspect of puppetry hinges on this feedback loop. We can now return to the definition of theatre performance to understand how puppetry functions as a species of theatre performance, and how the relationship between an inanimate object and its operator function in this autopoietic system. Furthermore, we see that the relationship between the puppet and its sources of energy has a profound impact on binocular vision.

I have identified theatre performance as an interactive process between artist and spectator which involves imaginative and metaphoric integration, where both artists and spectators react to the conditions of the live event through expressive and responsive behaviors. In puppet theatre, the subject is not a human artist but an inanimate object that makes temporal use of sources of power that are outside it and not its own attributes. The copresence of artist and puppet creates a triangular feedback loop: the binary dialectic (artist/spectator) is replaced by the triangular relationship between artist, object, and spectator. Unlike actor theatre, where there is total unity between the moving subject and its sources of motion,[10] the acting subject in puppet theatre presents two simultaneous signs: that of the puppet and the operator (Jurkowski 1998, 55). We might illustrate the relationships for the autopoietic feedback loop for puppet theatre thus:



In this system, the performance remains, to a certain degree, spontaneous and unpredictable.

It is important to recognize that the triangular relationship between artist/object/spectator is active in all forms of puppet theatre, even when the puppeteer is obscured or hidden from view. Because a puppet by definition makes use of sources of power that are outside of it and not its own attributes, the presence of the puppeteer is always implied (this is the chief feature that distinguishes

[10] An actor accomplishes "all the demands made on his body through his own power" (Jurkowski 1988, 54).

puppets from automata). The decision to hide or foreground the puppet's operator influences the conditions of reception, and has semiological and metaphorical implications (Tillis 1992). Jurkowski notes that "for centuries puppeteers looked for ways in which their puppets might be taken for human beings with a life of their own, perhaps even a magical life," and different forms of puppet theatre choose to either foreground or occlude the operator and the act of animation (1988, 54). The choice to hide the operator, as in marionette puppetry, ontributes to the illusion that puppets possess their own sort of life, and this illusion has implications for theatre scholarship.

The potential of puppets to acquire their own magical life has inspired numerous literary narratives (Gross 2012), and has also been used as a metaphor by theatre artists in search of more authentic or "pure" methods of representation. Heinrich von Kleist and Edward Gordon Craig both found the marionette an apt metaphor for the ideal state of a human actor— free from ego, superficiality, and affectation. In "On the Marionette Theatre," Kleist laments the "disturbing effect consciousness had upon the natural grace of human beings" and locates in the mechanical movements of puppets the appearance of grace free from consciousness (Kleist 86). Similarly, Craig's vision of the *Übermarionette* uses the puppet as a metaphor for restoring authenticity to the art of acting through the avoidance of imitation and mimicry:

> There is something more than a flash of genius in the marionette, and there is something in him more than the flashiness of displayed

> personality. The marionette appears to me to be the last echo of some noble and beautiful art of a past civilization. (Craig 82)

Despite their enthusiasm for marionette puppetry, both Kleist and Craig both consider methods for improving the form by eliminating the human actor/puppeteer: Kleist imagines a completely automated marionette where the puppet's movements are "transposed into the realm of purely mechanical forces," (Kleist 84), and Craig's vision of the *Übermarionette* makes no reference to a puppeteer:

> To that end we must study to remake these images—no longer content with a puppet, we must create an uber-marionette. The uber-marionette will not compete with life—rather it will go beyond it. Its ideal will not be the flesh and blood but rather the body in trance—it will aim to clothe itself with a death-like beauty while exhaling a living spirit. (Craig 84)

For both Kleist and Craig, the puppet's expressive powers are considered independently from its relationship with the human puppeteer: the operator remains completely hidden from view, and does not feature in their discussion of performance aesthetics. I will return to this issue again in Chapters Three and Four, but the point I wish to emphasize here is that Kleist's and Craig's visions are concerned with the outward effects of puppetry, and not with the semiotics of puppet theatre as Jurkwoski defines them.

Returning to the definition of puppet theatre as a species of theatre performance where the binary dialectic between artist/spectator is replaced by the triangular relationship between artist/object/spectator, we recognize the aesthetic experience hinges on the relationship between the puppet and its operator. In puppet theatre, the acting subject presents as two simultaneous signs—the puppet and the animator—and *it is through movement that the puppet transcends its status as object and becomes subject*. When the object is animated by a puppeteer, it undergoes a type of transformation by demonstrating expressive and responsive behaviors: the inanimate puppet physically responds to the forces that animate it, and becomes expressive. Through movement the puppet creates the illusion of life (or a different kind of life), and begins to evoke agency. However, when the puppet is no longer animated, it reverts immediately to its status as object: in the absence of movement the puppet is incapable of expressive or responsive behaviors and ceases to function as part of the autopoietic feedback loop. Like an actor who "breaks character," this disruption dispels the illusion, and spectators cease to regard the object "significatively" and apprehend only its utilitarian function. The puppet illustrates Goodman's understanding of how "an inert or purely utilitarian object may come to function as art, and a work of art may come to function as an inert or purely utilitarian object." Creativity cannot be instilled, it must be evoked, and movement is essential to this process.

The allure of puppet theatre arises partly from the way it challenges the audience's understanding of object and life, and of animate and inanimate forces. Puppet scholar Frank Proschan describes this process in semiotic terms as a "confrontation of visual codes" that is inherent to all puppet forms: puppetry demands that the puppets be perceived as signs and sign-systems, while at the same time acknowledging the "unavoidable materiality from which the signs are constituted" (1983, 26). In puppet theatres where the operators remain unseen by the audience, binocular vision functions similarly as in actor-theatre, allowing us to apprehend the puppet/object both phenomenally and significatively at the same time. When the operators are visible to the spectators or seen alongside the puppet— as in *bunraku* where three human operators manipulate a puppet in full view of the audience— the number of signs increases and the confrontation of visual codes increases, but the fundamental relationships of the autopoietic feedback loop remain stable. Whether the animation technique is foregrounded (as in *bunraku*) or occluded (as in traditional marionette puppetry), puppets create the illusion of life based on their expressive and responsive behaviors, and these behaviors are achieved through movement that is powered by a human operator. The puppet/operator relationship reinforces the illusionary and anti-illusionary processes at work, and binocular vision is central to the spectator's experience of these processes.

To summarize, how and when a live puppeteer animates a puppet, and the degree to which the technique is made visible to the audience contributes to the confrontation of visual codes and influences binocular vision. Binocular vision is that which enables the spectator to momentarily suspend their disbelief and delight in the illusion without experiencing discomfort or uncertainty about the nature of the illusion. States:

> Delight, it seems to me, could be translated as wrappedness in the image—not, as Dr. Johnson would say, for its "just gesture and elegant modulation," or for its successful execution of conventional usage, but for its autonomous life, or liveliness (to use a word particularly pertinent to theater). Thus there is a playful tug-of-war in the image between the useful and the delightful. Usefulness implies the image's transitivity, its sign-ness, or convertibility into social, moral, or educational energy; delight implies its "corporeality" and the immediate absorption of the image by the senses. So the sign/image is a Janus-faced thing: it wants to say something about something, to be a sign, and it wants to be something, a thing in itself, a site of beauty. (States 10)

Although States does not speak of puppetry in particular, we can connect this tug of war between the useful and the delightful to Proschan's concept of puppet as simultaneous sign and sign-system: the puppet oscillates between these two functions, enabling the object to be perceived phenomenally and significatively at the same time. The confrontation of these codes does not produce anxiety or uncertainty, but results in a "wrappedness" in the illusion of life or liveliness that it offers. In puppet theatre, it is through movement that the puppet transcends its status as material object and becomes subject. While States and Proschan might agree that part of the delight of theatre is derived from binocular vision and the confrontation of visual codes, the issue is problematized when it comes to the performance of robots and autonomous machines. Unlike theatre performance where “image and object, pretense and pretender, sign-vehicle and content, draw unusually close,” robots are unequivocally non-human and, like automatons, are designed to operate independently from their human operators. The conceit of an autonomous performance presents two challenges for robotic actors in the autopoietic feedback loop of theatre performance: 1) How to appear expressive and responsive without provoking uncertainty and 2) How to transcend machine status to create the illusion of liveliness. In the next section, we will see that in order to create the illusion of autonomy and evoke agency, robots must necessarily work differently than human actors and puppets to convince an audience of their liveliness.

Intentional Systems

In this section I present theories of autonomous agents and artificial intelligence to illustrate the ontological and phenomenological relationships between puppets and robots. However, we must acknowledge this critical distinction at the outset: human actors and puppets are never obliged to convince an audience of their liveliness, but robots must continually create the illusion of autonomy. This distinction arises because of the relation between the performing object and its sources of movement: for human actors, there is total unity between the moving subject and its source of power. For puppets, the source of animation lies visibly outside of the object. Robots occupy a liminal position, hovering between puppets and human performers: while a robot's mechanical features appear more aligned with the "total unity" of human actors (their power sources are contained within them), they are entirely artificial and, like lifeless puppets, must work to transcend their status as inanimate objects. This distinction was noted by Ghedini and Bergamasco who observed that robots are examples of "the ontological paradox that can take place in our technology saturated environment, as entities simultaneously 'occluding' and exposing their artificiality" (28). Any attempts to draw connections between actors, puppets, automata, or robots must acknowledge this paradox.

Because a robot must continually create and sustain the illusion of autonomy, it must remain sufficiently and convincingly animated during performance: failure to do so disrupts the spectator's suspension of the disbelief and impacts their willingness to ascribe agency to a system. Agency can be defined as the capacity to plan and act (Wegner et al. 2010), and assigning agency to artificial systems is pivotal to how a spectator interacts with both animate and inanimate objects. For entertainment robots, the notion of agency loosely corresponds to States' concept of "wrappedness": it is what persuades the spectator of the autonomous life or liveliness of an object. For example, while we might be willing to grant a puppet the status of subject—acknowledging it as one half of the two simultaneous signs—we traditionally we do not ascribe agency to puppets because of the implied presence of a human operator. In cases where a spectator does ascribe agency to a puppet (and Kleist and Craig have suggested this is part of the puppet's allure), the experience is usually momentary. However, for a robotic performer the inanimate, material object must work against its objecthood in order to convince the spectator of its liveliness. If the spectator is not sufficiently and (perhaps more importantly) consistently convinced of the object's liveliness, their experience of the "confrontation of visual codes" and binocular vision is disrupted. In short, the object ceases to be delightful or engaging and instead becomes useful, frightening, or boring. This is a significant problem that developers of automata and humanoid robots face: how to create robots that are engaging and convincing and not dull and predictable.

To understand how a machine can evoke agency, we must consider the two approaches to the creation and simulation of artificial life: mechanistic models and computational models. Automatons and humanoid robots are examples of mechanistic models, whereas human-machine communication programs such as ELIZA or a chess-playing computer are considered computational models. While these definitions are not mutually exclusive, it is helpful to momentarily think of them as separate strategies. Humans have long sought to mechanically reproduce the motions of human and animal beings. From the Greek *neurospastons* and mechanical theatres to the seventeenth century automatons, efforts to create simulacra of human and animal beings have traditionally hovered somewhere between entertainment and scientific inquiry. Automatons—machines that appear to operate independently once they are set in motion—are similar to robots in that they are intentionally designed to appear as independent from their human creators and their sources of power are contained within them. Although automata enjoyed a period of relative popularity (Kang 2011; Reilly 2011), these artifacts were never fully recognized as serious contributions to the advancement of scientific understanding. Derick J. de Solla Price addresses this tension in "Automata and the Origins of Mechanism":

> Amongst historians of technology there seems always to have been private, somewhat peevish disconnect because the most ingenious mechanical devices of antiquity were not useful machines but trivial toys. Only slowly do the machines of everyday life take up the scientific advances and basic principles used long before in the despicable playthings and overly-ingenious impracticably scientific models and instruments. (15)

Because historians of technology are reluctant to recognize the significant contributions of "trivial toys" and playthings, automata, animatronics, and robotic actors have traditionally gone unnoticed in performance histories. The omission can be attributed to the lack of spontaneous and unpredictable behaviors: automatons perform the same motions or set of behaviors without variance and irrespective of the spectator, and in this sense they do not function in an autopoietic feedback loop. However, we might also trace the omission of automata in theatre history to atavistic conceptions that place the human being at the center of performance (see Baugh 2005).

Some scholars have sought to address this omission: Gaby Woods, Minsoo Kang, and Kara Reilly have written separately about the history of automata, their influence on cultural imagination, and their contributions to the development of robotics. *Edison's Eve* (Woods 2003) addresses the distinction between automata as entertainment devices and tools for scientific inquiry: despite their persuasive demonstrations of the mechanical principles and functional anatomy of the human body, even the most sophisticated automata have been regarded as little more than mere entertainment devices. *Sublime Dreams of Living Machines* (Kang 2011) analyzes the cultural fascination with automata in the western imagination, and offers a well-documented history of classical attempts to create life through mechanical means. Finally, *Automata and Mimesis on the Stage of Human History* (Reilly 2011) ostensibly considers "automata as theatrical performers on the stage of history," but the examples from theatre history are limited to figurative representations in plays and ballets where the "machines" are performed by human actors, rather than actual mechanical figures (the theatrical legacy of Hoffman's *The Sandman* and Capek's *R.U.R.* comprise two chapters). Constructing a semiotic understanding of automata by reading the ballet *Coppèlia* is akin to modeling a robot according the technical specifications of robots in *R.U.R.* While these theatre productions might expand our awareness of automata and representation, they do not bring us closer to an understanding of machine aesthetics.[11]

The construction of automata is one method for creating human simulacra. Another strategy is the study of artificial intelligence, which although it is related to contemporary robotics research, has a unique historical lineage. Whereas automata

[11] Reilly offers a comprehensive reading of Capek's play, however her assertion that "Robots only came into existence because of the play *R.U.R.*" is as an overstatement of the role of etymology that minimizes the significance of mechanistic philosophy and the study of mechanism (Reilly 166).

represent a mechanistic approach to simulating artificial life, the field of artificial intelligence can be regarded as a computational approach. A comprehensive review of historical developments of AI is beyond the scope of this study, but there are two conceptual frameworks that elucidate the phenomenological aesthetics of machines: Alan Turing's "Turing Test" and D.C. Dennett's concept of "intentional systems."

Efforts to artificially simulate human intelligence, rationality, and creativity are the subject of cybernetics, Artificial Intelligence (AI), and Artificial Life (ALife) research. Scientists in these fields have sought to understand human intelligence by designing programs that calculate, reason, and interact with the physical world. AI can be defined as the effort to understand the nature of human intelligence through the design and construction of artificial systems that use computational tools with intelligent capacities, and that exhibit these capacities through observable behaviors (Franchi and Guzeldere 16). Historically, AI research was principally concerned with computational (rather than embodied) systems: two examples are the chess-playing computer and the language-based program ELIZA (Weizenbaum 1984). In addition to these computational programs, many AI labs use robotics in their efforts to combine computational models with machines that are able to sense and interact with the world. These efforts are called "cyber-physical systems" to distinguish them from purely computational models and to emphasize the tight coordination between a system's computational elements and its physical elements (Brooks 2002).

Conventional wisdom tells us that robots and computers can only perform what human programmers instruct them to do. This argument is known as Lady

Lovelace's Objection[12], which holds that a computer can never do anything truly intelligent because its behavior demonstrates the intelligence and skill of the human programmer and not that of the machine. Speaking of the dearly digital computer she developed with Charles Babbage, Lovelace states "The Analytical Engine has no pretensions to *originate* anything. It can do *whatever we know how to order it* to perform" (Turing 56, original emphasis). However, this has not dissuaded AI philosophers from pursuing methods that define and measure machine intelligence: the Turing Test is an example of an attempt to define a broader set of criteria for understanding artificial intelligence (Turing 1950). Turing addresses Lovelace's objection thus:

> A variant of Lady Lovelace's objection states that a machine 'can never do anything really new'. This may be parried for a moment with the saw 'There is nothing new under the sun.' Who can be certain that 'original work' that he has done was not simply the growth of the seed planted in him by teaching, or the effect of following well-known principles. A better variant of the objection says that a machine can never 'take us by surprise'. This statement is a more direct challenge and can be met directly. Machines take me by surprise with great frequency. […] …it is perhaps worth remarking that the appreciation of something as surprising requires

[12] Augusta Ada King, Countess of Lovelace is considered one of the pioneers of digital computing and is sometimes referred to as the first female computer programmer. Together with Charles Babbage she developed the Analytical Engine in 1837 (Franchi and Guzeldere).

> as much of a "creative mental act" whether the surprising event originates from a man, a book, a machine, or anything else. (Turing 56)

Turing's 1950 essay "Computing Machinery and Intelligence" shifted the paradigm of AI research by defining machine intelligence not as an intrinsic trait but instead as an attribute that is assigned to an artificial system by a human observer. The significance of the "Turing Test" to the present study is twofold. First, Turing reframes the question of machine intelligence by defining intelligence as a phenomenological experience. Similar to Goodman's strategy that redefined the art object as the subjective experience and Kemp's insistence on the active role of the beholder, Turing refrains from defining intelligence and instead asks whether a machine can convince a spectator of its intelligence through imitation. Instead of posing the question "Can machines think?" (which Turing describes as a question "too meaningless to deserve discussion"), the author considers what measures would indicate the *appearance* of intelligence. Like Goodman's "When is art?," this maneuver essentially redefines the notion of intelligence as a phenomenological experience: in order to gauge how "convincing" a performance the computer gives, Turing offers a test for evaluating how well a machine imitates human intelligence. This way, Turing cleverly avoids having to conclusively define intelligence while still providing a tractable and analyzable method for evaluating machines. If a machine could be perceived to emulate human intelligence in a convincing way, then the machine could be defined as intelligent.

While Turing envisioned the game with digital computers in mind—that is, computational systems— he was careful to point out that the question of machine intelligence should not be limited to the machines available at the time: "The short answer is that we are not asking whether all digital computers would do well in the game nor whether the computers at present time would do well, but whether there are imaginable computers which would do well" (43). Turing did not have to wait long for a computational program that convincingly imitated human intelligence. ELIZA[13] is a language-based computer program developed by Joseph Weizenbaum during the 1960's that models human-computer communication after techniques used in psychological therapy. The program generates methods for analyzing sentences and sentence fragments, locating key words in texts submitted by human users and creating new sentences and questions from these fragments (Weizenbaum 188). While the system has no built-in contextual framework (that is, it has no knowledge of human psychology or relationships), it creates a remarkable illusion for the humans who interact with it. "People who knew very well that they were conversing with a machine soon forgot that fact, just as theatregoers, in the grip of suspended disbelief, soon forget that the action they are witnessing is not 'real'" (Weizenbaum 189). The theatrical metaphor does not just extend to the human user but also to the computer program, who becomes a type of performer: "In a sense ELIZA was an actress who commanded a set of techniques but who had nothing of

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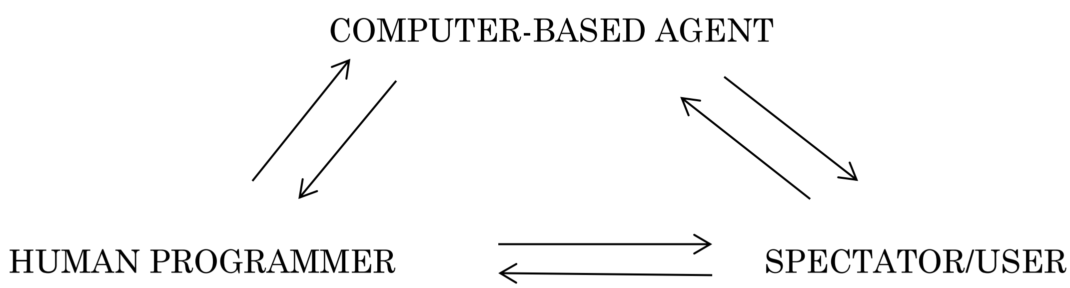
[13] Weizenbaum deliberately invokes the theatrical metaphor: ELIZA is named after the character Eliza Doolittle from Shaw's *Pygmalion*. Like the character, "the program could be taught to 'speak' increasingly well, although, like Miss Doolittle, it was never quite clear whether or not it became smarter" (Weizenbaum 188).

her own to say. The script, in turn, was a set of rules which permitted the actor to improvise on whatever resources it provided"(188).

Even though ELIZA uses a simple computational model and does not approach the complexity of a cyber-physical system like an autonomous robot, the program reveals a tacit feature of human-machine interaction: even in the absence of a physical body, human users readily ascribe agency to artificial systems. If the illusion of artificial life is persuasive enough to stimulate the imagination and captivate a human's attention, then computer programs can provoke the suspension of disbelief and evoke agency. This is the underlying concept behind the Turing Test, which has proved to be an enduring and elusive benchmark for machine intelligence.

The theatrical implications of the Turing's Imitation Game and Weizenbaum's ELIZA are irresistible. In both cases, the experiments revolve around acts of mimesis and are entirely illusionistic: role-playing is the method by which the artificial systems convince human observers of their intelligence, and a machine is determined intelligent or sentient only when a human observer experiences it as such. The mimetic impulse that undergirds these representations—both in terms of the representation of human intelligence and the active strategies of the spectator to interpret those representations—is reminiscent of binocular vision and the autopoietic feedback loop that we have used to define theatre performance. In *Computers as Theatre*, Brenda Laurel develops the theatrical metaphor further, arguing that computer-based agents, like dramatic characters, do not have to think, "they simply have to provide a representation from which thought may be inferred"

(Laurel 57). Laurel argues that realistic or believable representations result in the spectator's willingness to attribute thought or intentionality to a non-human or artificial system. Recognizing the emergent pattern of these computational approaches, we can conclude that agency and intentionality are evoked through an autopoietic feedback loop that is similar to that of a theatrical performance. The experience of interacting with a machine can evoke strategies of beholding—where the spectator actively seeks to make sense of the experience and make predictions about the system. This can sometimes lead the spectator to attribute intention and meaning to artificial systems, and results in exchanges that are to a certain degree spontaneous and unique. We might illustrate this relationship thus:



Applying the theory of performance as an autopoietic system to computational models, we see that theatre is not only a metaphor, but a useful method for understanding how human spectators ascribe agency to artificial systems.

The conception that intelligence, or mind, is in the eye of the perceiver is a well-argued premise in cognitive psychology. Wegner et al. cite several studies which find that "mental states—intentions, desires, and feelings—are the very states that best explain the behavior of independent entities" (384). Although cognitive psychology focuses on human understanding, and AI focuses on human-machine interaction, the foundations of perception psychology have been used to explain the experience between a work of art and spectator (Kemp 1998). Dennett's concept of intentional systems is partly predicated on these foundations.

In "Intentional Systems" (1971) Dennett proposes a theory for how human beings regard artificial systems this influences human-machine interaction. Dennett proposes three stances that humans adopt towards artificial systems in order to interact with them and predict their behavior: *design stance*, *physical stance*, and the *intentional stance*. Each of these stances determines how the human spectator will predict the behavior of the system and assign or withhold agency to it. The design stance dictates that "if one knows exactly how the computer is designed (including the impermanent part of its design: its program), one can predict its designed response to any move one makes by following the computation instructions of the program" (87). For example, in the case of ELIZA one could predict the responses of the computer program based on their knowledge of the psychological model and the specific algorithm used to generate the responses. With the physical stance, the spectator predicts how the artificial system will respond "based on the actual physical state of the particular object, and are worked out by applying whatever knowledge we have of the laws of nature" (88). With computational systems, "the physical stance is generally reserved for instances of breakdown, where the condition preventing normal operation is generalized and easily locatable"

(89). For example, if you are communicating with ELIZA and you notice that the computer isn't plugged in, you adopt a physical stance towards the system. For the intentional stance "one predicts behavior …by ascribing to the system the possession of certain information and by supposing it to be directed by certain goals, and then by working out the most reasonable or appropriate action on the basis of these ascriptions and suppositions" (90). Those users who—like theatregoers in the grip of suspended disbelief— are persuaded by the illusion that ELIZA creates may be said to adopt the intentional stance.

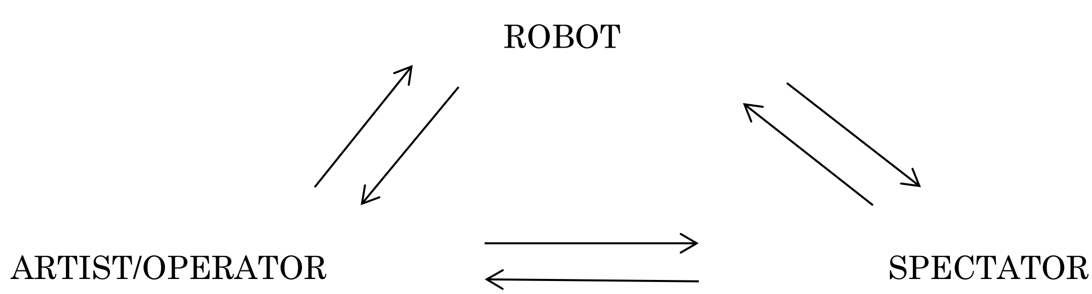
While Dennett's argument is primarily concerned with strategies for predicting the behavior of a computational programs (such as those that play chess), his focus on the phenomenological engagement between human and artificial systems is significant for the present study. Like Goodman, Shklovsky, States, and Turing, Dennett predicates his argument for intentionality on the active strategies of the spectator to understand and predict the behavior of the agent. The definition of intentionality that he offers

> does not say that Intentional systems *really* have beliefs and desires, but that one can explain an predict their behavior by *ascribing* beliefs and desires to them, and whether one calls what one ascribes to the computer beliefs or belief analogues or information complexes or Intentional whatnots makes no different to the nature of the calculation one makes on the basis of the ascriptions. (91, original emphasis)

Just as Turing presented a method for identifying machine intelligence without having to define it, Dennett's concept of intentional systems establishes a method for assigning agency (as signaled by desire or beliefs) to a system without having to classify that system as necessarily intelligent, human, or animate. After all, "it is much easier to decide whether a machine can be an intentional system than it is to decide whether machine can really think, or be conscious, or be morally responsible" (100). When it comes to computational programs such as a chess-playing computer or ELIZA,

> We do quite successfully treat these computers as Intentional systems, and we do this independently of any considerations about what substance they are composed of, their origin, their position or lack of position in the community of moral agents, their consciousness or self-consciousness, or the determinacy or indeterminacy of their operations. The decision to adopt the strategy is pragmatic, and is not intrinsically right or wrong. *One can switch stances at will without involving oneself in any inconsistencies or inhumanities*…. (91, my emphasis)

There are two points that I wish to highlight about the concept of intentional systems. First, a system is defined as intentional when it provokes the spectator to adopt the intentional stance toward the object (Dennett 87), and this stance is pivotal for the system to evoke agency. Although Dennett cited systems that employ computational strategies, we can also apply it to mechanistic strategies, specifically, to autonomous and semi-autonomous machines used in performance. I propose that inanimate objects are able to evoke agency through a feedback loop that is dependent on the agent and the spectator's strategies to understand and predict its behavior. Because a robot essentially performs an act of autonomy (it strives to move and operate autonomously in the real world), the spectator's strategy for understanding and predicting the robot's behavior is essential to whether or not that robot can evoke agency. Like creativity, agency cannot be instilled, it must be evoked (Kroos 401). If robots are to engage live audiences in an autopoietic model and produce performances that are spontaneous and unpredictable, they should be designed and animated so that they are perceived as intentional systems. We might illustrate this relationship thus:



The second conclusion we can draw from intentional systems relates to binocular vision. If we accept State's notion of binocular vision and recognize it as fundamental to the understanding and enjoyment of the confrontation of visual codes in puppetry, then we might use Dennett's theory to understand how robots can be perceived phenomenally and significatively at the same time. If a spectator is able to "switch stances at will without involving oneself in any inconsistencies or inhumanities," it stands to reason that this must also hold true for artificial systems in theatrical settings. Furthermore, the binocular vision that theatre performance provokes renders this movement delightful and necessarily part of the theatrical illusion. Entertainment robots can learn from puppetry how to use this binocular vision to their advantage.

CHAPTER SUMMARY

This chapter outlined two research questions: 1) Does robotic performance constitute a creative act?, and 2) How can engineers use puppetry to develop robots that better exhibit behaviors that are identified with creative performance? My purpose is not to prove that robots are creative in the same way that human beings are creative, but rather to consider the challenges of designing robots and to identify possible solutions for building robots that are dynamic and interesting. Using theories of performance and the semiotic study of puppetry, I proposed puppetry as a model for understanding how inanimate objects function aesthetically and how they are perceived in performance. Drawing on methods for identifying and measuring intelligence and agency in artificial systems, I articulated the similarities in the phenomenological perception of actors, puppets, and robots, and proposed that creativity (like agency) cannot be instilled but must be evoked. I have identified expressivity and responsiveness as two behaviors that are essential to evoking creativity, and identified puppetry's use of movement as essential to this process. For entertainment robots, kinesis can be regarded as the new mimesis. In the subsequent chapters, I consider specific examples from theatre history that utilize the techniques of puppetry to stage autonomous and semi-autonomous machines, and from these experiments I develop strategies for creating robots that are capable of generating compelling theatrical illusions.

CHAPTER III

PROTO-ROBOTIC ACTORS

The history of the theatre is the history of the transfiguration of the human form.

-Oskar Schlemmer

Theatre is transformation. It is a vision created by an artist, transforming…himself a puppet or even an object into an imagined character.

-Henryk Jurkwoski

CHAPTER OVERVIEW

This chapter identifies proto-robotic performances by the historical avant-garde that contributed to the artistic awareness and exploration of autonomous acting machines. Futurist and Bauhaus artists used theatre to explore new modes of perception and theatrical production made available by the Machine Age. These experiments can be characterized by abstraction, stylization, and a focus on geometry and mathematical precision that demonstrate both the urge to understand the mechanics of physical expression and the urge to create (or simulate) autonomous performing objects. Lacking the technological mastery to realize their artistic visions, these artists used puppetry as a tool for developing the objective, non-personal aesthetic of the autonomous art object—a deliberately nonrepresentational, expressive subject that creates the illusion of moving and operating in the world independently. The urge to create autonomous art objects exemplifies the avant-garde's search for modes of performance that moved beyond the subjective, psychic aspects of theatre (associated with naturalism and realism) and the espousal of phenomenological aesthetics that challenged the traditional actor-spectator dynamic. Although they were motivated by different political and aesthetic ideologies, these productions affirm the autopoietic feedback loop between human actors and machines through the creation of flexible, dynamic stages, performing objects, and mechanical costumes. Their use of puppetry and creative movement highlights the importance of kinetic movement as a powerful means of expression, prefiguring autonomous acting machines and helping to shape an emerging aesthetics of machines and robotic performers.

Productions by Italian Futurists (Filipo Marinetti, Enrico Prampolini, Fortunato Depero) and Bauhaus artists (Oskar Schlemmer, Laszlo Moholy-Nagy) combined principles of traditional puppetry with emerging stage technologies and joining human actors with performing objects and mechanical devices that led to new conceptions of the mechanized body and the mechanical performer. These experiments represent two approaches to machine aesthetics: that of automated motion and that of the human-controlled mechanism. While Depero explored a mechanistic approach by imagining theatrical landscapes populated by automated, autonomous acting machines largely free of human performers, Schlemmer explored human-machine interaction along the lines of traditional puppetry where the motor and rumoristic (sound) qualities of performing objects are directly linked to the human performer controlling them. Both approaches result in new types of animated figures that reflect ambiguous attitudes towards the mechanized body and the mechanical performer. Although the productions make use of the mechanics and dynamism of machines, the human figure remains central to the live theatrical event and reflects the utopian vision of some avant-garde movements which sought a unity between human beings and machines. While these productions did not feature robots *per se*, they signal the investigation of mechanical acting machines through the synthesis of science, engineering, and artistic expression. Furthermore, these artists shared a commitment to exploring more interactive performances, experimenting with performer-spectator dynamics in ways that challenged traditional modes of theatrical spectatorship.

MACHINE AESTHETICS AND THE HISTORICAL AVANT-GARDE

The development of machine culture at the end of the nineteenth and early twentieth centuries— commonly known as the Machine Age— provoked contradictory responses from modernist artistic movements. These responses ranged from fully-fledged endorsements of the potentials of machines to liberate humankind (the Futurists) and celebration of technology as the harbinger of social progress (the Constructivists), to fear and anxiety of technology's oppressive and destructive potential (the Expressionists and Dadaists). Historian Andreas Huyssen claims that these contradictory responses to technology and machine culture were fully explored in Fritz Lang's 1927 film *Metropolis*, which, in its depiction of robots and machine culture, attempts to resolve these two diametrically opposed views of technology (Huyssen 1986). However, artistic meditations on the impact of technology, science, and machines on human society were not limited to film: avant-garde painters, sculptors, dancers, and theatre artists throughout Russia and Europe were inspired by advances in science, technology, and philosophy to develop new modes of expression and production that would enable them to render and interrogate the rapidly changing and increasingly technologized life. According to Huyssen, "no other single factor has influenced the emergence of the new avant-garde art as much as technology, which not only fueled artists' imagination (dynamism, machine cult, beauty of technics, constructivist and productivist attitudes), but penetrated to the core of the work itself" (9).

For Huyseen, the integration of technology into the work of art during the twentieth century finds its ultimate fulfillment in photography and film; however, the promise and threat of technology were explored in plays and theatre productions of the period. These works challenged traditionally held views about the nature of representational art and bourgeois culture. Frequently, the face given to technology in culture and artistic representation was that of the puppet or automaton, where the puppet became the embodiment of the threats posed by technology.

> [B]y incorporating technology into art, the avant-garde liberated technology from its instrumental aspects and thus undermined both bourgeois notions of technology as progress and art as "natural", "autonomous", and "organic." On a more traditional representational level, which was never entirely abandoned, the avantgarde's radical critique of the principles of bourgeois enlightenment and its glorification of progress and technology were manifested in scores of paintings, drawings, sculptures, and other art objects in which humans are presented as machines and automatons, puppets and mannequins, often faceless, with hollow heads, blind or staring into space. The fact that these presentations did not aim at some "abstract human condition," but rather critiqued the invasion of

> capitalism's technological instrumentality into the fabric of everyday life, even into the human body, is perhaps most evident in the works of Dada Berlin, the most politicized wing of the Dada movement. (Huyssen 11)

The avant-garde's use of technology has been analyzed in relationship to the moral and political implications of the period, placing these experiments in a larger socio-historical framework that explores modernism's hostility to mass culture, attempts to overcome the art/life dichotomy, and the transformation of societies and everyday life. However, to focus only on the avant-garde's use of technology as a critique of mass culture and capitalism (Benjamin; Adorno), or to consider the patriarchal and misogynistic trends of modernism—as evidenced in Marinetti's *Futurist Manifesto* and the Constructivist fetishization of machines and production— (Huyseen; Haraway 1985) is to miss an opportunity to explore the creative approaches of these artists that merged scientific discovery, technological innovation, philosophical principles, and contemporary art practice. In Michael Kirby's words, "Why an artist produces a particular product may be interesting from a psychological or sociological point of view, but it is unimportant aesthetically. A work of art may have certain characteristics for the "wrong" (or the "right") reason, but it need be only the characteristic that concerns us" (18).

Given that the larger goal of this study is to develop an aesthetics of autonomous and semi-autonomous machines, I set aside for the moment Feminist and Marxist readings of the avant-garde technological body and instead call attention to how these productions staged machines and mechanical bodies in performance. Reading these productions through the lens of puppetry calls attention to the unique, creative atmosphere a period that witnessed an unparalleled cross-pollination of the arts, and gives fuller appreciation to the effort to reconcile machine culture and aesthetics with human performance.

Mapping the influence of puppetry on experiments by the historical avant-garde presents some difficulty because the puppet was utilized by artists and scholars varyingly, signifying different things at different times. The puppet was frequently employed as a metaphor for the human condition (in plays by Maeterlinck and Schnitzler, among others), as inspiration for the development of a theatre based only on movement and gesture (Craig, Schlemmer), as acting instructors *par excellence* (Kleist, Craig, Anatole France), and as vehicles for political satire (Jarry, Hauptmann). In *Pinnochio's Progeny*, Harold Segel traces the literary and dramatic fascination with puppets, marionettes, and automatons in modernist and avant-garde drama. Although Segel claims that the turn of the twentieth century is unparalleled in its "susceptibility to the allure of the puppet figure" (34), the analysis of numerous plays from the period that employed the puppet/marionette theme metaphorically is interesting because of how few of these plays actually featured puppets. When marionettes were called for onstage (as in the 1923 Spanish drama *Senor Pygmalion* by Jacinto Grau, Oskar Kokoschka's *Sphinx and Strawman*, or Marinetti's *Sexual Electricity*) the "marionettes" were usually played by human actors who were directed to move using stylized, mechanical gestures and movements in the "style" of marionettes. In these instances, rather than exploring the unique theatricality of the puppet figure, the puppet never moves beyond its metaphorical use—either as a critique of bourgeois values and culture or as an opportunity to introduce the element of the grotesque.

As Segel and Huyseen have suggested, during this period the puppet was most often used as a metaphor for the human condition, where man is conceived as a puppet figure and subject to forces beyond his ken. These plays rarely move beyond a superficial understanding of the unique aspects of puppets and puppet theatre. Puppets were sometimes adapted for use in political satire (as in Jarry's *Ubu Roi* and Hauptmann's *Festival Play in German Verse* (*Festspeil in deutsche Reimen zur Erinnerung an den Geist der Freiheits-kriege der Jahre actzehnhundertfeier in Breslau 1913*) (Segel 204), but more often the puppet or automaton appears only as a motif conducive to exploring emergent questions about culture, technology, and progress.

One of the most well-known examples from theatre history is Karel Capek's play *R.U.R.* which premiered in Berlin in 1922. While the production featured a strikingly innovative set designed by Bauhaus artist Frederick Kiesler that combined a mobile wall relief with "television panels" and film projection, the play that first introduces the neologism "robot" offers a surprisingly amateurish and non-technical image of artificial life (Goldberg 1979, 75). Rossum's robots were played by unmasked human actors wearing angular, geometric costumes and moved using stiff or mechanical-looking gestures. The production's depiction of autonomous robots is largely representational and naturalistic; there is nothing in the design or the costuming that suggested the merging of humans and machine. In *R.U.R.*, and the aforementioned plays which employ puppets, marionettes, and automatons as metaphors, the puppet does not work to reconcile the human and the machine in a unified aesthetic field, but only serves as a metaphor for the human condition or dystopian vision of modern culture or technology.[14]

However, some avant-gardists recognized the puppet as a technological instrument through which they could develop objective, non-personal art objects and performances. In these cases, puppetry provided a method for joining human actors with performing objects and mechanical devices onstage, providing a means for reconciling the human and the machine in a unified aesthetic field. Because puppets are not inanimate, they are more able to indicate an objective reality than a human performer. Hungarian puppeteer Dezsö Szilágyi recognized this distinction, arguing that the fundamental difference between live theatre and puppetry is that "puppet theatre is in a position to give objective reality and gossamer human fancy equal value, to unite them as equals, blend reality and unreality quite naturally, alternate the miraculous with the familiar, and express thoughts in visual metaphors" (in Jurkwoski, vol 2, 310). Szilágyi's description of puppet theatre echoes similar claims by Jurkowski, Proschan, and States discussed in the previous chapter, which recognized in the puppet the ability to reveal simultaneously the real and imagined, the phenomenal and the significative, the sign and sign-system.

[14] Interestingly, puppet dramaturgy of the period reflects a similar reticence towards experimentation. Jurkowski, notes that many puppet and theatre artists of the period never "ventured beyond naturalistic forms" (1988, 2:30). While dramatists used the puppet motif to highlight artificial behaviors and the grotesque, in turn-of-the-century puppet drama "the puppets remained not more than human figures in miniature." Experimentation in puppet theatre would change with puppet artists like Alexandra Exter and Nina Effimova, who focused on the dynamic properties of the puppets.

Artists such as Marinetti, Prampolini, Depero, Schlemmer, and Moholy-Nagy who were interested in developing a non-personal form of theatre and a method for rendering the dynamism of objects found in puppetry tremendous artistic potential. The puppet enabled them to develop the autonomous art object from two dimensional painting into three dimensional sculpture and—eventually—the time based-art of live performance.

Szilágyi's recognition of puppetry's symbiosis of "objective reality" with "human fancy" is similar to States' binocular vision discussed in the previous chapter: both theories underscore the phenomenological stance that undergirds all puppet performance. The phenomenological stance provoked by puppets intrigued modernist artists such as Craig and Meyerhold, who recognized in puppet theatre valuable approaches for a stylized human theatre. I have already mentioned the influence of puppetry of Craig's *The Actor and the Übermarionette* (1907). Meyerhold's consideration of the puppet theatre in his 1912 essay "*Balagan"* (*The Fairground Booth*) provides another example of how avant-garde artists mined the artistic potential of the puppet. Although Meyerhold and Craig were both ardent exponents of anti-realistic, anti-naturalistic, stylized theatre (Craig commissioned several large-scale marionettes and authored marionette plays, and Meyerhold's production of Gogol's *The Inspector General* featured large dolls), their interest in puppetry initially appears largely metaphorical. Puppets, in Craig's view, were instructors *par excellence* for human actors learning to avoid mimicry and affectation in their performances. In puppetry, Craig saw a useful metaphor and also a noble and holy theatrical lineage: he traces the history of puppetry as "descendants of a great and noble family of Images, images which were indeed made 'in the likeness of god'" (Craig 90). Segel suggests that Craig's notion of the Übermarionette was

> […] obviously inspired by Nietzsche's concept of the Übermensch, the superman who achieves the strength of will to overcome his own weakness and rise above the limitations of Judeo-Christian morality. In Craig's thinking the Über-marionette was to be the actor who overcomes his own human limitations, psychological, emotional, and even physical, by modeling himself instead on the puppet and marionette—emotionless, obedient, the perfect servant of his master's will. The master, of course, was to be the theatrical director; by making himself utterly submissive to the director, to be operated by him like a puppet or a marionette, the actor could achieve the status of an Über-marionette. (56)

Although Meyerhold's consideration of puppetry in *Balagan* is largely metaphorical, it underscores essential qualities of puppetry that would later be taken up by other avant-gardists. Like Craig, Meyerhold criticizes the imitative approach of realistic and naturalist acting styles, and celebrates puppetry's use of creative movement and gesture. He uses the example of two invented puppet theatres to illustrate his point: while one company aims at the imitation of human behaviors and gestures (where the puppets "look and behave like real men"), the other theatre is concerned with the specific, artificial quality of puppetry. Although the director of the second puppet theatre uses mimesis as a starting point,

> he quickly realized that as soon as he tried to improve the puppet's mechanism it lost part of its charm. It was as though the puppet were resisting such barbarous improvements with all its being. The director came to his senses when he realized that there is a limit beyond which there is no alternative but to replace the puppet with a man. But how could he part with the puppet which had created a world of enchantment with its incomparable movements, its expressive gestures achieved by some magic known to it alone, its angularity which reaches the heights of true plasticity? (Meyerhold 128)

Meyerhold identifies a paradox of puppet motion: through its design, the puppet partly resists the puppeteer's attempt to direct it, but it is because of this resistance that puppet is able to create powerful and expressive gestures and movement that rise above mere imitation. For Meyerhold, the audience delights in the movement of the puppets which, "despite all attempts to reproduce life on the stage, fail to resemble exactly what the spectator sees in real life" (Meyerhold 128):

> The puppet did not want to become an exact replica of man, because the world of the puppet is a wonderland of make-believe, and the

> man which impersonates is a make-believe man. The stage of the puppet theatre is a sounding board for the strings of the puppet's art. On this stage things are not as they are because nature is like that but because that is how the puppet wishes it—and it wishes not to copy but to create. (129)

Meyerhold's assessment of puppetry is consistent with notions of puppetry that we have considered so far—although rooted in mimesis, the goal of puppetry is not to produce an exact copy or realistic simulacra of life. The puppet's power of artistic expression is not determined by how well it mimics human behavior but rather by its ability to abstract the human experience and offer an artistic projection of a recognizable world from which we are partly or wholly free. Like Craig, Meyerhold saw in puppetry principles that were conducive for abolishing realistic and naturalistic acting techniques in favor of stylization, contrast, and dynamic movement. For Meyerhold, the puppet was "not a competitor of the actor, only the perfect teacher," because the underlying principle of puppetry is that the puppet wishes "not to copy, but to create" (Jurkowski 1998 2:42). Meyerhold applied some of these principles onstage in his production of Alexander Blok's *The Puppet Booth*, which featured human actors performing in the style of marionettes and *commedia dell'arte*. Despite his interest in puppets and their potential for creative movement, it ultimately would be Taylorism[15] that would provide Meyerhold with the methodology for his systematic approach to movement and choreography. Still, Meyerhold and Craig's interest in puppetry is a testimony to puppetry's influence on modernist thinking with regards to theatrical performance and creative, expressive movement as fundamental to artistic representation.

Meyerhold's consideration of puppet theatres in *Balagan* and Craig's concept of the Übermarionette reflects the turn-of-the-century interest in puppetry and the avant-garde's use of the principles of stylization and abstraction to reinvigorate theatre practice. Puppetry's emphasis on creative and stylized movement and gesture (as opposed to imitation and verisimilitude) results in a confrontation of visual codes that opens up an aesthetic distance between the performing object and the spectator. This distance allows the puppet (subject) to abstract the human experience and to transcend the psychic, subjective, and idiosyncratic qualities that characterize performances by humans. To understand how, precisely, the puppet was combined with human performers and mechanical bodies to create autonomous art objects, we must transition from Meyerhold and Craig's theoretical doctrines to the works of practitioners who formalized their methods: Russian artist and puppeteer Vladimir Sokolov and Futurist artist Umberto Boccioni. Considered together, their theories regarding space and kinetic motions of art objects demonstrate the shared principles of puppetry and avant-garde performance.

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[15] Meyerhold's "Biomechanics" sought to combine Frederick Winslow Taylor's theory of work gestures (published in *The Principles of Scientific Management* in 1911) with theatrical gestures and the natural possibilities of the human body through stylized gestures and choreography. See *Meyerhold, Eisenstein, and Biomechanics* by Alma Law and Mel Gordon (1996), and Felicia McCarren's *Dancing Machines* (2003).

THEORIES OF AUTONOMOUS ART OBJECTS

Avant-gardists valued puppets for their phenomenological and signifying functions. They also recognized puppets as technological instruments that rely on the principles of kinetic movement and abstraction. Russian artist Vladimir Sokolov, who ran the Puppet Workshop at Tairov's *Kamerny* theatre, experimented with traditional marionette puppetry as well as abstract puppetry and object theatre (Jurkowski vol 2, 32). In an essay published in *Das Puppentheater* in 1923, Sokolov describes two approaches to marionette puppetry which he believed enabled puppet theatre to reach its own "independent, artistic pinnacle." The first approach is that of "true eccentricity" where there are "no limits to the playing of the figures, from the point of view of their appearance, movement, acting, and acting space." Puppets

> can participate in the show as purely exterior manifestations of the grotesque, the eccentric, and the fantastic. For example, in one scene that I play, one figure literally loses its head, when he sees his beloved in an airship. Another figure has two heads, one to use on weekdays and the second on Sunday. You may have a figure with arms and legs and no body, or similarly a figure with many hands attached to its body. In this way I can present pictorially an efficient servant or waiter, always "at hand." In a piece called "The Devil's Tears" by Théophile Gautier, a love story is presented with objects,

> before the eyes of a young man inexperienced in such matters. An armchair caresses another chair with great sentiment, a brush seduces a comb. Two lamps glow with love, but when they draw near each other they are overcome by flames. We agree with all of this on our first approach: everything accords with the nature of the puppet, defines its characteristics and discovers its specificity. (Jurkowski 1998:33)

The way of "true eccentricity" described by Sokolov seems an apt description of the experiments by Futurists, Dadaists, and Surrealists, whose valorization of the illogical and the absurd featured improbable and hyperbolic gestures and actions. Sokolov's descriptions of the anthropomorphic furniture and a puppet that loses its head, is reminiscent of scenes in Apollinaire's 1903 *Les Mamelles de Tirésius* (*The Breasts of Tiresius*), which included a singing and dancing newspaper kiosk, and the scene wherein the heroine, Thérèse, renounces her gender by releasing her red and blue balloon "breasts" into the air, which were attached to her costume with strings. Puppetry's innate capacity for abstraction, eccentricity, and playfulness made it attractive to theatre artists interested in forms of expression predisposed to satire, parody, and the carnivalesque. But Futurists and Bauhaus artists were equally interested in developing a style of play based on principles of mechanism and objectivity, and it is here that their work intersects with Sokolov's second approach to puppetry:

> I call it the approach of true movement. Here the puppet may be free from any similarity to the human form. The marionette extols puppetry's virtue of creative movement and gesture over imitative, representational qualities. Perhaps the word "marionette" will disappear as well. On this road the show is played through associated or abstracted forms, through planes, lines, or sets of fixed points, as well as through the changing of light and colour— we deal here with a *complexity of movement*, with a complexity of interpenetration and permanent ascent, so with a complexity of separate endeavors, of *constant transformation*. (Jurkowski 1998:33, my emphasis)

Although there are scant records of Sokolov's work at the *Kamerny*, this passage in Jurkowski indicates Sokolov's vision of puppetry as significantly innovative for his time. Crucially, Sokolov's description of puppetry in abstract and geometrical terms echoes very the language used to define the emerging aesthetics of Futurism, Constructivism, and Bauhaus. Sokolov conceives of puppetry as a process of "constant transformation," where drama and meaning are created through the dynamic and creative movement of the performing object. This movement, in turn, frees the puppet of its "objectness" and allows it to be perceived simultaneously both phenomenally and significatively. This corresponds to the avant-garde's concern with developing modes of performance that transcended the subjective, psychic aspects of theatre in favor of abstracted and stylized forms, and echoes Schlemmer's conception of theatre as the "transfiguration of the human form." For Sokolov, a puppeteer's exploration of a puppet's inherent dynamic and kinetic properties enables the puppet to transcend its objectness through movement, resulting in an autonomous art object. In other words, the object/puppet performs without reference to an external representation. Through abstract design and movement, the work of art achieves a type of objectivity or autonomy.

What Sokolov identified as an essential aspect of puppet theatre, we can recognize in Umberto Boccioni's notion of dynamic movement outlined in the 1914 Manifesto "Absolute Motion + Relative Motion= Dynamism," which identifies the relationship between objects, dynamism, and plasticity in relationship to painting and sculpture. Boccioni's theory of dynamism influenced Futurist artists such as Prampolini and Depero, as well as Bauhaus aesthetics, and is reflected in the attention these artists give to dynamic, plastic objects and their surrounding spaces. As Boccioni's definition of dynamism is central to works discussed later in the chapter, it is worth quoting at length:

> Absolute motion is a dynamic law inherent in an object. The plastic construction of the object must here concern itself with the motion which an object has within itself, whether it be at rest or in movement. I have made this distinction between rest and movement so that I may make myself clear, although, in fact, there is no such thing as rest, only motion (rest being merely relative, a matter of appearance). This plastic construction obeys a law of motion which

characterizes the body in question. It is the plastic power which the object contains within itself, closely bound up with its organic substance, determined by its particular characteristics: colour, temperature, consistency, form (flat, concave, cubic, conic, spiral, elliptical, spherical, etc.).

The plastic power with which an object is endowed is its force, that is, its primordial psychology. This power, this primordial psychology, enables us to create in our paintings new subjects which do not aim at narrative or episodic representation; instead it coordinates different plastic values of reality, a coordination which is purely architectural, freed of all literary and sentimental influences.

In this initial state of motion, which I envisage as a thing apart—although in fact it is not—the object is not seen with its relative motion but is conceived according to its living outlines, which reveal how its motion would be broken up according to the tendencies of its forces. In this way we obtain a decomposition of the object, which is a method far removed from the intellectual schema of the Cubists. Instead it presents the *appearance* of an object, interpreting it through a sensation which is infinitely refined and superior to those of past times.

> This is how we consider the motion of an object, what one might call its breathing or its heartbeat. A hesitant, unconscious hint of this breathing can be discerned in Italian art from its beginnings. This is what plastic art is all about. (Boccioni 150)

There are two significant principles we can extract from Boccioni's artistic manifesto: 1) the power of movement to reveal artistic truths and 2) the identification of a life force contained within an inanimate art work. Boccioni's preoccupation with movement, the implied and dynamic movement of an object relative to itself and the space around it, was taken up by Futurist and Bauhaus artists who believed in the power of movement to reveal certain artistic truths.[16] By exploring the movement of non-personal, non-representational objects, their works pointed towards the possibility of the artificial and inanimate objects to reveal artistic truths. This interest contributed to the formal investigation of machine aesthetics and mechanical bodies.

The expressive human body and the machine were explored in terms of movement, often adapting the style of what Felicia McCarren calls the *economy of gesture*, which has roots in Taylorism and Fordism. McCarren suggests that the exploration of human and mechanized movement in painting, sculpture, and performance is directly related to the nineteenth century re-conception of machines as motor forces linked to thermodynamics and governed by internal, dynamic

[16] The representation of dynamic movement through scenic objects can also seen in the work of the Russian Constructivists, but as these experiments did not readily draw on puppetry I have not included them in the present study.

principles (15). McCarren points to the use of the word "motor" to describe the movement of machines and human and animal reflexes a demonstration of the "interlocking conceptions of human and machine." While these interlocking conceptions can be traced to earlier studies, such as Julien Offray de la Mettrie's *L'homme Machine* (1748), comparisons between humans and machines reached new fervency in the nineteenth century, and such ideas were explored in dance, theatre, and visual arts by avant garde artists.

McCarren identifies two simultaneous histories of the economy of gesture: "one recounting the stripping down of gesture and bodies to machine aesthetics and the minimum gesture, from Mareyism to Taylorism, the other recounting the fleshing out of machines with bodies, reconnecting technology to its mythic, ritual, or religious functions" (11). The works of the Futurist and the Bauhaus reveal these two trends, and reveal two distinct approaches adapting puppetry to explore dynamic movement. Prampolini and Depero designed stages and machines that used minimum, expressive gestures to give the expression of felt life, even when no human performers were seen on stage. In these objects, the sources of the motor and rumoristic powers were contained within the objects themselves. Schlemmer and Moholy-Nagy's work at the Bauhaus reflected the "fleshing out" approach, where costumes and mechanical apparatuses metamorphosed the human figure into (essentially) mechanical objects animated by human performers from within. Such productions combined Boccioni's interest in dynamism and kinetic movement with the traditional puppetry techniques identified by Sokolov: Prampolini and Depero both collaborated with Podrecca's *Teatro di Piccoli*, while the Bauhaus school had a puppet theatre operated by Paul Klee, Ilse Fehling, and Kurt Schmidt. Additionally, puppet theory looms large in Schlemmer and Moholy-Nagy's descriptions of the *kunstfigur* (autonomous art figure) and *Mechanized Eccentric*. It is my assertion that Futurist and Bauhaus artists utilized puppetry as a way to both conceptualize and realize new types of autonomous acting agents. Although they did not feature robots *per se*, the use of puppetry toward the creation of mechanical stages free of human performers, and mechanical performing bodies that appeared to perform independently from their human operators, represents a significant contribution to the aesthetics of autonomous acting machines.

Returning to Boccioni's manifesto, the second point of interest is the author's suggestion of the possibility of a life force contained within an inanimate work of art. His description of locating the "breath" or "heartbeat" of a work parallels puppeteer Basil Jones' description of the phenomenon of "breathed stillness" in puppetry. Jones proposes that some of the most powerful moments in puppet theatre are experienced when the puppet is still, but is perceived to be breathing (echoing the notion of a system close to equilibrium but not at it). Thus, Jones argues, the spectator enters "into an empathetic relationship with the object that is being brought to life" (Jones in Taylor, 262).[17] I would like to draw a parallel between the work of visual artists and the work of puppeteers: both are tasked with rendering inanimate objects animate, with imbuing unconscious, non-living art object with some life-force or the appearance of a soul. For Boccioni, this process

[17] Jones' concept is considered more thoroughly in Chapter Five.

could best be achieved not through realistic representation or through abstracted geometric forms of the Cubists, but through the formal exploration and rendering of an object's absolute and relative motion: dynamism. The puppet's implied potential for movement—what Proschan calls "creative energy" and Gross identifies as the puppet's "potential for motion"—commanded the attention of avant-garde artists. Lacking sophisticated technology and technical mastery, the puppet enabled them to move beyond two dimensional representations towards three-dimensional sculpture and performance. These works explored the processes of animating inanimate objects through movement, and in doing so demonstrate the power of artificial and inanimate objects to reveal artistic truths.

In their search for new forms of representation, Futurist and Bauhaus artists were preoccupied with plastic objectivity, and their work can be characterized by an indifference towards the expression of psychic aspects and a focus on how objects move and interact in the world, and how such objects are perceived by the spectator. This led to formal explorations of abstraction and the use of real elements to create works of art that were intended as concrete, autonomous objects, and machines and technology met this fundamental need. Or, as Pontus Hulten states in *Futurismo and Futurismi*:

> The machine acts as a model to direct the formative processes towards greater objectivity and structural rigor. Whether it retains figurative elements or moves towards abstraction, these works tend

> to appear as objective entities, perfectly self-contained and directed by autonomous laws, like a mechanical device. (543)

In the following section, I examine specific productions and designs for objects and performance that I identify as proto-robotic performance. Proto-robotic refers to work that incorporated either autonomous art objects or objects that create an illusion of autonomy through the manipulation of mechanical, geometrical, or spatial properties of the performing object and the surrounding stage space. I divide proto-robotic performances in two groups: mechanical scenery and mechanical bodies. In mechanical scenery, the focus is on creating flexible, dynamic scenic spaces where the dramatic action arises through the interaction of moveable scenic architecture with light and sound. In these performances, the human performer is no longer the subject of the performance but rather, like a puppeteer, directs the production from off stage. In this arrangement, the stage properties of scenic architecture (form, line), light (color), and sound act as the subjects of performance.

Mechanical bodies refers to the development of autonomous acting machines, where performing objects are animated through either direct human manipulation (costumes that metamorphose the human body), or through the design of mechanical objects (mechanical marionettes or automatons). The two types of mechanized bodies reflect the varying influences of traditional puppetry and mechanical automation. In the case of costume design, the human performer animates the costume through direct manipulation as a puppeteer animates a puppet. In this arrangement, the mechanized figure can be considered a puppet because it is powered by a human operator and makes temporal use of vocal and motor sources of power that are outside of it. Unlike mechanical costumes, mechanical objects function more like automatons, where the motor and rumoristic qualities are directed by sources within the object and do not require a human to perpetually operate them. The use of mechanical scenery and mechanical bodies reflect the avant-garde's incorporation of technology into art, and the larger task of reconciling the human and the machine in a unified aesthetic field. Both approaches resulted in new types of animated figures onstage, ushering forth new conceptions of both the mechanized body and the mechanical performer thereby introduced the possibility of autonomous acting agents.

MECHANICAL SCENERY

Marinetti's 1913 manifesto "The Variety Theatre" vehemently critiques the contemporary theatre's fixation on realism and the "photographic reproduction" of daily life. Marinetti advocates for the reconstruction of theatre through the use of "modern mechanics" to reinvent stage practice along the following lines:

> (a)Powerful caricatures; (b) abysses of the ridiculous; (c) delicious, impalpable ironies; (d) all-embracing, definitive symbols; (e) cascades on uncontrollable hilarity; (f) profound analogies between humanity, the animal, vegetable, and mechanical worlds; (g) flashes of cynicism; (h) plots full of wit, repartee, and conundrums that aerate the

> intelligence; (i) the whole gamut of laughter and smiles, to flex the nerves; (j) the whole gamut of stupidity, imbecility, doltishness, and absurdity, insensibly pushing the intelligence to the very border of madness; (k) all the new significations of light, sound, noise, and language, with their mysterious and inexplicable extensions into the least-explored part of our sensibility; (l) a cumulus of events unfolded at great speed, of stage characters pushed from right to left in two minutes ("and now let's have a look at the Balkans": King Nicholas, Enver-Bey, Daneff, Venizelos, belly-blows and fistfights between Serbs and Bulgars, a *couplet*, and everything vanishes); (m) instructive satirical pantomimes; (n) caricatures of suffering and nostalgia, strongly impressed on the sensibility through gestures exasperating in their spasmodic, hesitant, weary slowness; grave words made ridiculous by funny gestures, bizarre disguises, mutilated words, ugly faces, pratfalls. (Marinetti 180)

While Marinetti's demand that theatre incorporate "elements of a new sensibility" might have appeared novel to then-contemporary theatre practitioners, such elements were not only known to puppet artists, but practically constitute the entire purview of puppet theatre. Where else but in the puppet theatre can "a cumulus of events" unfold at great speed, and stage characters be pushed from right to left in two minutes? The "profound analogies between humanity, the animal, vegetable, and mechanical worlds" have been explored on puppet stages since antiquity. It should come as no surprise, then, to discover that it was in a puppet theatre where Futurists Prampolini and Depero first developed their ideas for kinetic stages, mechanical costumes, and automated performers.

Vittorio Podrecca's *Teatro dei Piccoli* at the Palazzo Odescalchi in Rome was a commercial puppet theatre specializing in musical variety shows that featured marionettes and glove puppets. It also served briefly as a laboratory for Futurist artists to try out their ideas for new stage architecture and performing objects and machines: in 1919 Prampolini designed sets for Podrecca's production of the French symbolist play *Matoum et Tevibar* by Pierre Albert-Birot and in April 1918 Depero staged *I Balli Plastici per Marionette* (Jurkowski 1998: 99). Puppet theatre influenced both Prampolini and Depero's thinking about kinetic stages and provided the platform for rehearsing and developing these ideas before adapting them to larger stages for human actors.

Enrico Prampolini (1894-1960) is a painter and designer best known for his contributions to scenic design, conceived of scenic spaces as plastic, dynamic play spaces towards the creation of a total theatre. He published his ideas for new approaches to scenic design in the 1915 manifesto *Futurista Scenografia*, (*Futurist Scenography*), which reflects the influence of Craig's *New Stagecraft* and Boccioni's theory of dynamism and presents a vision for a Futurist theatre (Kirby 75). Prampolini's aim was to "overcome the dichotomy of actor and stage machinery and to create performances, where the 'abstract entity of the stage becomes one with the scenic action'" (Berghaus 271). If, as Kirby has suggested, Marinetti's initial vision for Futurist theatre emphasized two distinct styles of play—the illogical or absurd and the mechanical or objective— then Prampolini can be understood as chiefly concerned with the latter. His focus on dynamic architectural structures and "moto-rumoristic costumes" for dancers reveal his study of laws of dynamics towards the creation of autonomous art objects. His scenography and costume designs reflect an interest in the nature of theatrical perception and the autopoietic feedback loop. Unlike Kandinsky who thought that stage compositions should aspire to manifesting psychological or emotive processes, Prampolini was intent on creating an objective work of art that could embody and communicate to the spectator the "lyrical emotion and sensibility of the material itself, rather than some external feeling or cerebral impulse of the artist" (Berghaus 267). To that end, Prampolini proposed plastic constructions "entirely derived from the intrinsic value of the material" (Berghaus 267). For Prampolini (like his contemporary Duchamp), meaning is evoked through a dialectical process, where the artist acts as an engineer that organizes the material in such a way that it evokes the "drama of matter" or the "lyricism of pure form" (Berghaus 267). To achieve this lyricism, Prampolini wanted to develop a new art form: "an abstract, autonomous, scenic event, uncontaminated by other artistic conventions and constructed from the elements of pure form, colour, light, and movement."

Prampolini was certainly not the first theatre artist to express an interest in creating moving scenery. Christopher Baugh writes about the profound ways in which science and technology have contributed to the evolving modes of narrative and representation and the impact on stage spectacle and moving scenery: "since the Renaissance work of Bernardo Buontalenti at the court of the Medici, and Inigo

Jones at the Stuart Court, the endeavor of the stage had been to enable movement, and to provide the *frisson* of excitement as the scenic world dissolved and reformed before your eyes (Baugh 87). The use of kinetic stages and the conception of the scenic stage as a type of "performance machine" found fuller realization during the modern period, when artists such as Craig, Appia, Meyerhold, and Fuchs (among others) developed new theories and practices for visual staging and lighting. *New Stagecraft* emphasizes the mechanical reality of the stage and sought to reveal "by means of movement the invisible things, those seen through the eye and not with the eye, by the wonderful and divine power of movement" (Craig 46). What distinguishes Prampolini's work from these other attempts to create kinetic stages and their interest in the construction of stage space is that the properties of the stage are not conceived merely as an architecture for performance, but rather as the subject of performance. While Craig might have imagined "the time when we shall be able to create works of art in the Theatre without the use of the written play, without the use of actors" (Craig 53), Prampolini actively imagines scenic spaces and stage phenomena replacing human performers as the sole subjects of performance.

Prampolini, Depero, Schlemmer and Moholy-Nagy imagined flexible, dynamic scenic spaces where the dramatic action arises through the interaction of moveable scenic architecture with light and sound. The result was a stage free from the psychology of human figures, and rather than replacing the human with representational puppet or objects, the "mechanistic organism" of the stage becomes the subject of the dramatic action. For these artists, the absence of human performers and representational forms is was what defined the autonomous art object: a performance/object is autonomous only if the object resembles itself alone and is not representative of another form. Prampolini's "Magnetic Theatre," Depero's "Teatro Magico" and Moholy-Nagy's "*Die mechanische Exzentrik*" (*Mechanized Eccentric*), applied the study of dynamism and abstraction to the theatrical stage. In these performances, the human performers and any references to them are omitted. These artists intended to create a "precise and fully controlled organization of form and motion, intended to be a synthesis of dynamically contrasting phenomena (space, form, motion, sound, and light)" (Moholy-Nagy in Gropius 54). In this new type of theatre, the human functions as a puppeteer or engineer that directs the production from offstage, and the subject of performance is the interaction of the essential stage phenomena. Without figural representations, the kinetic stage acquires a type of spiritual life-force, or the appearance of a soul, which presents the illusion of operating independently from any human impulse. In sum, the artists' formal explorations of movement and abstraction *vis a vis* the kinetic mechanical stage creates a non-representational, non-imitative, autonomous work of art.

In his 1915 essay *Futurist Scenography*, Prampolini defines scenic dynamism as the essential theatrical action, and uses the mechanical stage as the vehicle for exploring his aesthetic program. In the hyperbolic language typical of Futurist manifestos, Prampolini calls for a complete renovation of traditional stage practice, abolishing the practice of painted scenery and human actors and replacing them with a kinetic stage, dramatic lighting changes, and mechanized scene changes. The new stage would be comprised of

> […] *colorless electromechanical architecture, powerfully vitalized by chromatic emanations from a luminous source*, produced by electric reflectors with multicolored panes of glass, arranged, coordinated analogically with the psyche of each scenic action. With the luminous irradiations of these beams, of these planes of coloured lights, the dynamic combinations will give marvelous results of mutual permeation, of intersection of lights and shadows. From these will arise vacant abandonments, exultant, luminous corporealities. These assemblages, these unreal shocks, this exuberance of sensations combined with the dynamic stage architecture that will move, unleashing metallic arms, knocking over plastic planes, amidst an essentially new modern noise, will augment the vital intensity of the scenic action. (Prampolini in Kirby 205)

Prampolini's vision of a kinetic theatre without actors is an attempt to develop "interpretive equivalents"—or abstractions— that reflect the dynamic, shifting nature of life in the Machine Age. His suggestion that human beings may no longer be necessary for live theatre (the word he uses is "tolerated") but could be replaced by "actor gases," is not to suggest that the human condition should no longer be the subject of artistic exploration, but rather that the natural, human performer is no longer the most capable entity to express this new reality. Prampolini's kinetic stage signals the bodying forth of a different type of mechanical corporeal body is better suited to expressing the contemporary understanding of the human condition:

> Vibrations, luminous forms (produced by electric currents and colored gases) will wriggle and writhe dynamically, and these authentic actor-gases in an unknown theatre will have to replace living actors. By shrill whistles and strange noises these actor-gases will be able to give the unusual significations of theatrical interpretations quite well; they will be able to express these multiform emotive tonalities with much more effectiveness than some celebrated actor or other can with his displays. These exhilarant, explosive gases will fill the audience with joy or terror, and the audience will perhaps become an actor in itself as well. (Prampolini 206)

Prampolini proposes that the synthesis of kinetic architecture with sound and lighting effects and electric gases would produce artificial corporealities that would "inevitably arouse new sensations and emotional values in the spectator." His description is consistent with Fischer-Lichte's conception of theatre as an autopoietic feedback loop discussed in the previous chapter. Prampolini's vision of an actor-less theatrical production would be partially realized two years later in Giacomo Balla's production of *Fue d'Artifice* for Diaghilev's *Ballet Russes* (Kirby 82). The production was performed to Stravinsky's score, lasted five minutes, and contained forty nine lighting cues. However, the production did not make use of any moving scenery: the stage remained static, and the geometric shapes suspended from the ceiling were static. Possibly inspired by Balla's production, Prampolini conceived of the *Magnetic Theatre*, a total, synthetic, actor-less theatre which should be

> Made up of a mass of plastic constructions in action which rises from the center of the theatrical hollow instead of the periphery of the "scenic-arc". Auxiliary moving constructions rise, first on a square, moveable platform, standing on an elevator. On this in turn is erected a *moving*, *rolling* platform going in the opposite direction from the first, and likewise carrying other *planes* and *auxiliary* volumes. To these plastic constructions, *ascending*, *rotating*, and *shifting* movement are given, in accordance with necessity. The scenic action of the chromatic light, an essential element of interaction in creating the scenic personality of the space, unfolds parallel to the scenic development of these moving constructions. Its function is to give *spiritual life* to the environment or setting, while measuring time in *scenic space*. The chromatic ladder will be made with apparatuses of *projection, refraction, and diffusion*. (Prampolini in Kirby 87)

In 1925, Prampolini's design for the *Teatro Magnetico* was awarded the Grand Prize for Theatrical Design at the International Expositions of Decorative Arts (Kirby 87). This miniature theatre which (like so many Futurists designs) was never realized in full-scale, illustrates Prampolini's ideas about mechanical stages and machine aesthetics.

Although Prampolini called for abolishing the human actor onstage, Kirby argues that this does not necessarily mean the abolishment of personification: it is important to distinguish between kinetic scenery and objects that personify, and those that do not (91). For example, the actor-gases that were to "wriggle and writhe dynamically" and emit noises personify human behavior, whereas the "auxillary moving constructions" of the *Magnetic Theatre* do not. However, in all of these theoretical synthesis, Prampolini envisions the properties of the scenic stage: form, color, light, and sound kinetic stages, moving lights, scenic spaces, coming together to acquire a spiritual life, partly through their autonomous behavior and partly through the spectator's sensibility and desire to locate meaning in a work of art. The kinetic stage might not personify, but it does demonstrate unique characteristics that signal agency (movement that corresponds to some observable reality). In this way, Prampolini demands that the spectator adopt the same phenomenological stance towards the kinetic scenic space that they would when observing human actors or puppets onstage. Here, the essence of the performance is manifested chiefly through the relationships and transformations of space and mass. Through the eye of the beholder, the *Magnetic Theatre* acquires an imagined life— one that reflects the speed, light, mechanisms, and transformation of the human experience in the Machine Age.

Prampolini's description of the *Magnetic Theatre* echoes Boccioni's theory that the principle of dynamism can evoke the "primordial psychology" of objects: "This power, this primordial psychology, enables us to create in our paintings new subjects which do not aim at narrative or episodic representation; instead it coordinates different plastic values of reality, a coordination which is purely architectural, freed of all literary and sentimental influences." The technique for which Boccioni advocates in painting, Prampolini attempts to realize on the theatrical stage. The artist's vision for a total, synthetic theatre, represented in miniature by a scale model of the *Magnetic Theatre*, represents a bodying forth of new corporealities powered by machines, magnets, and electricity. While Berghaus credits Boccioni with influencing Prampolini's movement from painting to scenography and mobile scenic architecture (266-267), it is useful to remember that it was at Podrecca's puppet theatre where Prampolini first established himself as a scenic artist, moving for the first time from theoretical manifestos to actual stage practice.

The Futurist designs for actor-less, mechanical stages demonstrate the artists' lineage as painters, moving from two dimensional realm of painting to three-dimensional sculpture and, eventually, theatrical performance. Although the Bauhaus school "embraced the whole range of visual arts," the influence of architecture and sculpture is particularly strong. The mechanical stages of Walter Gropius, Oskar Schlemmer, Laszlo Moholy-Nagy, and Kurt Schmidt reflect this lineage: although theatre was not initially part of the formal program at the

Bauhaus school, the stage workshop would come to occupy a central and defining role in the development of Bauhaus aesthetics. Schlemmer and Moholy-Nagy's preoccupation with the interpretation of architectural space led to some of the most innovative set designs of the period. Their designs reflect Gropius' conception of the theatrical stage as a "great keyboard for light and space, so objective and adaptable in character that it would respond to any imaginable vision of a stage director; a flexible building, capable of transforming and refreshing the mind by its spatial impact alone."

Melissa Trimingham considers the modern and postmodern tendencies of Bauhaus by reading the stage experiments and conceptions of architecture and mechanization in light of the Edmund Husserl's study of phenomenology, emerging notions of intentionality, and Gestalt psychology (Trimingham 2011). Her goal is to reconcile the aesthetic idealism of the 1920's with the Bauhaus' "continual and insistent manifestation via the body on the Bauhaus stage" (5). She cites Schlemmer's commitment to the creation of "new forms, new combinations, complicated Gestalt forms" that explored "new combinations of light, scenery, the body, motion, objects, sound and time" (43). Trimingham suggests that the goal of these experiments was not (as is commonly held) merely to come to terms with mechanization and embrace the technologies of the Machine Age, but rather to interrogate the very nature of the creative act and to actively involve the spectator in that process. The Bauhaus' explicit acknowledgment of pivotal role of the spectator and the use of puppetry and mechanical scenic devices underscores this point: "At a basic level, puppetry and the manipulation of objects on stage enabled visual artists, who were keen on making and sometimes not so keen on appearing on stage as actors, to engage with performance" (Trimingham 14). The mechanical costumes and use of mechanized stage structures reveal the Bauhaus' ambiguous attitudes towards machine and mechanization.

In *Man and Art Figure*, Schlemmer identifies scenic dynamism as an essential theatrical action. Frist proposing that "the history of the theatre is the history of the transfiguration of the human form," Schlemmer subsequently identifies the stage as the "arena for successive and transient action" where this transfiguration takes place. The stage, according to Schlemmer, differs from the fixed arts of architecture, sculpture, and painting in that it provides the opportunity for the "kaleidoscopic play" of forms and colors in motion. He conceives of the "absolutely visual stage (*Schaubuhne*)," rid of human performers, where the only role for the human is as the "perfect engineer at the central switchboard, from where he [directs] this feast for the eyes" (Schlemmer 22). Schlemmer's vision of an entirely automated stage production was rendered by Moholy-Nagy's in *Die mechanische Exzentrik* (*The Mechanized Eccentric*), or a mechanized theatre landscape that offered "a concentration of stage action in its purest form," is reminiscent of Prampolini's ideas about scenic dynamism:

> Man, who no longer should be permitted to represent himself as a phenomenon of spirit and mind through his intellectual and spiritual capacities, no longer has any place in this concentration of action. For, no matter how cultured he may be, his organism permits him at

> best only a certain range of action, dependent entirely on his natural body mechanism. […] 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. (Moholy-Nagy 53)

For Prampolini, Schlemmer, Moholy-Nagy, the natural body of the human performer is at odds with the new mechanized and technologically sophisticated scenic space. One way of addressing this tension was through the development of mechanical bodies, the other was to eliminate the human being entirely from the stage.

Moholy-Nagy's performance score for the *Mechanized Eccentric* is published in *The Theatre of the Bauhaus* (Gropius 1961). The diagram shows three stages at various levels, indicating the simultaneous interaction of moving scenery and mechanized apparatus, automated human figures, film projections, lighting changes, and musical score comprised of live instruments, megaphones, and sound effects. The piece suggests an abstract, non-representational production, and there is no indication of human performers or dialogue. However, references to performances by "Gigantic Apparatuses," "Clownery," and "Mechanized Men," and "phosphorescence" evoke images of Prampolini's total synthetic theatre of moving mechanical arms and actor gases. As in Futurist scenography, the kinetic architecture and mechanized apparatuses replace human performers as the subjects of performance. The *Mechanized Eccentric* is a synthesis of "dynamically contrasting phenomena" of space, form, motion, sound, and light in a unified aesthetic field: that is, a non-personal, non-imitative live performance that appears to function independently from human consciousness. Despite his conception of an autonomous acting machine, Moholy-Nagy seems reluctant to banish the human figure entirely from the stage:

> One of two points of view still important today holds that the theatre is the concentrated activation (*Aktionskonzentration*) of sound, light (color), space, form, and motion. Here man as coactor is not necessary, since in our day equipment can be constructed which is far more capable of executing the purely mechanical role of man than man himself. […] The other, more popular view will not relinquish the magnificent instrument which is man, even though no one yet has solved the problem of how to employ him as a creative medium on the stage.

Similarly, Schlemmer's essay "*Buhne*"(Theatre) imagines a theatre without human performers, emphasizing the relation between the stage as autonomous acting agent and the performing automaton:

> We can imagine plays whose "plots" consist of nothing more than the pure movement of forms, color, and light. If this movement is to be a mechanical process without human involvement of any sort (except

> for the man at the control panel), we shall have equipment similar to the precision machinery of the perfectly constructed automaton.

Schlemmer and Moholy-Nagy's visions of an actor-less theatre point to one of the central questions of this study: can a mechanical stage, devoid of any human performer, constitute a creative act? Or, *are there imaginable stages/robots/automatons that can convincingly imitate the creative act?* Could such productions provoke the intentional stance and evoke creativity? Despite his attempts to consign the role of the human performer to the back-stage engineer who directs the mechanical production, Schlemmer also expresses uncertainty about the aesthetic appeal of an entirely automated performance. He wonders whether a purely technical, mechanized theatre would be enough to engage and sustain the audience's interest:

> How long, that is, can any rotating, vibrating, whirring contrivance, together with an infinite variety of forms, colors, and lights, sustain the interest of the spectator? The question, in short, is whether the purely mechanical stage can be accepted as an independent genre, and whether, in the long run, it will be able to do without that being who would be acting here solely as the perfect "machinist" and inventor, namely, the human being. (Schlemmer in Gropius 88)

Schlemmer and Moholy-Nagy's anxiety can partly be attributed to the limited technology at the Bauhaus school, (Schlemmer bemoans the lack of funding compared with government-subsidized stages), but both men appear uneasy with the idea of completely replacing the human performer with mechanical stages and automated figures:

> Man remains perforce our essential element. And of course he will remain so as long as the stage exists. In contradistinction to the rationalistically determined world of space, form, and color, man is the vessel of the subconscious, the unmediated experience, and the transcendental. He is the organism of flesh and blood, conditioned by measure and by time. And he is the herald, indeed he is the creator, of possibly the most important elements of theatre: SOUND, WORD, LANGUAGE. (91)

While this passage—and in particular the focus on language and the spoken word—may appear to contradict Schlemmer's conception of theatre as a fundamentally spatial art (Schlemmer 85), we can interpret Schlemmer and Moholy-Nagy's resistance to an entirely mechanized theatre as representative of the avant-garde's complex— and sometimes contradictory— attitudes toward technology and machines. The task for Futurist and Bauhaus artists was not only to develop machine aesthetics, but also to figure out how to employ the human actor as a creative medium on the mechanized stage. Moholy-Nagy frames the problem thus:

> Is it possible to include [the actor's] human, logical functions in a present-day concentration of action on the stage, without running the risk of producing a copy from nature and without falling prey to Dadaist or Merz characterization, composed of eclectic patchwork whose seeming order is purely arbitrary? (60)

The problem of incorporating the human actor into a mechanized landscape was summarized in the art journal *L'Espirit nouveau*: "The problems that have been solved in the mechanical sphere give substance to the desire to find the same precision in that rhythmic machine that is the human body" (Berghaus 409). In the next section, we see how avant-gardists used puppetry to approach this problem. In their efforts to move beyond realistic representations of life towards abstracted and mechanized performers, these artists combined traditional puppetry techniques with human performers to arrive at hybrid, mechanical bodies. If, as Hulten has suggested, the machine acted as the model to direct the formative processes of Futurist artists towards greater objectivity and structural rigor, then the puppet was the tool that enabled them to achieve the kinetic figural and abstract representations of the man-machine.

MECHANICAL BODIES

Marinetti's vision of Futurist performance was partly a vision for the creation of an autonomous, non-imitative art object. His ideas for the theatre privileged an aesthetics of the impersonal and the mechanistic over the personal and idiosyncratic (Kirby 25). In the 1914 manifesto "Dynamic and Synoptic Declamation," Marinetti describes an impersonal and mechanistic approach to costume design, anticipating the geometrical designs of Prampolini, Depero, and the Bauhaus artists. Just as Boccioni used the study of geometric forms to communicate his theory of dynamism, Marinetti advocates for the use of geometric forms in conjunction with the human body to arrive at a less-personal, mechanical performance style. Like Kleist's mechanical marionette or Craig's Übermarionette, Marinetti argued that geometrical costumes would render the human performer devoid of personal and idiosyncratic traits which would result in a more abstract and mechanical performance:

> Marinetti transforms, at least in theory, every aspect of the performer: he should wear anonymous clothing without any details of color or relief; his face should be free of personal expression; his voice should make no use of "modulation or nuance"; his movement should be "geometric." In describing the use of gesture, Marinetti suggests a repertoire of "cubes, cones, spirals, ellipses, etc." that

> prefigures the basic geometrical vocabulary of Bauhaus theory. (Kirby 32)

The geometrical forms that Marinetti describes in theory and Boccioni advocates for in painting influenced the costume design and mechanical marionettes described by Fortunato Depero and Oskar Schlemmer. Depero and Schlemmer's costumes and designs for mechanical figures did not aim at imitative reproduction of human movement, but rather urged the abstraction and stylization of the human figure. Costumes transformed natural, human gestures into mechanical or abstracted movement; this approach is stylistically similar to Sokolov's description of the approach of "true movement" in puppetry. Depero and Schlemmer not only recognized the value of puppet for its phenomenological and signifying functions, they also recognized the puppet as a technological instrument that relies on the principles of kinetics and abstraction. These two salient features of puppetry: kinetics and abstraction, combined with puppetry's flexible approach to scale and visual transformation, were applied to costume designs that metamorphosed the human body. These principles were also applied to the design of automated and mechanical actors reminiscent of automatons. The result was a new type of corporeality that expanded the range of physical expression of human performers and resulted in artificial, autonomous actors.

I have already identified Prampolini's relationship to the puppet theatre. Depero also worked at Podrecca's *Teatro dei Piccoli*: his production *of I Balli Plastici* (*The Plastic Dances*) premiered there in 1918. The Bauhaus, too, had a formal relationship with puppet theatre: between 1916 and 1925 the artist Paul Klee produced puppet performances with marionettes, and there are designs for at least one marionette production (which was never produced) by Kurt Schmidt and T. Hergt (*The Adventures of the Little Hunchback*, circa 1924) (Gropius 58). Bauhaus productions such as Schlemmer's *Der Triadisches Ballet* (*The Triadic Ballet*), *Figural Cabinets I* and *II*, and Schmidt's *Mechanical Ballet* demonstrate how Bauhaus artists used traditional puppet techniques to integrate the human performer into a mechanized, total theatre. Considered together, these works demonstrate how avant-garde artists utilized puppetry to reconcile the human performer with the mechanical stage in a unified aesthetic field.

Fortunato Depero was a painter, sculptor, theatre director, and playwright. His work for the stage and his writings reveal a primary concern for the physical and mechanical properties of stage and actors, and with creation of the "Artificial Living Being of the Future" (Berghaus 296). As early as 1916 Depero was already envisioning through his writing and sketches a theatrical performance comprised solely of autonomous acting machines. In his art work and productions—which include kinetic sculptures called *Plastic Complexes*, the designs for the never-produced plays *Mimismagia* and *Colori*, and the production of *I Balli Plastici*—Depero used principles of puppetry to design proto-robotic, autonomous acting machines.

In his 1916 essay *Notes on the Theatre*, Depero re-conceptualizes theatrical mimesis and the art of representation, calling for a "vast re-recreation of mimicry." The influence of puppetry—in particular the fixity of expression, flexibility scale, and power of transformation— looms large in his re-conception of stage and theatre characters:

> Every displacement of an object or figure, every thought, dream, intention, and vision will be mimetically in direct relationship to the environment: also mimicry will be the only scenario in some cases; e.g. turning flowers, moving mountains, trees and steeples that oscillate, houses that uncover and open themselves; wind that tosses, shakes, drops, and overturns the landscape with whirlwinds, while, in a tragic fixity, characters remain immobile. A single figure, too, can become the protagonist of plastic-magic phenomena: enlargement of the eyes and various illuminations of them. Decompositions of the figure and the deformation of it, even until its absolute transformation; e.g. a dancing ballerina who continually accelerates, transforming herself into a floral vortex, etc. (Depero in Kirby 207)

Depero's re-conception of mimicry is rooted not in the imitation or reality of verisimilitude, but rather according to principles of movement, transformation, and abstraction. As in puppetry, the purpose of mimicry should not be to copy living forms, but to create new forms or images of life. To that end, Depero imagined mobile, kinetic scenery and a re-conception of the scenic stage that would allow for moving walls, wings, ceilings and floors and contrasting scenic perspectives. He envisions a theatre where performer (human or non-human) moves and interacts fluidly and dynamically with the theatre space. Depero's vision of a more dynamic stagecraft evokes Marinetti's vision of a theatre capable of staging "a cumulus of events unfolded at great speed," Prampolini's total theatre, and Moholy-Nagy's *Mechanized Eccentric*. However, in Depero's theatre the abstract scenery and moving sculptures are deliberately personified in order to mimic the real world where "everything turns-disappears-reappears, multiplies and breaks, pulverizes and overturns, trembles and transforms into a cosmic machine that is life" (Kirby 208).

Like Marinetti, Depero was fascinated by the cinema's ability to render the speed, transformation, and perpetual motion of life in ways that evaded the methods of purely representational theatre. Rather than accepting film's superiority, he proposes that theatre adapt "everything that is suggested by cinematography, including "Exaggerations"; the development of "Transformations (hands-feet; plastically artificial)"; "Disproportion, according to necessity"; "Dissolve characters, scenes, and objects, Masks, feet, hands, objects that act separately on their own behalf"; and finally "Artificial Flora and Fauna" (Depero in Kirby, 208). While Depero cites cinema as his inspiration, we can recognize these features as the salient features of puppetry discussed in Chapter Two: kinetics, abstraction, flexibility of scale, and transformation.

Depero's concern with mobile scenery and anthropomorphic architecture can be traced to his earlier work with Giacomo Balla. In 1915 the two artists co-authored a manuscript entitled: ""Futurist Construction of the Universe," which drew on

Depero's 1914 essay "Plastic Complexes. Free Futurists Game. Artificial Living Being" which is a collection of writings, drawings, and photographs of kinetic sculptures designed by him and Balla. The artists describe their exploration of kinetic sculpture toward the development of autonomous art objects:

> The lyrical appreciation of the universe, by means of Marinetti's Words-in-Freedom, and Russolo's Art of Noises, relies on plastic dynamism to provide a dynamic, simultaneous, plastic and noisy expression of universal vibration. We Futurists, Balla and Depero, seek to realize this total fusion in order to reconstruct the universe by making it more joyful, in other words, by an integral re-creation. We will give skeleton and flesh to the invisible, the impalpable, the imponderable and imperceptible. We will find abstract equivalents for all the forms and elements of the universe, and then we will combine them according to the caprice of our inspiration, to shape plastic complexes which we will set in motion. (Balla and Depero 197)

The *Plastic Complexes* were fixed and mobile kinetic sculptures made from a variety of materials reminiscent of materials used in puppetry:

> Strands of wire, cotton, wool, silk of every thickness and coloured glass, tissue paper, celluloid, metal-netting, every sort of transparent

> and highly coloured materials. Fabrics, mirrors, sheets of metal, coloured tin foil, every sort of gaudy substance. Mechanical and electrical devises; musical and noisemaking elements; chemically luminous liquids of variable colours; springs, levers, tubes, etc. (Balla and Depero 198)

The authors even call for the use of pyrotechnics, water, and fire. The descriptions of these "Complexes" describes their intended motion in terms of rotations (on one axis, horizontal, vertical, and oblique; one more than one axis, in congruous and opposing directions); decompositions (in volume and layers, taking different shapes in successive transformations, sometimes while playing music), and "Miracle Magic" (objects that appear and disappear). Balla and Depero specify the fundamental features of these complexes as

> 1. ABSTRACT.
> 2. DYNAMIC. Relative movement (cinematographic) + absolute movement
> 3. EXTREMELY TRANSPARENT. For the speed and volatility of the plastic complex which must appear and disappear, light and impalpable.
> 4. HIGHLY COLOURED AND EXTREMELY LUMINOUS (through the use of internal lights).
> 5. AUTONOMOUS, that is, resembling itself alone.
> 6. TRANSFORMABLE
> 7. DRAMATIC
> 8. VOLATILE

9. ODOROUS
10. NOISE CREATING. Simultaneous plastic noises with plastic expression.
11. EXPLOSIVE, elements that appear and vanish simultaneously with a bang.

Depero's *Plastic Complexes* are attempts to form a synthesis of the plastic arts—moving sculptures that emit sound, light, and transformation to produce theatrical effects. These effects seem designed to address the concern expressed by Schlemmer and Moholo-Nagy about the ability of a purely mechanical theatre to create compelling theatrical illusions capable of sustaining dramatic interest. Although the objects themselves do not constitute theatrical productions *per se*, Depero's focus on the performative qualities of the sculptures (their noises, their transformations) reflects the urge towards the theatrical in general, and toward the puppet theatre in particular.

In his descriptions of the *Plastic Complexes*, Depero seems almost at pains to describe these works without mentioning the word "puppet." Are these figures puppets? If we accept Jurkowski's definition of puppets as acting subjects that make temporal use of vocal and motor sources of power which are outside it, and which are not its own attributes, then the *Plastic Complexes* do not, strictly speaking, constitute puppets. They are more like kinetic sculptures, where the relationship between the subject (art object) and its power source does not change. Because the rumoristic and motor sources are contained within the art object itself, these objects belong more to the realm of automata than puppets. If, however, the subject (in this case, the art object), requires a power source outside of it, for example, a human operator to trigger the levers and pulleys that result in a special effect, then the object begins to function as a puppet, and acquires the semiotic and aesthetic significance of puppet theatre. Like Prampolini's *Teatro Magnetico*, the complexes are distinguished from kinetic, moving scenery because they constitute the subjects of performance rather than mere architectural spaces for performance. Depero's experiments with puppetry at *Teatro dei Piccoli* suggest that the *Plastic Complexes*, as well as his deigns for the *Teatro Magico*, were rooted in the aesthetic and techniques of traditional puppetry.

Perhaps Depero avoided the term "puppet" in order to distinguish his work from the commercial puppet theatres of the time. Commercial puppet theatres were largely seen as substitute for human theatres, and typically staged productions of established literary works or variety shows. We cannot know definitively why Depero avoided the term puppet, but we can identify some striking similarities in the approaches to design and construction of his complexes with traditional puppetry techniques: abstraction, dynamic movement, and flexibility of scale. These are the features that Depero identified as central to the creation of an "artificial living being":

> From now on, I shall dedicate myself to the creation of polyexpressive artificial living beings, which I have named plastic-rumoristic complexes. These compositions will be constructed with mechanisms of all kind: pulleys, handles, wires, wheels, clocks, noisy

> and luminous machines, pumps, motors, tubes, levers; wood, tin, mirrors, stained glass; lights and water, smoke, noise, smells, etc., with the application of all kinds of inventions and physical, chemical, and electrical contraptions. These elements will be used to create rhythmically vibrating towers, make emerge and disappear animals and clouds, open and close doors, windows, eyes and mouths, agitate the characters inhabiting the work of art or conjure up dawn and dusk in order to provide pleasure to the spectator. (Depero in Berghaus 297)

The above description reveals Depero's profound interest in the synaesthetic effects of theatre, and the potential of these "polyexpressive artificial living beings" act as subjects or co-actors in the performance. Regardless of whether or not Depero considered the *Plastic Complexes* puppets, his play *Colori* (Colors) specifically uses marionette puppetry to develop his idea of a dynamic, synesthetic theatre. The play is set in an "empty cubic, blue room" with no windows or door frames, and features four marionettes called "Abstract Individualities." The characters are identified as 1. GRAY, a dark-grey, plastic, dynamic ovoid; 2. RED, red, plastic, triangular, dynamic polyhedron; 3. WHITE, white, plastic, long-lined, sharp point; and 4. BLACK, black multi-globe (Depero 278). The mechanical movements of the figures are executed by "invisible strings," and the dialogue, which consists only of nonsensical noises and sounds, were to be produced (presumably) offstage. After a series of dialogues consisting only of non-linguistic noises, the play ends with sound of a whistle.[18] The play merges kinetic sculpture with live performance: "devoid of any content or symbolic meaning, [*Colori*] relied entirely on an emotional response to the material aesthetics of artistic means" (Berghaus 300). Although the play was never produced, we can read it as an attempt to develop machine aesthetics and autonomous acting machines. Berghaus presumes that Depero's marionettes would be operated by human puppeteers, and with human actors generating the sound from offstage, but there is nothing in the script that suggests human presence. Omitting the specifics of how the work would function, Depero appears less concerned with the technology required to achieve the effects and more concerned with the creation of abstract, non-personal, mechanical objects in the place of traditional, representational marionettes. His conception of non-human performers embodies the confrontation of visual codes identified by Proschan as essential to puppetry, and explores two of the unique properties of puppetry: kinetics and abstraction.

In another unproduced play from the period titled *Mimismagia* (1916), Depero experiments with dynamism and human-machine hybrid figure. Once again forsaking traditional dramatic modes of language and plot, the play is based solely on the choreography and gesture of the augmented human performer. *Mimismagia* (Mimesis-Magic) is a mime that combines human dancers with costumes that transformed their human shape and produce noises. The theatrical action centers entirely on the interaction of the metamorphosed humans with mobile scenery, and

[18] The play text appears in (Kirby 1986).

the interweaving of human-generated and mechanical sounds. Inspired by Loïe Fuller's illuminated stage costumes, Depero conceived of the costumes as "magical mechanical equivalents to a complex simultaneity of forms, colours, onomatopoeic sounds, and noises," where the fabric of the costumes could be manipulated by the actors to "release certain springs and open certain fan-like contrivances and be accompanied by luminous apparitions and rhythms of noise-producing contraption" (Berghaus 298). We can read *Mimismagia* as an effort to combine the *Plastic Complexes* with the human figure: the costumes expand the range of human performer, transforming the human into a proto-robotic or cyborg figure. The mechanical costumes alter the quality and the type of movements available to the performer, emphasizing Depero's preoccupation with the nonhuman, abstract art figure:

> The dancers in this mime seemed to have the sole function of animating the costumes, which resembled the earlier Plastic Complexes because of their plasticity, transformability, polymaterialism, chromaticism, and noisiness. But here they functioned scenically in a dramatic mime. They helped convey a story, to provoke dramatic emotions, and to function within a stage set. The actor was subservient to the costume—an idea that was developed at that time, on a much more advanced level, by the *Ballets Russes*. (Berghaus 298)

It is difficult to distinguish between a theatrical costume and a puppet that is worn and manipulated by an actor; this question is considered more fully in Chapter Five. But *Minismagia*'s creative use of costumes animated by a human actor, together with multi-level, multi-perspective, moving scenic architecture, resembled mechanical toy theatres and reflected the Futurist's "commitment to integrate figures and scenery in one continuous environment" (Goldberg 24). This harmonious landscape between mechanical stage and performing objects was the subject of Prampolini and Moholy-Nagy's experiments, but while those artists wanted to eliminate the human figure entirely, Depero's intent is to combine abstract, anthropomorphic figures with a kinetic landscape. He achieves this by eliminating the "idiosyncratic and realistic details of human movement and to substitute for them a vocabulary of movement that would correspond more closely with the lines of the setting" (Kirby 101). This playful, fluid interaction of actor and mechanical devices with dynamic scenery can be understood as an attempt to reconcile the human performer with the mechanical stage in a unified aesthetic field.

Depero's work on *Mimismagia*, together with his designs for the scenery and costumes for the Ballet Russes production of *Le Chant du Rossignol* (*Song of the Nightingale*), led Depero to conceive of a theatre without human performers, and populated entirely by mechanical figures and marionettes:[19]

[19] Although Depero had completed a substantial amount of the work on *Le Chant du Rossignol*, the ballet was never produced, partly because of Diaghilev's extended financial commitments (Berghaus 300-305).

> Having just finished the costumes and scenery for the Russian ballet, a thought came to my mind: in order to gain a wider geometric expression, the freedom to change the proportion of costumes to people and settings to characters, it would be necessary to abandon the use of human performers, and to replace them with a "living" automaton, meaning a new kind of marionette, liberated from natural proportions, in a style full of invention and fantasy, capable of delighting us with its paradoxical and astonishing mimicry. (Depero in Jurkowski 1998:55)

One attempt to realize this new form of expression was I *Balli Plastici*, which Depero created with Gilbert Clavel and the distinguished puppeteer Ottorino Gorno dell'Acqua. *I Balli Plastici* was a play comprised of four short vignettes, featuring slightly-less-than life-size, wooden marionettes in a brightly colored, Cubist landscape. The vignettes were "*Pagliacci*" (Clowns), "*L'uomo dei baffe*" (The man with the Mustaches), "*L'orso azzurro*" (The Blue Bear), and "*I selvaggi*" (The Savages). The production drew from a wide range of puppet techniques:

> Partly rooted in the Futurist Synthetic Theatre, partly in the grotesque humor of his early literary experiments, these playlets were predominantly concerned with the physical and mechanical properties of stage and actors. Verbal language was eliminated, whilst the complex functions of light and colour were given greater

> prominence. Although the marionettes or robots still resembled human beings, their stylized movements and transformations went far beyond naturalistic conventions. Similarly, the scenery made reference to knowable and identifiable locations, but in the treatment of the theatrical space Depero moved into the realm of abstract theatre. However, the cerebral elements of this 'pure' theatre were always counter balanced by scenic actions that created an atmosphere of magic and emphasized the ludic quality of theatre (humor, surprise effects, transformations, acrobats, etc.). (Berghaus 309)

One particular example of a transformation, flexible scale, and grotesque effect appears in *The Savages*. In this vignette, the figure of the "Great Female Savage"— which was taller than a human performer— was constructed with a trap door that opened from the marionette's abdomen, revealing a small marionette stage that featured tiny "savages" performing their own marionette routine (Jurkwoski 1998:56, Berghaus 313). This demonstrates the playful use of flexibility of scale and transformation of puppets, and these features were also found in the scenic design:

> Vertical and diagonal planes intersected at oblique angles, and gave the stage architecture a dynamism that was enhanced by the strange angles of the light projections. Deep shadows, colorful gels, angular patterns in the gobos: these anti-naturalistic lighting effects,

> together with the different sized marionettes and the multiple-perspective stage set offered the spectators a most unusual, innovative, and startling spectacle. The highly rhythmic and dissonant music underlined the avant-garde feeling of the production, which some of the more traditionalist spectators found rather annoying. (313)

Depero's work regarded as too experimental for the audiences of *Teatro dei Piccoli* who were used to more traditional forms of puppet theatre. (Podrecca's collaborations with avant-gardists appear limited to the two productions with Prampolini and Depero discussed in this chapter). As Berghaus has suggested, critics had difficulties characterizing these abstract performances, which bore little resemblance to traditional marionette plays. In his review of the production in the newspaper *Tribuna*, Alberto Gasco wrote:

> Da quanto abbiamo scritto di desume chiaramente che *I Balli Plastici* non possono essere considerati come una compiuta realizzazione d'arte: pero in essi noi riscontriamo i germi di future creazioni teatrali molto ragguardevole e degne di incondizionata simpatia.

> From what we have written, the facts clearly show that *The Plastic Dances* cannot be considered a complete realization of art: but we do

> find in them the seeds of future theatrical creations which are quite remarkable and worthy of regard. (in Calenda and Signorelli)

Depero's work on the *Plastic Complexes* and *I Balli Plastici*, and on the unrealized production for *Ballet Russes*, led Depero to conceive of a new type of plastic theatre called *Teatro Magico*. Berghaus speculates that many of these works went unrealized because they did not meet with positive or constructive responses from the professional theatre (317). However, describing his ideas for a "Magical Theatre," Depero alights on the idea of creating puppets with more flexible material (substituting wood with the more pliable and dynamic properties of rubber, fabric, tin, and spring mechanisms), in the creation of a spectacle where scenery and performers would exchange roles and interact:

> The dynamic scenic apparatus would become a performer (e.g. a landscape with growing plants, budding flowers, meandering rivers, growing mountains, wandering stars, all bathed in colored lights and emanating smells), and the performer could be transformed into scenery (e.g. a dancer turning pirouettes until he becomes 'a floral vortex'). Or, for a while the ballerinas, marionettes, acrobats, automata, etc. would perform their ever-changing gymnastics, tricks, and transformations, only to stand still in the next screen, when the landscape would turn into a whirlwind of wondrous permutations. (Berghaus 316)

The development of Depero's ideas from *Notes on the Theatre* (1916) to his description of a mechanical "Magical Theatre" (1919-1920) reflects not only the influence of puppetry on his conception of live theatre, but also presages the idea of dynamic, anthropomorphic figures central to animation. Depero's images of dancers transforming into "floral vortexes" immediately call to mind the dream-like transformations and evocative spectacles of Disney animation films like *Fantasia* (1940) and later efforts to adapt animated films for the live theatrical stage.[20] In this way, Depero's work might be said to anticipate the spectacle-driven productions by Disney and Dreamworks Theatrical (*Beauty and the Beast*, *The Lion King*, *Shrek*, *How to Train Your Dragon*), which created magical transformations, anthropomorphic characters, and dynamic, moving landscapes that approximate their animated progenitors. For Depero, puppetry was the inspiration that caused him to imagine these worlds, but it also provided the means for exploring how these animated worlds might be bodied forth on the live stage.

Similar to Depero's experiments, Oskar Schlemmer's designs for Bauhaus productions of *The Triadic Ballet*, *Figural Cabinets I* and *II*, *Glass Dance*, and *Slat Dance* combine puppet techniques with theatrical costumes in ways that prompt consideration of mechanization and the reconciliation of the human actor in a mechanized landscape. As Trimingham has suggested, it is a mistake to consider

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[20] One is also reminded of the more recent example of Disney's stage adaptation of *Beauty and the Beast* (1994), where the production had to stage the real-time metamorphoses of the Beast into his human form. For the stage musical, the difficulty there was to replicate the process of transformation of a human figure onstage in a way that was originally developed using animation (Rozario (2004).

these productions as fully fledged endorsements of mechanization and responses to the industrialization of machine culture; rather they represent the complex and evolving notions concerning the relationship between machines, humanity, and technological culture, where "hope in and concentration of the future was at least equally balanced with neo-Romantic Expressionist sensibilities" (32). Schlemmer's contemplation of metaphysical mystery and the creative evolution of humanity is reflected in the following passage from his essay "Man and Art Figure":

> A further emblem of our time is mechanization, the inexorable process which now lays claim to every sphere of life and art. Everything which can be mechanized *is* mechanized. The result: our recognition of that which can *not* be mechanized (Schlemmer 17).

In these productions, the human remains central to the experiments, and staging of technology and mechanization actively investigates these two competing tendencies: that which can be mechanized and that which can not be mechanized. One way of exploring this tension was to eliminate the idiosyncratic and realistic movements of human performers through three-dimensional, geometrical costumes that abstracted the human form. The experiments can be read as embodied investigations of the geometric principles described in Boccioni's essay on dynamism. Like the costumes for *Minismagia* which were animated from within by a human performer, Schlemmer's costumes necessarily expand or limit the expressive range of the human performer by stressing or violating conformity to geometrical and mechanical laws that govern the human body in space. In other words, the costumes were less about staging "man as a machine" and more concerned with the formal investigation of the principles of line, form, motion and the aesthetics (and limits) of mechanical movement.

Segel, Bell, and Trimingham have written separately about the influence of puppetry on Bauhaus aesthetics. This influence is evident in the *Figural Cabinet I* and the *Triadic Ballet*, and undoubtedly contributed to Schlemmer's meditations on the possibility of eliminating the human performer from the stage. After the 1922 premiere of the *Triadic Ballet*, Schlemmer writes:

> One might ask if the dancers should not be real puppets, moved by strings, or better still, self-propelled by means of a precision mechanism, almost free of human intervention, at most directed by remote control? Yes! It is only a question of time and money. The effect such an experiment would produce can be found described in Heinrich Kleist's essay on the marionette. (197)

The effect he refers to, suggested by Kleist, is the appearance of grace free from human consciousness. But while Kleist and Craig used the figure of the marionette metaphorically, Schlemmer imagines the creation of an autonomous acting agent to replace the human performer. Schlemmer calls this object the *Kunstfigur* (Gropius translates the term as "artificial human figure") and not unlike Depero's "polyexpressive artificial living beings" and Craig's *Übermarionette*, presents the vision of a mechanical or artificial figure whose performance is free from personal psychology and enters the realms abstraction and autonomy. The *Kunstfigur* can take the shape of either a totally mechanical figure, or a human figure transformed through engineering and technology in order to free the performer from his "physical bondage" and heighten the performer's "freedom of movement beyond his native potential" (Schlemmer in Gropius 28). By his own confession, Schlemmer and his Bauhaus collaborators lacked the technological expertise and funding to develop purely mechanical performers and instead focused on transformation of the human performer through costumes. These costumes drew on the central principles of puppetry, like *Mimismagia*, the human performers became puppeteers animating their costumes from within. These experiments with costumes that metamorphosed the human figure were directly related to Schlemmer's preoccupation with stage space. Jurkowski summarizes:

> Schlemmer acknowledged that man seeks meaning in theatre, and submits to his anthropomorphic impulses in order to create his own gods and idols, forever looking for his own likeness, his equal or his superior—his "superman"—to relate to his reality of fantasy. On entering a theatre a man becomes a presence in an abstract cubical space, where the relationship between space and man is antagonistic. Each strives to gain superiority. Which will win? The abstract space may be adapted to man's body and transforms itself into an imitation of nature, as happens in illusionist theatre. Or

> "natural" man may adapt himself to become a part of the abstract setting, as in abstract theatre. (Jurkowski 1988:62)

Jurkowski's description of the relationship between the actor and the physical stage space suggests an autopoietic feedback loop between that involves not only artist and spectator, but the entire scenic space. The stage becomes a type of subject, and Schlemmer goes as far as to define the stage as an "architectonic-spatial organism where all things happening to it and within in exist in a spatially conditioned relationship" (Gropius 85). The acknowledgment of the conditioned relationship between humans, technological apparatus, and scenic space goes beyond simple application of mechanistic philosophy and indicates how even inanimate spaces acquire intentionality and agency.

For Schlemmer, costumes and masks were tools for resolving the fundamental tension between the stage space and the body of the human performer: the costumes enable the human performer to explore the different possibilities of relating to the stage space, and it can also change the dynamics of his interaction with the space. Schlemmer proposes the following approaches:

> 1. *The laws of the surrounding cubical space*. Here the cubical forms are transferred to the human shape: head torso, arms, legs are transformed into spatial-cubical constructions. Result: *ambulant architecture*.

2. *The functional laws of the human body in relationship to space.* These laws bring about a typification of the bodily forms: the egg shape of the head, the vase shape of the torso, the club shape of the arms and legs. The ball shape of the joints. Result: *the marionette.*

3. The laws of motion of the human body in space. Here we have the various aspects of rotation, direction, and intersection of space: the spinning top, snail, spiral, disk. Result: *A technical organism*.

4. The metaphysical forms of expression symbolizing various members of the human body: the star shape of the spread hand, the ∞ sign of the folded arms, the cross shape of the backbone and shoulder; the double head, multiple limbs. Division and suppression of forms. Result: *dematerialization*.

(Gropius 26-27)

Costumes and masks designed according to the above specifications transform human performer and emphasized the object-ness of the performing body. Such techniques were used in the *Triadic Ballet* which premiered in 1922. The abstract, colorful costumes illustrate the third principle above, and were designed to explore the laws of motion of the human body in space. Drawing heavily on the geometric shapes of cones, spheres, and triangles that exaggerate the human shape, the body of the performer is metamorphosed but not completely abstracted: the performers retain their human-like shape. *The Triadic Ballet* consisted of three parts stylized dance scenes, moving from the humorous to the serious. The first “Yellow series” is described as a “gay burlesque with lemon-yellow drop curtains,” the second “Rose series” as “ceremonious and solemn,” and the third “Black series” as a “mystical fantasy.” Three dancers (two male and one female) performed twelve dances in eighteen different costumes, which were made of padded cloth and stiff paper-mâiché, and painted with metallic and colored paint (Gropius 34). Schlemmer writes:

> The dance of the trinity. Changing faces of the One, Two, and Three in form, color, and movement; it should also follow the plane of geometry of the dance surface and the solid geometry of the human bodies, producing that sense of spatial dimension which necessarily results from tracing such basic forms and the straight line, the diagonal, the circle, the ellipse, and their combinations. Thus the dance, which is Dionysian and wholly emotional in origin, becomes strict and Apollonian in its final form, a symbol of the balancing of opposites. (Schlemmer 1972, 127)

Here, the effort to balance the Apollonian and Dionysian tension can also be understood as an attempt to reconcile the mechanical and the human, and the personal and the non-personal aspects of art objects. Performance becomes a way of actively investigating that which can be mechanized and that which can not be mechanized. This tension is explored in several Bauhaus performances.

The costumes for *Glass Dance* and *Slat Dance* go further in abstracting the human form and restricting the movement of the human performer using less flexible materials. In *Glass Dance* (1929), which was performed by Carla Grosch, the performer it outfitted with a hooped skirt made of long, vertical glass rods, her head covered in a clear glass globe (reminiscent of an astronaut's helmet), and holding two glass globes—one suspended by a string, the other by a rod— in each hand. A harness fixed around Grosh's shoulders suspends several smaller globes in a circle around the body, and the performer's range of natural motion is severely limited. In *Slat Dance* (1927), the body of performer Manda von Kreibig was equipped with long, thin slats of wood attached at different points to the body. Like prosthetic limbs, the slats are attached at major joints (knees, elbows, shoulders), and elongate the shape and movement of her natural limbs as she manipulate the slats in all directions. The costume amplifies Kreibig's movements, creating sharp intersections across the horizontal and vertical planes and resulting in what Schlemmer refers to as "ambulant architecture." In both of these performances, simple movements and gestures acquire great significance: subtle human movements are transformed into large geometric shapes or mechanical gestures. The human performers approach a level of abstraction and metamorphose into non-human, non-representational "performing objects."

Futurist and Bauhaus artists developed mechanized costumes and imagined artificial, mechanical actors that could exist harmoniously within kinetic and dynamic stages. These two types of mechanized bodies reflect the varying influences of traditional puppetry and automation on avant-garde aesthetics. In the case of costume design, the human performer animates the costume through direct manipulation as a puppeteer animates a puppet. This is true of Prampolini's motor-rumoristic costumes, Depero's costumes for *Mimismagia*, and Schlemmer's costumes for *der Triadisches Ballet*, *Glass Dance*, and *Slat Dance*, where the movement of the performer is tightly coupled to that of the costume/puppet. This approach merges machine aesthetics with the principles of puppetry, where the costume functions as a type of prosthetic or mechanical device that metamorphoses the human figure into a type of mechanical object. The resulting performance is both expressive and responsive, and invokes the binocular vision of the spectator. Because the human is visibly present and understood to animate the object, the mechanical object appears creative without appearing uncanny or routine.

The second approach to creating mechanical bodies is that of artificial, mechanical actors as envisioned by Prampolini, Moholy-Nagy, Depero, and Schlemmer. These attempts combined kinetic sculpture with drama and performance in an effort to replace human performers with autonomous and semi-autonomous acting machines. The goal of these machines was not to imitate human beings, but rather to open up new possibilities for expression and theatrical illusion. Unlike lifelike automatons, these artificial actors offered the possibility for wider geometric expression, a freedom from natural proportions, and lent themselves to inventive and fantastical theatrical illusions. Like puppets, these autonomous machines utilized the principles of abstraction and dynamic movement to create illusions of liveness. Thus, the proto-robotic figures of the avant-garde challenged the spectator's understanding of machine aesthetics through the creation and exploration of creative movement. Puppetry's contribution to this process was vital.

CHAPTER SUMMARY

At the turn of the twentieth century, the study of machine aesthetics influenced artists and philosophers throughout Europe, and particularly in Italy, Germany, and Russia where avant-gardists explored the mechanization of the human body through choreography, set design, and costume design. However, just as the puppet/robot/automaton metaphor was employed varyingly in the dramaturgy of the period, so, too, did the mechanization of the human performer lack in ideological clarity. Berghaus notes that "[a]lthough there was a tendency towards a mythical transfiguration of the technological advances of the Industrial Revolution, no consensus could be achieved as to what the metaphor of the machine was referring to" (409). One reason for this indeterminacy was that the theories of performance and machine aesthetics (for example, those expressed in artistic manifestos) were not always congruent with actual artistic production. While the Futurists may have extolled the supremacy of machines, very few of their productions featured actual, working machines: productions were more likely to feature actors in painted cardboard costumes that crudely resembled steam engines or humanoid robots. Similarly, written descriptions, sketches, and scale models by Prampolini and Depero depict moving sets and mobile scenic architecture, but these designs we rarely realized on actual theatre stages. It was Russian Constructivists like Lyubov Popova (and later, Josef Svoboda) who realized the "scenic technical revolution" that combined human actors with kinetic stages (Baugh 71). The schism between aesthetic theory and actual artistic production has prompted criticism of the Futurists' aesthetic aspirations:

> Unfortunately, while the ideas of a Prampolini are often interesting as projects, their realization…reveals a dilettantism which accords very badly with the grandiloquent utterances with which the Futurists in general have regaled the world…We see artists influenced out of measure by the work of the engineer and, as they often have no knowledge concerning the technical laws which control machinery, we see them bring into being strange assemblages of forms which outwardly resemble a machine of some sort, but a machine which does not go; in short, a parody of the machine.…The machine of the artists is usually only ridiculous and still […and] we refuse to discover any beauty in the infantile machines which Depero proposes for the theatre. (Fuerst and Hume in Berghaus 410)

Fuerst and Hume identify a significant challenge in analyzing the machine aesthetics of Futurist performance alongside more developed works of the Bauhaus: artistic designs for unrealized productions or parodies of machines do not approach the engineering expertise required to build and construct automata or functioning mechanical devises. However, omitting these works from our discussion of machine aesthetics and robotic actors would overlook how these experiments help shape the cultural imagination of machines and influenced the how future artists and spectators conceptualize machines through performance.

The Futurist and Bauhaus experiments discussed in this chapter defined autonomous art objects in two ways, where autonomy refers both to the object's ability to represent itself alone (without reference to other meanings or representations) and also to its ability to perform independently from a human operator. Whether these objects were only described in theory or in plays that were never produced, they constitute attempts to explore the aesthetic potential and philosophical implications of autonomous acting machines. These works explored the possibility of objects to generate their own artistic meaning as abstract objects and as independently-operated entities. Although the artists were not all skilled engineers, their knowledge of puppetry helped them fill the "technology gap" and allowed them to experiment with non-human, expressive performing objects.

Futurist and Bauhaus artists used technology and their knowledge of puppetry to create dynamic and kinetic stages to achieve what Prampolini called "absolute synthesis" and Moholy-Nagy called a "theatre of totality." The attempt to create a "total theatre" can be understood as theatrical manifestations of the concepts of kinetics and dynamism expressed in Boccioni's manifesto and Sokolov's notion of a theatre of "true movement." The designs reflect an interest in a unified spectacle that achieves a "psychological synchronism" in the soul of the spectator—where music, painting, and gesture harmonize without losing their independence (Kirby

97). This synchronism does not hinge on psychological realism or narrative, but rather on the unity of performance in ways that privilege the sensory dimensions of the theatre experience and minimize the intellectual dimension.

To arrive at an autonomous theatre, artists sought new methods for creating objective, non-personal, autonomous art objects, and puppetry emerged as an important method for realizing this processes. Puppetry's approach to creative movement and its unique semiotic sign system which, through the confrontation of visual codes, acknowledges binocular vision, proved central to the conception of autonomous acting machines. The theatre—and in particular the puppet theatre—provided the setting wherein these artists could move beyond the fixed moment of painting and explore more fully the "dynamic sensation" of objects in motion. For these artists, the puppet was not only a useful metaphor but essential to the development of the autonomous art object. Jurkowski highlights the puppet's versatility as essential to its re-emergence during the avant-garde:

> The puppet proved itself adaptable enough to deal with all kinds of artistic activities, and was capable of dealing with all the demands of the artists: realistic, imitative and experimental, in other words, with all the genres which have tended to reveal the artificial nature of the puppet. It seems that the puppet attends on human initiative, and is able to adapt to each. It is not in the area of superiority but in that of creativity where puppetry offers unexpected opportunities. (Jurkowski 1998:67)

Unlike modernists like Craig, who extolled the "superiority" of the puppet, the works discussed in this chapter were inspired by the creative opportunities provided by the puppet to depict the ineffable. Experimentation with puppetry and machines in performance facilitated the development of art objects that were (or at least appeared to be) free from consciousness. While Futurists like Depero appear more concerned with mechanistic exploration of the art object by imagining theatrical landscapes full of automated, autonomous acting machines free from human influence, Schlemmer's Bauhaus experiments are more in line with techniques of traditional puppetry that rely on human beings as operators. However, both approaches created visions of new types of animated figures onstage, ushering forth new conceptions of both the mechanized body and the mechanical performer. Trimingham observes:

> [The] deliberate manipulation of material form that is the performer/puppeteer's/body image and haptic sense flows into the object/costume/puppet which is/are being animated, and meaning is literally 'bodied forth' before our eyes in the moment of performance and forms new perceptual 'Gestalten' in the audience—all of which are moments that are fundamentally implicated in the shaping of our culture. They both reflect the culture and are proactive in its formation. (119)

In his writings, Schlemmer continually acknowledges the pivotal role of the spectator in the theatrical process. For Schlemmer, the success of the "new theatre of glass, metal, and the inventions of tomorrow" is entirely dependent on the "inner transformation of the spectator" (Gropius 32). Mechanical performances and robotic actors will not thrive unless they are able to provoke "intellectual and spiritual receptivity and response" on the part of the beholder. The technological (and budgetary) limitations of the period prevented Schlemmer from ever having to confront a completely mechanized stage or robotic actor. In the following chapters, we will see how these experiments by the avant-garde relate to contemporary efforts that combine puppet techniques and with robotic machines towards the development of interactive and lively animated figures. The question of the phenomenological aesthetics—which was of central concern to avant-garde artists—continues to influence our conception of autonomous and semi-autonomous machines used in performance. The task of provoking intellectual and spiritual receptivity and response becomes more complex as mechanized stages and robotic actors become technologically feasible.

CHAPTER IV

REPRESENTING HUMANS[21]

[21] A version of this chapter appears under the title "Programming Play: Puppets, Robots, and Engineering" in *New Perspectives on Puppetry* (Routledge, forthcoming).

CHAPTER OVERVIEW

This chapter considers the design and control of human-inspired robots, and proposes that puppet-inspired choices might help engineers to design humanoid robots that are more dynamic and capable of demonstrating more spontaneous and interactive behaviors. Unlike the abstract and non-personal aesthetic of the avant-garde machines discussed in the previous chapter, the traditional approach to designing human-inspired robots has been to mimic the functional anatomy and behavioral mechanisms of humans through automated (fully scripted) or tele-operated (direct control) means. This tradition links humanoid robots more strongly to the history of automata than puppetry, and results in machines which may bear a strong physical likeness to human beings but whose motions often appear rigid and mechanical. Despite claims by engineers that tele-operated robots have the potential to be more precisely controlled than any human actor (Ishiguro and MacDorman 2006), the "functional-anatomy" approach to movement leads to motions that are rigid and predictable and limit the robot's ability to create convincing or compelling performances. I refer to this challenge as a kinematic version of the Uncanny Valley.

Citing my work on the *Pygmalion Project,* [22] a collaboration between Northwestern University, Georgia Institute for Technology, University of Colorado, and Disney Research that utilizes puppets to explore the mechanics of movement, I present a new theory for automated motion based on the principles of traditional puppetry. Our automated robotic platform for controlling marionettes uses the principle of abstraction native to puppetry to generate movement that suggests human motion rather reproduces human functional anatomy. This allows the automated movement (which is controlled by robots) to appear more artful than kinematic motions because the illusion of motion requires the spectator's participation and provokes binocular vision. Binocular vision is a cognitive mechanism that enables the automated motion of inanimate, human-shaped objects to avoid appearing uncanny or perfunctory; therefore the objects are more likely to provoke the intentional stance.

The design of collaborative robots that are capable of sensing and responding to the environment and the evolving conditions of a live performance emulates aspects of human-powered puppetry such as collaboration, intuition, and control. These features result in emergent behavior, where the robots exhibit interactive and spontaneous behaviors—traits we typically associate with creativity and live performance. While one might be reluctant to identify these robots as creative in the

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[22] This material is based upon work partially supported by the National Science Foundation under award IIS-0917837. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. The robotic system was developed in collaboration with Lanny Smoot at Disney Research (patent pending). Choreography was developed with dancers from the University of Colorado and Brooks & Co.

same way that human performers are (the robots are not conscious of their actions), the overall performance appears more creative than a purely automated or pre-programmed performance. These findings suggest how the developers of entertainment robotics might use puppet-inspired design choices for creating and controlling robotic actors for more dynamic and interactive performances.

HUMAN-INSPIRED ROBOTS

Traditionally, engineers have approached the task of imitating movement through mechanization, powering the motions of robotic limbs through individual motors or hydraulics located inside the body of a mechanical figure or robot. In many ways, this approach is similar to the Greek *nuerospasta*, which used a complex system of interior stringing to automate mechanical motions (Jurkowski 1996:46). Because of the tremendous difficulty of reproducing complex movements such as walking or dancing, robots designed for entertainment purposes (like their classical predecessors) are heavily stabilized and equipped with a limited set of pre-programmed gestures, and the mechanics are usually hidden rather than exposed. The reliance on a reduced set of behaviors and gestures ensures that the robotic actors are stable and perform reliably, however the mechanisms involved with replicating human motions make the robots heavy and difficult to work with. Attempts to realistically mimic facial expressions and physical gestures often result in jerky, mechanical motions that appear jarring or uncanny: the rigidity of motion contrasts with the realistic physical appearance. The contrast between the ultrarealistic design and non-realistic motion disrupts the theatrical illusion and impacts the machine's overall ability to provoke the intentional stance and evoke agency. Before robots can emulate the grace or creativity of a human performer, engineers must learn how to develop mechanical systems that address these challenges.

Historically, automated and tele-operated robots that imitate human form and behaviors have been discussed in terms of their uncanniness and how readily (or not) humans interact with them based on varying feelings of amusement, fear, or anxiety. Minsoo Kang's study of automata *Sublime Dreams of Living Machines*, posits that in Western culture the automaton has functioned as a conceptual tool for meditating "on both the possibilities and consequences of the breakdown of the distinction between the normally antithetical categories of the animate and the inanimate, the natural and the artificial, the living and the dead" (7). The allure of the automaton, Kang suggests, lies in its physical resemblance to the human form and the appearance of autonomous movement, which challenge the human mind's ability to categorize the object as living or being. In short, automata defy our attempts to fit them into an established conceptual schema, and this experience provokes complex attitudes of delight and anxiety. The complex experience of objects that hover indeterminately between the living and dead has been defined (separately) by Jentsch and Freud as the *uncanny* (Kang 22).

A humanoid robot's uncanniness is often understood as synonymous with how realistically the robot resembles the physical likeness of a human being. Our understanding of verisimilitude has changed over time: the human-inspired automata created by Vaucanson and Jaquet-Droz may have appeared incredibly lifelike to their eighteenth century observers, but they strike contemporary spectators as rather simplistic or crude when compared with the highly-expressive faces of contemporary robots. Mori's 1970 essay on the uncanny prompted debate within the robotics community over whether to build robots that realistically resemble human beings or more abstract robots, and my survey of the literature indicates that this debate is far from resolved. Engineers have argued for methods either that avoid the Uncanny Valley by resisting human-shaped robots or to span it by creating ever-increasing realistic looking features (Ishiguro 2006; Solon 2011; Hanson 2011). The focus of this debate is overwhelmingly preoccupied with physical design of robots, rather than how robots move. As we have seen from our study of puppetry and performance thus far, how an object moves has tremendous bearing on how that object is perceived.

Mori's theory of the Uncanny Valley is predicated on two factors—the physical appearance of the robot and how it moves. In contemporary robotics, the debate has focused disproportionately on the physical appearance (perhaps, as Kang suggests, because of the human predilection for objects that defy our attempts to fit them into an established conceptual schema). The focus on physical appearance means that engineers overlook the central role that movement plays in our aesthetic experience of a robot. Mori asserts that the uncanny effect is inextricably tied to how a robot moves:

> Movement is fundamental to animals—including human beings—and thus to robots as well. Its presence changes the shape of the Uncanny Valley graph by amplifying the peaks and valleys. For illustration, when an industrial robot is switched off, it is just a greasy machine. But once the robot is programmed to move its gripper like a human hand, we start to feel a certain level of affinity for it. (In this case, the velocity, acceleration, and deceleration must approximate human movement). Conversely, when a prosthetic hand that is near the bottom of the Uncanny Valley starts to move, our sensation of eeriness intensifies. (99)

On Mori's graph, the presence of movement steepens the slope of the Uncanny Valley, as indicated by the straight and dotted lines that trace the Uncanny Valley (Figure 1, page 162). Mori suggests that one way to avoid the Uncanny Valley is through design. Inspired by *bunraku* puppets—which are evocative of the human form but resist verisimilitude by retaining the principle of abstraction—Mori advocates for building robots that are inspired by non-human design. For autonomous and semi-autonomous machines used in performance, movement is as fundamental as design.[23] A robot's uncanniness—or the degree to which the robot provokes or dissuades our affinity—is equally dependent on the physical design and the mechanics of movement. I therefore suggest that puppets be used as a model for

[23] Puppeteer Mervyn Milar says that in puppetry, the "movement must be more persuasive than the form" (Millar, P. 2007).

designing automated movement. Because puppetry does not use realism as its starting point (verisimilitude is not the goal, abstraction is), puppet-inspired design might help robots to avoid the Uncanny Valley.

To understand the importance of movement on our perception of robots, let us consider two human-inspired robots that represent two different approaches to design, but share a similar approach to movement. The *RoboThespian* (developed by Engineered Arts) (Figure 2) and the *Geminoid F* (developed by Ishiguro and Kokoro Laboratories) (Figure 3) are humanoid robots designed and programmed to kinematically mimic the functional anatomy of a human. Kinematic motions are described in terms of joint motions and trajectories of points and lines, and do not consider the mass of the object or the forces acting on it. Although both robots use kinematic motions where the sources of power are contained within the robot, the two robots illustrate two different approaches to design. The mechanical skeleton of the *RoboThespian* is exposed and reveal the mechanical motors and pneumatics that power the movements, while the *Geminoid F* is covered in a polymer material that looks like real skin and hides the mechanical skeleton underneath. The robots have two distinct control mechanisms—the *RoboThespian* is automated and moves according to a pre-determined script, while the *Geminoid F* is tele-operated (direct-control) remotely by a human operator in real time. Despite their outward appearances, which would suggest two fundamentally different approaches to the Uncanny Valley problem, the robots share precisely the same approach to movement. The *RoboThespian* and the *Geminoid F* are both powered by pneumatics (forced air) and servo motors embedded in the mechanical skeleton, and (because of the mechanics involved) neither can walk or locomote. Both robots are heavily stabilized (they are fixed to chairs or platforms) and rely on a limited range of motion: their expressive behaviors are confined to facial expressions and simple arm gestures. The robots are further limited because they are unable to originate any movement sequence without the direct control of a human operator or computer program. For both the Geminoid and the RoboThespian, the approach to movement mimics the functional anatomy of humans and results in movements that are stiff, mechanical, and limit the robot's overall expressive capabilities. We might say that these human-inspired robots suffer from a kinematic version of the Uncanny Valley: because they use physical realism as both the starting point and the goal, the robots are incapable of communicating any truths other than mechanical ones. These humanoid robots are fundamentally limited by their inability to convincingly imitate expressive and responsive behaviors. Their rigid mechanical movements fail to provoke the intentional stance and the likelihood that they will be perceived as creative.

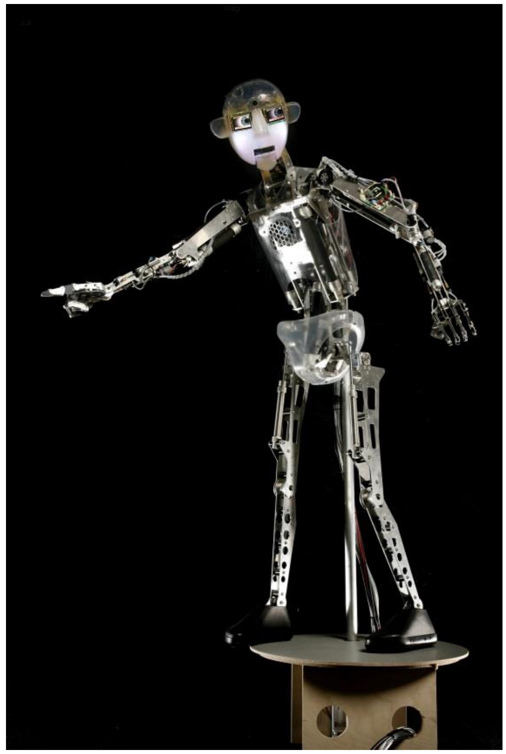

Figure 2. The *RoboThespian* (by Engineered Arts) is a programmable animatronic that uses automated motion.

Figure 3. The *Geminoid F* (developed by H. Ishiguro and Osaka University and ATR Intelligent Robotics and Communication Laboratories) is a tele-operated animatronic.

Not long ago, this degree of autonomy was unimaginable because of the technical complexity of seemingly simple tasks such as obstacle avoidance and computer vision. However, recent advancements in engineering and computer science have resulted in humanoid robots that are able to perceive their environment and interact with world autonomously. Robots like *Robokind* made by Hanson Robotics (Figure 4) use algorithms to successfully navigate and act in the real world independently from human operators and interact with human users using behavior-based models for communication. Such machines are considered autonomous because of their ability to move and act in the world is not dependent on automated motion or tele-operation by a human agent. In robotics research, this is known as *emergence*, where "the intelligence of the system emerges from the system's interactions with the world and from sometimes indirect interactions between its components" (Steels and Brooks 29). Irrespective of the physical design, robots that demonstrate emergence (such as Robokind and the Nao and DARwIn robots discussed in Chapter One) are rapidly impacting conceptions of human-robot interaction and ideas about agency. Given their availability, versatility, and the ability to safely and robustly interact with humans in real-world settings, sophisticated robots like these are likely to be used in entertainment venues. Because these objects are early in their development—that is they have not yet inundated our theme parks and theatrical performances in the way that industrial robotics (i.e. Mori's "greasy machines") were quickly appropriated for animatronics—we are in a unique position to consider how these robots might benefit from puppet-inspired design choices.

Figure 4. *RoboKind* (developed by Hanson Robotics) is an autonomous walking robot that is capable of expressive facial gestures based on interactions with human users.

In puppetry, the aesthetics of the material object is tightly coupled with the mechanics of movement; design and function cannot be considered independently. This makes puppets a good reference point for considering how to design robots for entertainment settings. Secondly, puppetry provides an established cognitive mechanism for perceiving objects as alive or autonomous, even when the objects do not realistically resemble humans or precisely mimic the functional anatomy of humans. As Meyerhold said, the principle of puppetry is “not to copy, but to create”. Rather than developing new models for cognitive mechanisms that support robot-human interaction, as Ishiguro and MacDormand have argued for (2006), we can use puppets to understand what kinds of behavior are perceived as recognizably human and develop automated systems that are capable of more interactive and spontaneous behaviors. Puppetry’s principle of abstraction, which approximates human motion rather than replicating it mechanically, suggests how engineers might benefit from puppet-inspired design choices.

My work on the *Pygmalion Project*, a collaboration between Northwestern University, Georgia Institute for Technology, University of Colorado, and Disney Research that utilizes puppets to explore the mechanics of movement, inspired me to consider how robotics might benefit from puppetry-inspired design choices. My involvement with the project as playwright, choreographer, puppet-builder, and archivist has afforded me a unique perspective on the research: in the second part of this chapter I introduce the project and discuss its relevance with relation to other robotic and puppet-centered work involved with mimesis and representation. Our initial findings suggest that puppet-inspired robots can allow for more expressive automated movement that is not constrained by mimicry-based approaches, and proposes a new paradigm for entertainment robotics.

KINESIS IN THE AGE OF MECHANICAL REPRODUCTION

Throughout theatre history, engineering techniques have proved vital to theatrical representation. In ancient Greece, theatre productions developed innovative engineering techniques that enabled them to dramatize the powers of the gods and the relationships between deities and human beings. In Euripides' *Hippolytus*, the goddess Artemis enters from above to visit Theseus and Hippolytus, and in *Medea* the heroine appears above the stage in Helios' chariot. These spectacles were achieved using a crane (*mechane*) which swung the actor out over the orchestra, literally producing the figure of a "god from the machine," or *deus ex machina* (Wiles 120). In essence, technology facilitated fantastical illusions that dramatized important questions about the nature of humanity and the mysterious or unknowable forces that shape human experience. The *deus ex machina*, along with other classical mechanical devices such as automata, puppets, and mechanical theatres led to engineering techniques such as the pulley system and pneumatics-powered devices that are still used on theatre stages today (discussed in Chapter Five).

Automated mechanical figures have delighted audiences from antiquity to the present, but, because of the technical and conceptual difficulties involved with precisely replicating human and animal locomotion, engineers have traditionally had to choose between two types of movements: large scale motions such as walking, or small, refined gestures such as speaking, drawing, or playing musical instruments. Because of the technical challenges involved with ambulatory movement such as dance or acrobatics, engineers have typically favored the latter approach, which result in heavily stabilized automata capable of ever-increasingly realistic behaviors and expressions. The human-inspired automata of Philo of Byzantium (third century BCE), Hero (Heron) of Alexandria (first century BCE), Leonardo Da Vinci (fifteenth century), Jacques de Vaucanson (eighteenth century), and Henri-Louis and Pierre Jaquet-Droz (eighteenth century) are forerunners to contemporary entertainment robots found in stage productions and theme parks.

The merging of mechanical construction with theatrical entertainment traces its origins to earliest examples of automata: Hero's two extant works, *Pneumatics* and the *Automatic Theater*, contain detailed descriptions of automatic figures as well as a "fully articulated puppet theater driven by air, steam, and water power" (Kang 16). Fragments of Hero's writing, which were preserved in the works of the Arabs and Byzantines, were among the first Greek works to be translated into Latin by Giorgio Valla in 1501, and in 1589 Heron's *Pneumatics* was translated and published by Giovanni Battista Aleotti. Aleotti's translation included several sketches made by the translator to illustrate the automata and mechanical scenes described in the text (see Hero 1971). The engineer who gave us the first steam-powered engine also gave us the first automated puppet theatre. Hero's descriptions of the mechanical theatre describe a "system of levers, rollers, and wheels connected and moved by means of plant fibers, which were saturated in special wax and resins and loaded by lead weights" (Jurkowski 1998:39). This lineage establishes the linkage between mechanical inquiry and theatrical engagement that developed throughout the Renaissance and Enlightenment eras and continues to the present day.

Silvio Bedini traces the role of automata in the history of technology from Hero's pneumatic and hydraulic devices through their Renaissance and Enlightenment era manifestations up to the advances of Cybernetics and the Space Age in the 1960's. He argues persuasively for the importance of automata in the progress of technology, suggesting that "efforts to imitate life by mechanical means, for whatever purpose, resulted in the development of mechanical principles and led to the production of complex mechanics which have fulfilled technology's original aims—the reduction or simplification of physical labor" (42). According to Bedini, despite automata's ties to entertainment and decorative arts—such as the elaborate water gardens of the Renaissance or the elaborate animal-figures featured on mechanical clocks found in cathedrals throughout Europe—efforts to mechanically imitate life can be directly linked to modern conceptions of automation, feedback mechanisms, and control theory:

> A study of the history of automata clearly reveals that several of the basic inventions produced for these attempts to imitate life by mechanical means led to significant developments culminating in modern automation and cybernetics. The invention of cams,[24] for example, which governed the movements of the androids, is

[24] Cams are small cylinders that behave like small computers: they store information that can be turned into movement. The basic principle of the Cam is to turn circular motion in to one that moves up and down. (*Automata* 2012).

> applicable to numerous modern automatic machines. Although the cam is a far older invention, attributed originally to Archimedes, its employment by Jacquet-Droz in his group of three figures operating in three fundamental different directions, however, resulted in the first machinery having multiple combinations and opened up tremendous possibilities for a great variety of applications. (41).

Bedini discusses in detail how Renaissance engineers like Leonardo da Vinci and Tomasso Francini, and Enlightenment era craftsman such as Lorenz Rosenegge constructed human and animal-inspired automata from Heron's initial designs. These machines were powered by both hydraulic and pneumatic forces, and later by mechanical clockwork mechanisms. Bedini attributes the distinction of the first android— a mechanically figure which simulates a living human—as belonging to Hans Bullmann of Nuremburg during the sixteenth century, but credits Jacques Vaucanson as "unquestionably the most important inventor in the history of automata, as well as one of the most important figures in the history of machine technology" (Bedini 36).

Kang refers to the period 1637-1748 as the "intellectual golden age of automata," citing the publication of Descartes' *Discourse on the Method* and La Mettrie's *Man a Machine* as the intellectual treatises that bookend this phase (Kang 112). During this period, scientific inquiry and entertainment were intertwined. Human-inspired automata not only reflected the mechanistic worldview that dominated from the second half of the seventeenth century, but also "served as the central emblem of the era's views on the nature of the world, the state, and the body" (Kang 9). Gaby Woods has argued convincingly that Vaucanson's automata and other human-inspired machines dangerously "trespassed on ground that was thought, insistently, to be the exclusive province of the living" (Woods 63). Woods also shows how the worlds of entertainment and scientific inquiry drew unusually close during this period. While these mechanical figures were "bathed, at the time of the Enlightenment, in the pure light of reason, and discussion of them took place in unambiguous 'scientific' terms" (Mazlish 179), Woods reminds us that these automata were not displayed in laboratories but rather in popular entertainment settings for non-scientific audiences. Although they designed with the purpose of demonstrating scientific principles (Vaucanson's flute player featured a bellows system that mimicked the functional anatomy of human lungs), the behavior that the automata emulated was conceived largely from the perspective of entertainment—playing musical instruments, writing poetry, and drawing pictures. Historically, automata were all engaged in performances—they were conceived and designed to perform behaviors that simulated artistic behaviors such as drawing, painting, or playing musical instruments. Thus, automata have traditionally linked mechanical inquiry with theatrical illusion. Until the advent of computers and digital technologies, automata were praised for their physical likeness and artistic behaviors, but unlike robots they were passive and un-spontaneous. Brooks:

> These automatons were impressive to the people of the time, and the more sophisticated of them remain awe-inspiring when seen in

> operation in museums today. They could act in the world. But these artificial creatures lacked spontaneity. They did exactly the same thing every time they were activated. They did not respond to their environment in any way. Electronic technologies were needed to give this extra aspect of realism to physical artificial creatures. (2002, 15)

In engineering terms, the automata of this period are embodied, but not situated: they lacked perceptual models of the world and the ability to interact with the surrounding world in a responsive or meaningful way. This distinction is what separates automatons from robots, and I address the significance of this distinction in the latter half of this chapter. However, because movement is the subject of my argument, it is necessary to define automata and categorize them according to how they move.

We can define automated figures—or automata—as artificial beings which imitate human and animal behaviors and gestures using mechanics. Although they appear to operate independently and without human agency, automata require a human operator to set them in motion (for example, by turning a crank or pressing a button). Automated figures can be operated by pneumatics (pressurized gases or hydraulics), through a system of springs and pulleys, or clockwork mechanisms. Animatronic figures, such as Disneyland's Abe Lincoln android or the RoboThespian, are automata that are powered electronically and rely on hydraulics and individual motorized joints to move. They operate according to a predetermined or fully-scripted program run by a computer which determines the time, sequence, and duration of their movements. Automata and their animatronic counterparts do not require any sustained operator interaction to function (although the do have the capacity to be tele-operated by a human operator in real time). While automated figures might feature a variety of programmed movements—Vaucanson's life-size flute player could play twelve different melodies and Jaquet-Droz's *Draftsman* could sketch four different drawings— their range of expression is limited to a pre-determined set of behaviors. Their expressive and responsive behaviors do not participate in an autopoietic feedback loop, and their performances are unvarying and entirely predictable. For this reason, they do not often provoke the intentional stance, and although they may imitate creative behaviors, they do not evoke creativity.

Tele-operated figures are similar to automata, as they are mechanical figures in the shapes of humans, animals, or other fanciful creatures and emulate human and animal behaviors, but they differ in their sources of power. Tele-operated figures are inanimate objects that are operated by direct control in real-time by a human operator that controls the movements remotely. Like automata, these figures have a narrow range of expression that is limited by a set of pre-determined set of expressions and gestures, and require a separate controller for each degree of freedom (DOF). Hoffman *et al.* have argued that direct-control systems require lengthy rehearsal times and often require more than one operator to control them, making it difficult to control the motions in a believable way (Hoffman 2008). Furthermore, it is virtually impossible for tele-operated robots to make eye contact with human users because "more than one operator has access to the joint chain leading to the eye DOF," making it very difficult to coordinate movement (Hoffman *et al.* 354). However, because these objects are directly controlled by human agents, they often appear to be more expressive and responsive than their automated counterparts. A tele-operated figure has more in common with traditional puppetry because it relies on vocal and motor sources of power which are outside of it, and which are not its own attributes.[25] Examples of tele-operated robots are the *Geminoid F* and the Disney/Pixar animatronic *Wall-E* robot, each of whose expressive limbs and facial gestures simulate human motions and behaviors through the control of human "puppeteers" off-stage.

Because of the constraints of live-performance, such as the uncertainty introduced by the presence of other actors and a live audience, the developers of entertainment robots must decide how to design and program robots that create pleasurable theatrical illusions without compromising the stability of the system or the safety of the audience. In some ways, theatre is an ideal venue for tele-operated robots because a stage production is the type of narrowly defined domain in which automated figures can excel. In a scripted production, the dialogue, technical cues, and choreography of the other actors are predetermined and directed by a human agent (the stage manager) who oversees the event from offstage. This arrangement makes it relatively easy to insert tele-operated robots into a live performance alongside human or other robotic actors because (unlike in real life) the interactions are scripted and human agents offstage can respond immediately to changing

[25] According to Jurkowski's definition, tele-operated figures would be considered puppets because they require an outside force to animate them, but automated figures would not.

circumstances. Introducing fully-automated robots into this setting presents a far more difficult task, and often involves a trade-off between more dynamic behaviors (such as responsive facial gestures and speech which require a human operator) in favor of more stable and repeatable motions which do not require an operator. The latter performances are unvarying, which leads to motions that appear dull or predictable. Like automata, these performances are unvarying and entirely predictable, and are not likely to provoke the intentional stance in the spectator. In both cases, tele-operated and fully automated figures are heavily stabilized, and, because of the machinery involved, are cumbersome to work with. The combination of motion control challenges, weight, and safety concerns prevent these inanimate objects from creating compelling theatrical illusions and being perceived as intentional systems.

In terms of movement, both automated and tele-operated robots are similar to rod puppets, where movement is defined in kinematic, geometric terms—that is, by precisely mapping the motions of joints to the motions of the puppet in space, and placing a motor at each joint to power that motion. In rod puppetry, the puppeteer provides stability for the puppet, and the expressive movement is directly controlled by the geometry of the human-powered rod. Programming a stabilized robot to reproduce these gestures mechanically is a rather straightforward engineering task (as demonstrated by Disney's audio-animatronics and the *RoboThespian*), but because there is no human intention or artistry powering the motions, the resulting movements looks mechanical or rigid. The absence of human feeling and impulse make it nearly impossible for mechanical figures to communicate any truths other than mechanical ones. The lack of human impulse is even detected in tele-operated robots controlled by human operators in real time. As we witnessed with *RoboThespian* and the *Geminoid F*, tele-operated robots rely on the same approach to movement as automated robots. Because human-inspired robots use realism as a starting point, where individual motors and pneumatics mechanically reproduce the functional anatomy of humans, the movement almost always appears rigid or jerky regardless of whether it is controlled by a computer or a human operator. The "mechanical" appearance of even the most sophisticated-looking robot makes it difficult to accept the object in front of us as pleasing or engaging.[26] This can be described as a kinematic version of the Uncanny Valley.

Because of the difficulty of replicating complex locomotion like walking, running, or dancing, robots designed for entertainment purposes have traditionally relied on two types of automated movements—refined gestures of the head and torso where small motors in the face mimic human emotions with expressive facial gestures, or the use of stabilized bodies that are controlled by pneumatics (forced air) or hydraulics to perform repetitive gestures. *Wakamaru* and *Geminoid F* (both developed by Hiroshi Ishiguro and ATR) are tele-operated robots that have appeared on theatre stages in Japan and Australia, where human operators control the motions and dialogue of a robot on stage. The 2008 play *I, Worker* (Hataraku

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[26] When I met with the Geminoid DK in a laboratory at Aalborg University, I was surprised by the amount of noise that even the smallest of facial gestures produced. The simple gesture of blinking produced a loud noise similar to the sound of a camera lens, which was caused by the motors and actuators that produce the motion. This is an effect that is difficult to imagine when faced with 2D images of realistic robots, but indicative of the kinematic problem where every isolated gesture requires a discrete motor.

Watashi) and the 2010 *Sayonara*, both written by Oriza Hirata and produced by Seinendan Theatre Company, feature robotic actors alongside human actors in plays that purposefully question the nature of human-robot interaction.

In *Sayonara*, a play that was billed as the "first human-android drama," a human operator controlled the robot from offstage during the twenty minute performance. The plot centers on a relationship between a terminally ill woman, played by a human actor, and a robot who serves as an end-of-life companion for the dying woman. The play was written specifically for the android by Ishiguro's longtime collaborator Hirata and consists of dialogue between the two women which centers on poetry and meditations on death. I have been unable to locate any published reviews of the production (which also toured to Australia at the Arts Centre Melbourne in August 2012), but I have corresponded with several audience members who attended the production in Japan and Denmark and they all described the performance as dull and predictable.[27] Although the robot is considered to be one of the most realistic looking androids in the world, it is still incapable of walking or moving its arms, and at the end of the performance the robot had to be physically carried off the stage by another actor. One online review describes the narrative device that was used to justify the awkward stage exit, but one can only assume how disruptive this image must have been for an audience conditioned to respond to the robot as a stand-in for a human (Eckersley 2012).

[27] I spoke separately with Kathy Foley, puppeteer and professor of theatre at UC Santa Cruz, and Henrik Schärfe, Director of the Center for Computer Mediated Epistemology at Aalborg University in Denmark. Neither were particularly impressed with the theatrical experience.

Whether tele-operated or automated, these human-inspired machines suffer from a kinematic version of the Uncanny Valley, which is inherent because of the mimicry-based approach to movement. Using realism as their starting point, humanoid robots are designed to mimic the functional anatomy of a human, but the commitment to the mechanical reproduction of human movement prevents the spectator from developing an affinity for them. Robots designed for entertainment and interaction with humans must work harder— and work *differently*—than humans to create theatrical illusions that are compelling. This is one of the research goals behind the *Pygmalion Project*.

THE PYGMALION PROJECT

The *Pygmalion Project* is a collaboration begun in 2007 between artists and engineers to develop an automated platform for operating and controlling marionettes. Here I describe our methodology, which uses puppetry as a model for creating expressive automated robots that avoid the limitations of conventionally automated and tele-operated figures. This approach, which emulates the indirect control of human puppeteers, results in automated puppets that are capable of dynamic movement such as walking and flying—motions that are typically beyond the range of traditional animatronics because they are heavy and unstable. Using the natural dynamics of marionettes, where puppets create the illusion of life through the art of indication rather than precise mechanical reproduction, our robot-controlled puppets have a wide range of physical expression and are capable of interacting more fluidly with human operators and spectators than traditional animatronics. Our initial findings suggest that one way to avoid the kinematic Uncanny Valley is by using puppet-inspired design and movement that does not aim at precise mimicry. Replacing human-inspired design with puppet-inspired design allows us to create performing objects that are recognizably human, but avoid appearing uncanny because they look and move differently than humanoid robots. I anticipate that this approach will help promote human-robot interaction by creating robots with which humans can comfortably and intuitively relate. Furthermore, because humans have an established cognitive mechanism for perceiving and interacting with puppets, it is easier to develop an affinity for these automated performers. Ultimately, I anticipate that this will make it easier to create more compelling and artistically pleasing entertainment robots.

The *Pygmalion Project* uses puppetry as a model for situated, embodied systems (robots) and apply this puppet-centered approach to relevant problems in engineering such as dynamic modeling and motion control. While engineers at Carnegie Mellon University, Nanyang Technological University, and National Chiao Tung University have experimented separately with automating marionette and glove puppets (Chen *et al.*, Hu *et al.*, and Yamane *et al.*), efforts to combine robots and puppets have traditionally focused on mimicking the functional anatomy of humans in the methods described above. Our approach is fundamentally different than that of traditional animatronics, androids, and automata: we automate the physical motions of the human puppeteer and the forces outside of the puppet body, rather than powering the motions from within the puppet. The robots in the *Pygmalion Project* are not the actors and do not appear onstage themselves, but, like human puppeteers, they act as the external agents of puppet motion. Removing the machinery from the puppet body results in automated motion that is less rigid and more graceful, because the sources of automation are indirect and hidden from view. Furthermore, the use of traditional marionettes invites the phenomenological gaze—or binocular vision— normally reserved for puppets (rather than robots), thereby helping our system to avoid appearing uncanny. We have found that indirectly automating a performing object, as a puppeteer animates a marionette, is a useful method for investigating the dynamic, interactive processes between the puppeteer and the puppet, and generates a unique movement aesthetic.

The field of puppetry has a rich history of creative movement that suggests the illusion of life. From the perspective of movement, puppets are interesting because they partly resist a puppeteer's attempts to direct them: puppeteers are forced to reach a compromise with the puppet to create the illusion of life. This tension was explored in Heinrich von Kleist's 1810 essay "Über das Marionettentheater," and was discussed in Chapter Two. The puppet's power of artistic expression is therefore not determined by how well it mimics human behavior, but rather by its ability to abstract the human experience and throw it into a type of relief, offering an artistic projection of a recognizable world from which we are partly or wholly free. For marionettes, puppeteers have developed approaches that enable them to balance the dynamics of the puppet against the need to execute expressive choreography that convincingly imitates—but does not replicate—human and animal motion. Unlike humanoid robotics, puppets do not use realism as a starting point and therefore they are capable of creating the illusion of life (or a different kind of life) in ways that pure mechanical replication cannot. For this reason, I anticipate that entertainment robots will benefit from incorporating puppet-inspired design choices.

The Pygmalion myth—the story of the Greek sculptor who carves an ivory statue of a woman which is magically brought to life— provides the plot for our play and the title of our project. We were interested in a narrative that prompted reflection about the nature of our research—the relationship between humans and their attempts to create artificial forms in their own likeness. However, using the Pygmalion myth as a metaphor for mechanically engineering artificial life is not entirely apt: Kang reminds us that in the Pygmalion myth "the transformation is made through the divine power of the goddess of love, not by the mechanical ingenuity of man" (Kang 16). However, the metamorphosis in the Pygmalion story is a movement from the inanimate towards the animate, a theme that resonates in both puppetry and robotics. Furthermore, we determined that the story could be told though movement alone and using only two characters, and that the choreography for each puppet could be isolated (this last feature would prove important once the design for the system was finalized).

In the Pygmalion myth, Aphrodite transforms the ivory statue into Galatea, a fully living woman (rather than a life-imitating machine). When conceiving the choreography to dramatize this part of the story, we knew that the success of the production would depend on how believably we were able to imitate the illusion of a living being with simple materials. The decision to work with traditional string marionettes, which are lightweight and have many more degrees of freedom than a traditional animatronic figure, removes the rigidity of mechanical motions but also makes the figures more difficult to control. This is due to the indirectness of the control mechanism: like traditional puppets, our marionettes are operated from above by robotic controllers. The indirect control system introduces a new set of problems for controlling the movement of the marionettes and creating compelling movement: the engineer must learn to yield herself to the requirements of this new system, just as the puppeteer learns to yield himself to the specific weight and pendular motions of the marionette, or the sculptor learns to shape the weight and hardness of stone in order to create illusions that are evocative of sensuous flesh or motion.

We know from puppetry inanimate objects can succeed in creating compelling illusions even though they resist a puppeteer's attempt to direct them. This is especially for marionettes, where choreography is not conceived in kinematic terms (as in traditional rod puppetry or animatronics) and the puppeteer has far less control over the isolated movements of the puppet. A puppet's resistance to control is a well-known feature of puppetry. In *Tall Horse*, puppeteer Mervyn Millar writes about teaching puppeteers to work with the weight and impulse of the large puppets (discussed in greater detail in Chapter Five), while Gross writes of the difficulties of controlling an articulated puppet hand where "the indirectness of the control, the dependence on collaborating with gravity through small shifts of position, meant that each new gestures seemed to spring from the wooden hand itself" (Gross 66). Gross identifies this feature as native to all forms of puppetry:

> Puppeteers I have met indeed often speak of waiting for some impulse from the puppet they hold, a gesture or form of motion that they can develop, often being shocked by what emerges. In some shows that I have seen, the most fascinating life resides in a puppet left untouched, laid on the ground or just hanging, swaying only as motion is communicated to it by the vibrations of the air or the shakings of the stage (…). (66)

A robotic controller cannot rely on "some impulse from the puppet they hold" to direct its movement. Using puppetry as our model, we developed a system of robotic controllers and corresponding software that would enable us to replicate this process as closely as possible given the absence of a human agent. Because engineers want to design robots that can move and operate in the real world, and human puppeteers have demonstrated a reliable ability for controlling dynamic objects in the physical world, puppetry makes a good test-bed for exploring these issues.

Learning to automate marionette motion requires a wholly different approach than automating kinematic motions. We cannot program a motor to move the individual joints directly; rather, we must approach the problem indirectly by considering how the human puppeteer interacts with the puppet to control the movements—balancing the need for descriptive motions against the reality of the physical motions— and automate that process. Focusing our attention on the indirect control of the human puppeteer (rather than directly powering the individual motions of the puppet), we account for the string marionette's unique properties by using an approach called *optimal control*. In this approach, the puppet's geometric movements are used to specify how and when a robotic puppeteer should be programmed to exert forces on the puppet in order to create the desired motion, minimizing the amount of effort required to produce the motion.

For example, to represent a human walking we start with the marionette body and calculate how to operate the strings and controller in a way that best indicates the walking motion, given that a marionette that cannot precisely reproduce human locomotion. Marionettes have significantly more degrees of freedom than other types of puppets, but they have far less than a human body: depending on the number of strings, a typical marionette has between 45-60 degrees of freedom, while a healthy human possesses a number far greater than that.[28] And yet, in the hands of a skilled puppeteer, these figures are capable of a wide range of expressive and nimble choreography that emulates human movement. Rather than replicate the mechanical processes of a human walking, a marionette *indicates* walking, using the ground only as reference point, and not as a physical constraint. As Kleist observed, unlike humans, marionettes appear immune from gravity's forces: "puppets need

[28] "Quantifying the enormous number of degrees of freedom for a human body is a difficult task because of the complex neuromuscular system of the human body, which produces redundancy and flexibility in the range and number of movements that a human body is capable of. This has made it difficult to accurately produce mechanical models of human anatomy, as the properties of the muscles change based on the human body's interactions with the external, physical world" (Bernstein 1967:136).

only to touch upon the ground, and the soaring of their limbs is newly animated through this momentary hesitation" (24). Within this abstracted framework—where puppets operate according to a different set of dynamic (and aesthetic) laws than humans and humanoid robots— puppeteers have developed a system to control figures that is artful, stable, and reliable. This is the process that we emulate.

We have established that marionettes are technological tools capable of a wide range of expressive gestures which are dynamic—their movements are controlled by forces outside of the object. In our initial conversations with Ludwig, we learned of an approach to puppet motion known as the *Imitate, Simplify, Exaggerate* method: imitate an observed behavior, simplify the motion to its basic components, and exaggerate the behavior to an appropriate level of animation that creates the illusion of motion for the spectator. This approximates the engineering concept of optimal control, which seeks to reduce the number of DOF of a given motion in a reasonable way. Our first task was to describe the puppeteer's three-step process in computational terms. To do this, we had to model mathematically what a puppeteer does intuitively.

Ludwig described how marionette choreography is divided into small units of motion, each lasting a specific amount of time (Egerstedt *et al.* 2007). Puppeteers coordinate the timing of a motion so they can interact with other puppeteers, sometimes collaborating to control a single marionette or groups of puppets, ensuring that the marionettes remain animated throughout the performance. Scripts of puppet plays describe the action using four parameters: temporal duration, agent, space, and motion (when, who, where and what). Individual motions are grouped and executed according to counts that specify when each motion begins and ends. During rehearsals and performance, the puppeteer makes decisions about the use of force, dynamics, and movement qualities that determine the expressive characteristics and the overall visual effect, handling complex choreographic sequences and solving problems of uncertainty, often before they arise. In engineering terms, this can be described as a "closed-loop" model for movement, where the puppeteer incorporates the sensory feedback of the puppet and the surrounding environment and changes her behavior accordingly. Real-time decisions are vital to the overall effect of puppet motion, and they are also tremendously difficult to quantify because they are based on heuristics and intuition. Building automated systems that emulate these cognitive abilities is a far more difficult task than programming kinematic motions.

Unlike the puppeteer who relies on a combination of heuristics and intuition, engineers must work with comparatively simple building blocks to approach choreography. For the *Pygmalion Project*, we used two interdependent approaches: we created a software program called *trep* that translates human choreography into puppet choreography by mathematically transforming human motion into feasible puppet motion, and we designed a robotic platform for controlling the marionettes. The software programs the robots to "perform" a marionette play, essentially enabling the robotic controller to assume the role of a human puppeteer and perform a play based on human choreography. Unlike a traditional puppetry script, an engineer cannot rely on a human agent to interpret the "script." In a fully-automated system, the performing object (marionette) and its robotic controllers remain passive and mechanical; therefore, the engineer must consider other factors, such as how many robots should operate one puppet, and how to coordinate the movements of several robots controlling a single puppet. A human puppeteer operating a marionette relies on what Chris Carroll calls "a vast unconscious vocabulary of movements": they always know where the audience is seated, and are continually aware of the positions of their left and right hand at any given moment (73). One of the most challenging parts of the experiment was coordinating and controlling the movement and efforts of the robotic controllers in such a way that approximates this intuition—something human puppeteers do instinctively.

We devised the choreography with professional dancers— a wholly different approach from that of a traditional puppeteer, but one necessary to generate a set of data points to act as a mathematical "script" to start with. First, we encouraged the dancers to move with their natural gait and full range of motion (thereby ensuring a large number of DOF), we then simplified the choreography to a level that would sufficiently communicate the story and recorded their choreography using a motion-capture system (Figure 5). A motion-capture system uses infrared sensors to track individual points attached to the dancer's body and record each motion.[29]

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[29] Motion capture is used to generate computer graphic images in animation and film and has been adapted for video gaming and home animation with the Microsoft Kinect.

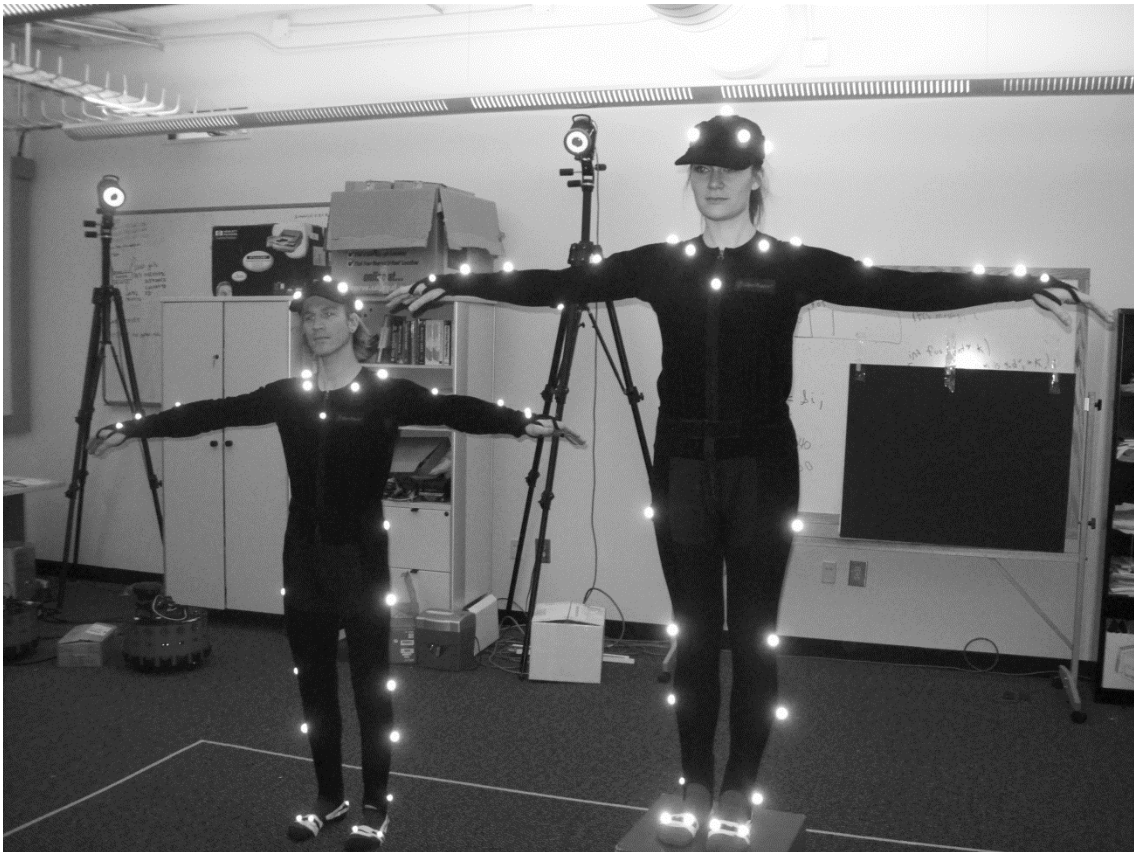

Figure 5. Dancers Stephen Loch and Stephanie Johnson (Brooks & Company Dance) performing choreography that was recorded using motion-capture technology.

It is interesting to note that the process of recording human motions for the study of movement has been central to the study of motion dynamics since the development of instantaneous photography in the 19^{th} century (Bernstein 1). The use of instantaneous photography laid the foundations for the quantitative studies of movement, and the photographic experiments by Muybridge were instrumental in developing mathematical models for understanding process of locomotion for human and animal subjects. Motion capture has long been a meaningful way of capturing data for the investigation of the physiological and biomechanical analysis of the processes of movement. To a certain degree, our work is a continuation of this approach.

From the data, we calculated the speed, duration, and forces for each movement and choreographic sequence, and used this information to develop software that would translate the human motion into abstracted marionette motion. The *trep* software uses algorithms to determine how to program each individual string attached to the marionette, and simulates what this motion will look like using two-dimensional imaging (Figure 6). These "inputs" are then used to program robotic controllers which, like a human puppeteer, control the marionette by pulling on its strings from above. By indirectly operating the puppet, we are able to create different type of automated motion for the puppet that is indicates recognizable motions without precisely replicating the physical processes involved.

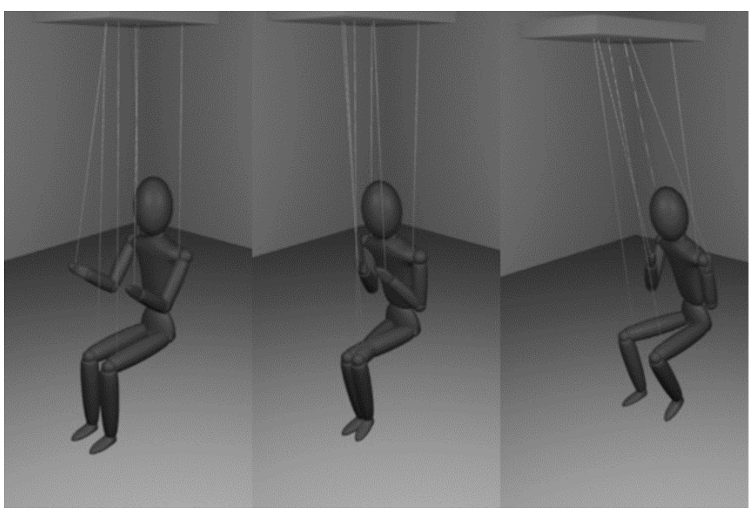

Figure 6. A computer rendering of marionette choreography based on motion-capture data and simulated using the original software program *trep*.

One might ask why we did not use marionettes to choreograph the play from the outset. Wouldn't it be simpler to use the motion-capture system to record the motions of marionettes directly operated by a professional puppeteer? The answer is that this approach would have sidestepped the more difficult—and more interesting— question of abstraction. Because marionettes have fewer degrees of freedom than humans, their movements are already abstracted. Since we are interested in exploring the mechanics of movement—that is, understanding what motions are recognizably human and can be reliably reproduced using a minimum amount of effort and control—it was necessary to begin with the fullest range of dynamic and expressive motion possible.

Originally, we intended to control the puppets using a stage comprised of two pivoting mechanical arms equipped with individual motors to power winches for pulling the marionette's strings.[30] While this design partially imitated the process of a human puppeteer, it was limited because the marionettes could not traverse the stage as in traditional puppetry. In some respects, this early design was as limited as the heavily stabilized systems we were trying to avoid: although the puppet motions were controlled by marionette strings, the robotic arms relied on kinematic motions which (for reasons already described) cannot approximate the fluid, dexterous, and full range of motion of a human puppeteer. Around this time, engineers at Disney Research and graduate students involved in this project developed a more flexible system for controlling marionettes, which would lead to

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[30] The initial design was not unlike those used in Chen et al. (2005) and Yamane et al. (2003).

the prototype for the *Pygmalion Project*. We first experimented with the design of a freely-moving robotic controller operating a single-stringed butterfly marionette. This design enabled a range of motion that more closely approximated the motions of a human puppeteer: the robotic controller (and by extension, the marionette) could move around the entire stage fluidly and quickly, although not very reliably. The task of operating larger, heavier, and more articulated marionettes would require a redesign of the robotic controllers.

We replaced the robotic arms of the original design with a custom-designed metal chassis equipped with individual winches that operate the strings, and separate motors to drive around the stage (Figure 7 and Figure 8). A unique feature of the design is that the robotic controller is suspended from above using magnetic wheels that attach to a plastic "roof" covering the stage. This allows for a wider range of motion than the original design, increasing opportunities for locomotion for both the robots and the puppets they control. The robots have three main functions: to move around the stage synchronously, to bear the weight and force of the puppet, and to reliably animate the limbs of the puppet using winch-operated strings. After early experiments with lightweight objects such as a ball and a plastic skeleton (Schultz *et al*. 2012), we determined that each puppet would require more than one robotic controller to operate it. Currently, a single human-shaped marionette is controlled by three robots, and it is attached using six strings: two head strings, left forearm, right forearm, left knee, and right knee. The positions of the strings, and the string lengths, can be attached to the robotic controllers in any combination. Using three robots to control the marionette distributes the weight of the puppet, making some movements more stable. However, this system presents a new set of problems for automating marionette motion.

Figure 7. Three robotic controllers operate a traditional wooden marionette suspended from a plastic ceiling that covers the stage. The robots each control two puppet strings and collaborate with each other to perform the motions of a puppeteer and generate marionette motion.

Figure 8. The figures of Pygmalion (left) and Galatea (right) suspended from the stage ceiling. Each puppet is approximately three feet tall.

We approached the task of imitating human movement from two directions: automated motion and tele-operated motion. For automated motion, we used the *trep* software to replicate as closely as possible the original choreography recorded from the human dancers.[31] Working with short choreographic phrases, we learned

[31] Videos of the trep simulation and the corresponding marionette motions are available at HTTP: < http://vimeo.com/channels/numarionette>.

which motions are the most aesthetically interesting and stable (or unstable). Controlling the natural swing of the marionette in between movement phrases is a particular challenge. The second approach is tele-operating the robots in real-time using remote controls, which allows us to experiment with the system more directly, as a puppeteer would operate a marionette controller, only without the tactile feedback that a puppeteer experiences. The lack of tactile feedback makes it quite difficult to develop an intuition for operating the puppets.

In light of this limitation, we have experimented with Microsoft's Kinect, a motion tracking system that uses an RGB camera and depth sensors to track and record the motions of human bodies without any markers or trackers.[32] Although originally developed as a tool for video gaming, the Kinect has proven a useful tool for generating human motion capture data and for designing animations in 2D and virtual environments (Moore 2012). The Kinect enables human users to control human-shaped avatars in virtual environments, and can also be used to generate animations for non-human avatars. For example, a computer animation program can use information obtained using a Kinect console to track the motions of a human arm, say, in the motion of creating a shadow puppet. The software can then use this data to map that movement or gesture onto a corresponding animation on a computer of a non-human figure, such as a bird or rabbit. This system combines human-generated choreography with hardware (the Kinect) and software (the

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[32]Kinect is a gaming console that functions as a motion capture system. The portable device has been used in many virtual simulations and animations (Moore 2012).

animation) and results in a new form that combines the principles of shadow puppetry with computer animation.

Because the present study is concerned with the movement of embodied and not virtual systems, I will explain how we use the Kinect on the *Pygmalion Project* to generate choreography for marionettes and why this approach is unique. We use the Kinect to record movement from human agents, and *trep* uses the data to compute how to reproduce those motions first in a two dimensional animation, and then generates inputs to program the robotic controllers for controlling the marionette. The result is that any human user without prior knowledge of puppetry, robotics, or computer animation can generate a short sequence of movement or choreography, and within minutes the software will compute the inputs that allow that motion to be reproduced on the marionette. Wakabayashi *et al.* have demonstrated the ability to control a small humanoid robot using human motion capture data obtained through a Kinect, and argue persuasively that such a system promotes more lively and intuitive communication between humans and tele-operated avatars (127). This is not dissimilar from the methods used to control tele-operated robots like *Geminoid F*, which rely on similar sensing techniques to mimic human facial expressions. The ability to tele-operate a robot using only gestures and facial expressions is undoubtedly a powerful and intuitive interface.

The imitation process underlying the *Pygmalion Project*, however, is fundamentally different from these other approaches because it does not represent a one-to-one correspondence between human controller and artificial performer. Rather, the performance is mediated through the robotic controllers, which translates human motion into puppet motion. In other words, we do not overlay human motion directly onto human-shaped robots or artificial devices (which we have already determined produces dull, perfunctory movement); rather, our system abstracts human motion to create a new type of motion, mediated by software (*trep*), hardware (robots), and puppets. As such, our approach differs from the traditional automata and animatronics which rely on mimicry-based approaches that mimic the functional anatomy of humans. Using a puppet-inspired approach, rather than human-inspired approach, allows us to retain the principal of abstraction native to puppetry which results in movement that works within the aesthetic conceit and technical constraints of marionette puppetry. We have learned to work *differently* to create mechanical motion that is more artful and compelling than traditional animatronics.

At the time of writing, we have completed a prototype and programmed the robots to perform sections of the original choreography. Our system was featured at the Museum of Science and Industry in Chicago during National Robotics Week in 2012 and 2013, where we performed short segments from the play and demonstrated the user-interface. Visitors were able to interact with the system, designing marionette choreography in real-time by using software that translates their movements into choreographic sequences for marionettes. While we have not yet realized a full production, our ongoing research has led to useful findings about the complex task of automating human motion and the profound difficulties involved with computing what a puppeteer does intuitively. Our results suggest how the developers of entertainment robots might use puppetry as a model for designing and programming robotic performers that are more dynamic than the current generation of entertainment robots.

Currently, engineers at Disney are experimenting with variations of the automated marionette system by experimenting with lightweight marionettes equipped with individual motors located on the puppet joints to create more controlled and defined movements. The forces created by the individual motorized joints help to stabilize some of the swing dynamics of the marionette and create more stable and reliable motion trajectories. In the lab at Northwestern, we continue to develop the original Pygmalion choreography obtained from the human dancers, using only the robotic controllers. We are currently focused on grouping together longer choreographic phrases.

The robotic platform for controlling marionettes is a system comprised of hardware, software, and puppets. Although we have not yet performed a full-length play, we have demonstrated the ability to use this system to perform both automated motion and tele-operated motions. A unique feature of the design is that three robotic controllers work together to direct the motions of a single puppet. I have indicated that the puppeteer's process approximates the optimal control problem in engineering, where engineers develop systems for controlling machines in such a way that optimizes the motor control for a given aspect of task performance. In this case, the task is the execution of puppet motion, or controlling a marionette's strings. This is a two-step process, which involves developing computational models that simulate these effects in two-dimensional environments and executing these commands in the real world. Even though our models might work in simulation, the conditions of performing in the real world presents a new set of problems tied to the material constraints such as the motors on the robots and the limbs of the puppets.

In order to faithfully interpret the original choreography (whether automated or tele-operated), the robotic system must have a model for understanding how good of a job it is doing at executing the given task. We can think of this as a type of autopoietic feedback loop, where the puppeteer regulates her motions in response to the direct physical interactions with the puppet. Again, for a human puppeteer this process happens intuitively. In order for our robots to emulate this skill, they must be equipped with sensing mechanisms that provide feedback about how well (or not) they are achieving their objective. To create this "closed loop model" for our robots, we use a separate Kinect console to track the positions of the robots relative to each other, and relative to their starting points during the entire course of movement. This information is compiled in the robot operating software (ROS) program written specifically for our system which provides the robots with information (on average thirty times per second) about how precisely they are executing the given choreographic phrase. This method approximates the coordination and regulation of motions found in self-regulating— or autonomous—systems, such as the purposeful movements of humans and animals.

Nikolai Bernstein, a pioneer in the study of motor control and motor learning, identified the necessary components for a self-regulating system as: *effector* (motor activity); a *control element* (which conveys to the system in one way or another the required value of the parameter which is to be regulated); a *receptor* (which perceives the factual course of the value of the parameter and signals it by some means to); a *comparator device* (which perceives the discrepancy between the *factual* and *required* values with its magnitude and sign); an *apparatus* (which encodes the data provided by the comparator device into correctional impulses which are transmitted by feedback linkages to); a *regulator* (which controls the function of the *effector* along the given parameter) (129). Together, these components comprise a closed-circle interaction that functions during the course of movement for any given action. While this model was developed to describe the control of motions within an organic system (such as the human body), we can extrapolate this system to arrive at an understanding for how this closed-circuit interaction functions for a puppeteer effecting puppet motions. In marionette terms, we might say the puppeteer (effector) uses the control (control element) to operate a puppet, and uses her sight and touch (receptors) to perceive what the puppet is actually doing (the factual course), when compared to the envisaged choreography (comparator device), and decides how to makes corrections to the system (apparatus), which result in new or corrected motions (regulator).

When we first developed a prototype for our system, the ROS did not include any feedback mechanism for providing the robots with information about the discrepancy between the actual trajectories and the desired trajectories for the puppets (or the factual versus the required values). This meant that although the choreography might have appeared reasonable in the computer simulation, running the play in the real world did not always function as we had envisioned. If any single robot become slightly off track— either because it was too slow or if a puppet string was entangled— the puppeteer had no way to realize its error, and no way to regulate its actions. Even the smallest error (or discrepancy between the factual and the envisioned trajectory) could magnify over time and begin to effect more changes to the path that would eventually disrupt the entire system. Using the Kinect, we were able to address this problem by tracking the robots, and use the data provided by the Kinect to "update" the pre-computed plans by modifying them slightly and sending a new set of commands (or modified version) to the robots. The result was a collaborative system capable of coordinated movements in the physical world.

A self-regulating system that is able to perceive its actions and make changes based on this information may be said to possess autonomy. While the *Pygmalion Project* robots have some features of autonomy (they are situated and embedded) they are not fully autonomous: the robots still perform according to a predetermined script. The robots cannot, for example, suddenly decide to improvise a scene or spontaneously interact with the audience the way a human puppeteer might. However, our system does have perception faculties and displays features of coordination and control that are not dissimilar from the organic regulation of systems that govern human motions. As I have demonstrated in this chapter, this behavior is substantively different than any method of programming or control found in traditional automated or tele-operated animatronics, because in our system the human motions are mediated through software and hardware that translate human motion into puppet motion. While I will refrain from asserting that this small degree of autonomy defines our system as inherently creative, I do propose that our system emulates processes of coordination and control that we associate with intelligent and creative behavior.

As I hope this discussion of the *Pygmalion Project* has shown, we do not have to wait for the appearance of fully-autonomous acting machines on theatre stages before we can begin to construct a theory of aesthetics for how these artificial creatures function in live performance. Questions about what makes a machine autonomous or what characteristics and traits we identify with creative behavior raised by this experiment (and others like it) indicate that we are already in a position to consider the implications of autonomous and semi-autonomous machines. My aim is to raise and formulate some questions about how autonomous and semi-autonomous machines operate on an aesthetic level, and why we might be forced to make room for non-organic actors on our stages and in our theoretical models of performance.

THE AESTHETICS OF AUTONOMY

(Or, *Fake It Till You Make It*)

Through the artful imitation of human and animal motions—using either the techniques of traditional puppetry (objects operated through direct human manipulation) or automated motion (objects that move autonomously)—inanimate objects succeed in creating compelling illusions because of States' conception of "binocular vision" discussed in Chapter Two, the phenomenological stance where the spectator has the ability to "hold in mind two categories—that of the real and that of the imaginary—that are fused into a single phenomenon" (States 1985:169). While binocular vision is pronounced in puppetry and productions that feature robot actors, the nature of the theatrical illusion is problematized because, unlike human actors, puppets and robots are material objects that simultaneously occlude and expose their artificiality (Bergamasco *et al*. 2010).[33] This paradox presents a challenge for puppets and robots, as the very features that make them appealing (their physical appearance, their dynamic movements) are also those features that put them at risk of appearing frightful or uncanny. In light of recent technological developments which result in increasingly automatous robots that are able to independently navigate in the real world and demonstrate emergence, I anticipate that this paradox will be of increasing relevance for the designers of robots. To resolve this tension, I have advocated for the position that engineers use puppet-inspired approaches for designing and controlling movement. Furthermore, I have proposed that the cognitive mechanism that humans have developed for interpreting and interacting with puppets (binocular vision) is evoked in any interaction between a robot and a human user.

Essentially, a robot performs an act of autonomy for a human spectator. In this way, a robot's autonomy or agency is evoked through a dialectical exchange, or autopoietic feedback loop. Kroos *et. al* have argued that agency cannot be instilled in an artificial object, but rather that it is evoked in a dialectical exchange based on

[33] For further discussion of "binocular vision" in puppetry see Tillis (1992).

the interplay between the robotic "actor" and the human "spectator." According to Kroos *et al.*, "agency emerges from the interplay of the robot's behavior and the environment and that, in the systems' interaction with humans, it is to the same degree attributed to the robot as it is grounded in the robot's actions" (Kroos 401). A phenomenological reading of robots places a tremendous amount of importance on the perception of the spectator, challenging the notion that the agent – "the one who is driving, leading, acting"—is a distinct entity that has been put into a machine" (Kroos 401). If it is true that agency emerges from the interplay between the performing object, the machine, and the environment, then I argue that engineers can use puppetry to design robotic systems that fit more readily into this cognitive model and develop automated performances that provoke the intentional stance and evoke creativity.

Writing about their robotic installation, the *Articulated Head*, and the perception-action control system designed to control it, Kroos et al. speak to the question of agency and robots and propose that the Cartesian mind-body dualism that decouples the sensing and thinking processes of robots from the outward movements and behaviors is a misconception.

> The question of who is driving the agent, the agent within the agent, is exposed as an unhelpful recursive affair. This is also the reason we speak of "evoking" agency. The agent is not considered something that is in the machine, like a homunculous, controlling it; agency emerges from the interplay of the environment, including other

> agents, and the machine. In the interaction with humans, agency is grounded in the agenda of the agent to the same degree as it is in the attribution of agency by the human. Most of all, however, (…) it is grounded in the dynamics of the interaction itself. (401)

Kroos' notion of agency relates to Goodman's concept of situatedness and Fisher-Lichte's autopoietic model for theatre performance discussed in Chapter Two. The goal of the Articulated Head performance was to have the robot's behavior "emerge from the interaction of the control system with the environment," avoiding pre-determined or pre-scripted behavior (403). If engineers wish to create entertainment robots that appear autonomous, they would do well to consider the dynamics of the interaction, which, as I have argued, can be understood in terms of a theatrical performance.

Unlike robots, traditional puppets avoid appearing uncanny or dull part because they are controlled by a separate agent. Because a puppet never has to convince a spectator of its autonomy—the puppeteer's presence is implied even when unseen by the audience—we can enjoy the illusion without experiencing uncertainty about sources of power. A robotic actor, however, always risks appearing uncanny because it is designed to perform independently from its human programmer. Furthermore, because human-inspired robots use realism as their starting point, they are disadvantaged by their mechanics: the kinematic version of the Uncanny Valley dictates that motions will always appear mechanical because of the geometrical precision and the corresponding materials necessary to power these movements electronically, hydraulically, or pneumatically.

The ability of autonomous and semi-autonomous machines to operate in the real world brings up the issues of embodiment and situatedness. Brooks defines situatedness and embodiment as two fundamental principles of robotics, where "a situated creature is one that is embedded in the world, and which does not deal with abstract descriptions, but though its sensors with the here and now of the world, which directly influences the behavior of the creature" and an embodied creature can be defined as one that "has a physical body and experiences the world, at least in part, directly through the influences of that world on that body" (Brooks 2001, 52). While automata like Vaucanson's musicians or Jaques-Droz's figures have physical bodies that act in the real world they cannot be defined as situated because they are not able to perceive the real world and do not act based on information or conditions of the surrounding environment. Traditional animatronics also lack situatedness—like industrial robots, they can only perform the pre-determined motions they are programmed to do, and for this reason they do not exhibit features of expressivity and responsiveness, and are unlikely to provoke the intentional stance.

Through the incorporation of electronics and computer software programs, humanoid robotics such as the *Geminoid F*, some human-inspired robots have achieved *partial* situatedness—the movement of the robot's face and mouth can be controlled and operated by a human operator through sensing technologies that are mediated by a computer program. In this sense, the robot's movements are based on actions that occur outside of it, in the physical world. However, because the acts of sensing and perceiving happens by a computer located outside of the robot (and not "onboard" the robot), the control happens indirectly and the robot cannot be said to satisfy situatedness as defined by Brooks. While the figure has a physical presence in the real world, and the figure is undoubtedly imbued with a charged presence that suggests liveness, the physical body of the robot remains passive and purely mechanical. It cannot be said to "experience" the world in the way that other types of robots that navigate their environment do. This is not just because the robot is stationary and has no locomotive properties: like Vaucanson's automata, the Geminoid robots have no intelligent capabilities and are only able to execute behaviors which are directly programmed by a human operator. The Geminoids are not currently equipped with any sensing technologies of their own. In this sense, it is not just the kinematic quality of movement that makes the performing object appear dull, it is also the robot's inability to perceive the world and respond to it which makes it ultimately uninteresting to audiences.[34]

Returning to Kleist's essay on the marionette theatre, how is it possible for the author to locate a marionette's soul in its "merely physical center of gravity," while automated robots and animatronics are habitually perceived as soul-less? I have already suggested that part of this can be explained by the presence of the human puppeteer who enters into the gravity of the marionette, allowing "his own human

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[34] In my conversation with Dr. Henrik Schärfe, on which the Geminod DK is modeled, he spoke of the *doppelgänger* effect as one of the most compelling features of the robot. He suggested that much of the interest and enthusiasm for the robot is generated when he and the robot appear together, and observed that public interest in the robot (gauged by the number of people who sought out opportunities to interact with robot) wanes when he is not present.

feeling and impulse to be drawn toward and translated through the inanimate body, finding a home for them there, making the puppet itself into an actor," (Gross 64). But if all a robot required was the presence of a human operator, then figures such as the *Geminoid F* would be perceived as captivating and interesting because the motions, behaviors, and speech are imbued with human feeling and impulse of the operator. I have already suggested that the kinematic approach to movement produces behaviors that are dull, predictable, and uninteresting even when they are powered by a human operator. However, engineers can learn how to animate these machine so they are better able to imitate expressive and responsive behaviors, and provoke the intentional stance.

Engineered Arts is the entertainment company behind the *RoboThespian* discussed at the beginning of this chapter, and advertises the figure as "the original robot actor." The "fully programmable robot" claims to be "fully interactive, multi-lingual and can communicate and entertain on a way that few people have experienced before" (theatre of Robots 2012). The system uses open-source 3D animation software called Blender, which allows a user to develop a play in software, and then run the program on the robots in the real world. However, before we can celebrate the realization of Craig's *Übermarionette*, we must acknowledge the limitations of the system: the RoboThespian cannot locomote and has no properties of emergence. The *RoboThespian* is a more sophisticated automaton that can be programmed to perform any dialogue or predetermined set of gestures (be it a guided museum tour or a three hour production of *Hamlet*). Engineered Arts' "Theatre of Robots" is available for rent through its website, and can be adapted to most indoor performance venues. According to the company's website, the ready-made theatre comes with: three RoboThespians, a modular stage, and an integrated control system, lighting and projector rig. The company specifies that the performance venue should come with a "hand rail or barrier to prevent visitors touching the *RoboThespian*" and also, the client should provide "an audience." While the handrail might be easy to produce, producing a captive audience may prove the more difficult task, as these robots suffer from a kinematic version of the Uncanny Valley. While audience's might delight in watching a robot (from behind a handrail) "saw the air too much" with its mechanical arms while reciting Shakespearean verse, such a performance is unlikely to hold anyone's attention for long. Because the robot is not animated in such a way that contributes to the autopoietic model of theatre performance, it is unlike to provoke the intentional stance or evoke creativity.

One example of an animatronic that uses animation to imitate expressive and responsive behaviors is Disney's humanoid robot introduced in Chapter One. This robot is capable of playing catch and juggling with a human user, and this physical interaction imitates expressive and responsive behaviors that the RoboThespian does not. In "Playing Catch and Juggling with a Humanoid Robot," the authors cite limited physical interaction between robots and humans as a major barrier for creating meaningful interaction between humans and robots in entertainment environments. Physically, the human-inspired robot suffers from the same physical traits that limit robots like the *RoboThespian* and the *Geminoid F* which physically mimics the functional anatomy of humans. Like other animatronics, the mechanical motions are kinematic, and the robot is heavily stabilized and does not locomote. However, engineers have demonstrated an ability to work differently within these constraints, finding a unique way to bridge both the physical and psychological distances that separates the humanoid robot from the human.

First, the authors developed a test bed for a throwing and catching game scenario, which relies on an external camera system (that is, not onboard the robot) to locate the balls in space and predict the timing and destination of the incoming balls. The game of catch closes the physical distance between the human and the robot without compromising the safety or stability of either.[35] Secondly, and more important for our understanding of autonomous behaviors, is what happens when the robot misses the ball. The designers have cleverly included animations for scenarios that are automatically triggered when the robot fails to achieve the task, which include looking at the ground or directly behind it to locate the ball, or as shoulder shrug to imitate a human-like response. Here, the use of clever animations effectively turns failure into a new opportunity for human-robot interaction:

> We found that adding subtle motions in addition to the functionality required for catching and throwing, generally made the system more appealing. For example, an early version of the system could not detect whether the ball had been successfully caught or not. Users appeared irritated when the robot did not react appropriately to a

[35] A video of the experiment is available at www.disneyresearch.com/project/juggling_robot.

> missed ball and attempted to throw back empty handed. We therefore set the vision system to detect ball catching failures, and acknowledge them with appropriate animation. Additionally, head motions were added to give the appearance of ball and participant tracking, as opposed to unnaturally staring out into space. (4)

Even though the robot does not use its eyes to track the ball or the human participant (it relies on external cameras), the engineers understood the importance of realistic gaze direction for creating a meaningful interaction. Gaze direction is also crucial in emulating behavior that acknowledges a missed ball. Before each new throw, the robot is automatically programmed to look directly at the participant, and when the ball drops below the catching plane this triggers a randomly chosen response from one of three simple animations: a shoulder shrug, shaking the head, and looking down. When the camera detects that a ball has dropped behind the robot, this triggers an animation where the robot looks backwards in the direction of the floor (5). These animations successfully turn a mechanical failure "into something unexpected and entertaining, as well as create an opportunity for new interaction" (7). The authors write that these animations prompted human users to address the robot as they would a human counterpart—scolding the robot for missing a catch or apologizing to the robot for a poor throw. Disney's experiment not only demonstrates a platform for exploring human-robot physical interactions at a close-distance, it also indicates how simple animation tools can be highly effective in emulating human sentience and creating robots that appear more interactive and spontaneous. The authors are forthcoming about how this approach might impact the use of robots in entertainment venues:

> Our platform allows us to begin examining various storytelling scenarios within theme park or entertainment venues where guests can interact physically, but safely, with animatronic characters. Guests will be able to obtain a physical connection with characters and become participants in story events, creating a greater sense of immersion within fantasy environments. (7)

Disney's experiment with the throw and catch animatronic demonstrates the necessity of learning to work differently to create mechanical motions that are more compelling than those of traditional animatronics. Combining task-oriented motions together with animated motions help create the illusion of agency and even liveness. The robot is semi-autonomous, and the randomly-chosen animations, together with realistic gaze direction and an interactive task results in a robot that *appears* more autonomous than its programming suggests. In the absence of a human operator, binocular vision indicates how a participant might be persuaded, momentarily, to forget that this robot cannot move its legs, or that its motions are purely automated. Varied, choreographed animations that are context-dependent are one way to avoid the Uncanny Valley, both in terms of physical likeness as well as kinematic motion. Such research indicates a trend toward more lively and interactive robotic actors by involving human users or spectators more directly.

The issue of whether to build robots that physically resemble humans is far from resolved. Robots—whether they appear in the physical likeness of humans some other abstracted form—are capable of increasingly autonomous behaviors. Regardless of their physical verisimilitude, the appearance of creativity emerges from how these artificial agents move and interact in the word. To develop more compelling entertainment robots, engineers must learn to develop automated motion that is expressive and responsive. The methods of the *Pygmalion Project* represent one approach: our system models a closed-loop system for controlling marionettes that allow the robots to coordinate their movements based on their interactions with each other in the real world. Because the performing objects are marionettes, the creative movement is necessarily abstracted, and perhaps appears more artful precisely because it does not use realism as its starting point. As we continue to develop the *Pygmalion Project* by moving our experiment out of the lab and into live performance settings such as museums and theatres, we can begin to test more rigorously the effects these puppet-inspired choices. Another approach to developing automated motion that is expressive and responsive and more likely to provoke the intentional stance is the use of creative animation and sensing technologies that promote interaction and support the autopoietic model for theatre performance. These two approaches suggest how the developers of entertainment robotics might use puppet-inspired choices for creating and controlling robotic actors for more dynamic and interactive performances.

CHAPTER V

REPRESENTING ANIMALS

CHAPTER OVERVIEW

Animal-inspired entertainment robots can be divided into two categories: 1)*Relational artifacts* which are small, inanimate objects that present themselves as having "states of mind" for which an understanding of those states enriches human encounters with the objects, and 2)*Large-scale animatronics* designed for use in film and live performance settings. In the former case, the machines are products designed to operate autonomously as toys, pets, or therapeutic devices, whereas the latter machines are semi-autonomous and often rely on several human operators to tele-operate them from both within and without the machine body. Both types of robots are designed to interact with humans or to perform communicative behaviors which are typically modeled on human-to-human communication and human social behaviors. Because relational artifacts are conceived as sentimental objects on which humans project their feelings and emotions, they are evaluated almost exclusively in psychoanalytic terms where the machine's expressivity and responsiveness are judged by how well the robot promotes and sustains human interaction and substitutes as a proxy for human beings (Turkle 2006). The focus on human-computer interaction to design "sociable robots" encourages the engineers to make aesthetic and design choices that privilege lifelike imitation and mimicry. Similarly, large-scale animatronics are typically informed by representations of animals that are either modeled after real animals (such as dinosaurs or birds) or imaginative creatures that were originally conceived using digital animation (such as flying dragons). These machines are mostly evaluated according to lifelike imitation, or how closely they physically resemble their digital progenitors. As such, animal-inspired entertainment robots are caught in a design and control trap: the robots require more sophisticated motors and increasing levels of technology to reproduce the movements of the "real" figures on which they are based, but the increasing levels of technology make them more likely to fall into the kinematic Uncanny Valley where robots can communicate no truths other than mechanical ones. Furthermore, the increasing levels of technology further distance the human operators from the act of animation, making it difficult to develop intuitive models for controlling the figures in performance. If engineers wish to create animal-inspired robots that artfully and convincingly engage the human imagination, they must find new modes of representation that do not rely on mimicry-based approaches. Rather, engineers should turn their attention to creating dynamic and interactive movement. As with human-inspired robots, I propose that puppetry-based approaches will help cross the kinematic Uncanny Valley and produce animal-inspired robots that are more likely to provoke the intentional stance and evoke agency. Kinesis is the new mimesis.

To explain how puppeteers approach the task of representing animals, I use Deleuze and Guattari's concept of *becoming-animal* and Merleau-Ponty's notion of the phenomenal body. The concept of becoming-animal describes a process of identification or *copresence* of human and animal, and this concept is useful for understanding how puppetry's methods for simulating animal movement fundamentally differ from that of traditional animatronics. Citing the innovative hybridization of humans and puppets in the stage productions of Julie Taymor's *The Lion King* and Handspring Puppet Company's *War Horse*, I argue that puppetry offers a method of becoming-animal that is not rooted in mimicry, but rather emerges from the dialectic between the human operator and the puppet. In these instances, the hybrid figure can be read as a type of human-machine interaction, where, following Merleau-Ponty's theory of motility and body image, the human operator incorporates the technology of the puppet into his/her own body, and through this assimilation achieves an altered kinesthetic awareness of being in the world. The hybrid body forges a new body image based on the expanded tactile, kinesthetic, and visual inputs provided by the puppet, and this awareness promotes fluid and intuitive interaction between the human and the technological apparatus. The hybrid form provokes binocular vision, which impacts how these objects are perceived in performance.

Given the recent trend of adapting animated feature length films (which often feature animals or other non-human characters) for live performance—Dreamworks' Theatrical's *How To Train Your Dragon* and the forthcoming Global Creature's musical *King Kong* are two recent examples—I outline how the developers of animatronics might learn from puppetry to create more intuitive interfaces for operating and controlling robots that are more likely to be perceived as intentional systems.

ANIMAL-INSPIRED ROBOTS

The previous chapter considered the capabilities of human-inspired robots to emulate human behaviors and evoke agency. The question of agency and intentionality shifts when the figures designed to represent human experiences are designed in the shape of animals or non-humanoid forms. Literature, theatre, music, and film have established conceptual frameworks for using animals as proxies for human experience. This conceptual framework has implications for animal-inspired robots used in performance.[36] Our readiness to anthropomorphize objects—evidenced by our willingness to ascribe meaning and purpose to inanimate objects even when they are not deliberately anthropomorphic (Terada *et al.* 2007)—urges a different set of considerations for non-humanoid entertainment robots. While some researchers have argued that non-human entities that resemble human beings are often perceived as having more "mind" than those that do not (Wegner *et al.*), I suggest that in performance non-humanoid objects can more readily provoke the intentional stance than human-inspired objects. Whereas human-inspired robots tend to draw focus to the ways in which the object is *not* human, deliberately non-human objects create more room for imaginative play and more readily invite intentionality. As animal-inspired puppets on theatre stages have shown—from the flat leather puppets used to create dynamic shadow representations in Indonesian *Wayang Kulit* to the innovative use of rod puppets used in *The Lion King*—

[36] I am thinking of the Indian epic *Ramayana*, Aesop's *Fables*, Sergei Prokofiev's *Peter and the Wolf*, and Disney's *The Lion King*, although there are countless others.

spectators are prompted to place less value on physical likeness and more value on how the performing object moves and interact in the world.

However, because animal-inspired robots (and in particular those designed for entertainment) have been driven in large part by the desire to create what Sherry Turkle calls relational artifacts—inanimate objects that present themselves as having "states of mind" which enriches human encounters with them— animal robots often resemble crude imitations and sentimentalized projections of animals. Like human-inspired robots, animal-inspired robots rely on mimicry-based approach to achieve effective representations and fall in the same design-and-control trap that plagues human-inspired robots. Engineers are forced to make decisions about how realistic a thing looks and moves and how nimbly or expressively the object moves.[37] Forced to choose between dynamic behaviors (such as responsive facial gestures, speech, or locomotion) and stable and repeatable motions, engineers must choose between designing robots that are completely autonomous and have a limited set of gestures, or tele-operated robots that have more dynamic movement possibilities. The former robots might promote human interaction by giving varying "performances" based on the input obtained through sensing technologies (voice recognition software, gaze direction, etc.), but because of their limited range of motions these objects can appear dull or predictable. Relational objects such as the

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[37] The terms human-inspired and animal-inspired are meant to distinguish between the physical characteristics of the robots and animatronics I discuss. The term humanoid robot can often be misleading, as the sociable robot Leonardo developed by Stan Winston for the MIT Media Lab is considered a humanoid robotic but it does not physically resemble a human (Figure 11).

Paro Seal[38] (Figure 9) or the Sony Aibo (Figure 10) might prove entertaining in domestic settings or useful as therapeutic devices, but their limited range of motions prevent them from being compelling theatrical performers.

The use of large-scale, animal-inspired tele-operated robots, known as animatronics, have had a tremendous impact on the film and television industries (e.g. *Jurrassic Park*, *Star Wars*, and the BBC miniseries *Walking with the Dinosaurs*), and are more likely to be used in theatre and other live-performance settings than relational artifacts.[39] Adapting the size and scale of these puppets for the conditions of live performances presents many challenges. As the machines grow in mechanistic complexity, they become more difficult to control because of their size, weight, and the number of operators they require to operate them. Furthermore, the increasing levels of technology often result in control mechanisms that further distance the operators from the act of animation and make it difficult to develop intuitive control systems.

[38] The Paro Seal is a plush, therapeutic robot designed to interact with patients suffering from Alzheimer's and other forms of dementia, and the Sony Aibo was a consumer-priced robot modeled in the shape of a dog).

[39] The Oxford English Dictionary defines animatron as "a robotic model in the likeness of a human, animal, etc. which if programmed to perform intricate, lifelike movements, often in synchronization with a pre-recorded soundtrack." Animatrons differ from robots because they typically have no autonomous capabilities and entirely controlled by human operators or pre-programmed scripts.

Figure 9. The Paro Seal resembles a plush toy and is designed principally for therapeutic use.

Figure 10. The Sony AIBO can be considered an animal-inspired robot, but the physical attributes announce its machine status.

Figure 11. Despite its animal-like appearance, *Leonardo* is considered a humanoid robotic because it is designed for traditional social interactions based on human communication strategies.

The technical and commercial success of animatronics in film and television has prompted the developers of these technologies to experiment with using animatronics in live stage productions. Creature Technology Company (founded by Sonny Tilders who designed and built animatronics for feature films such as *Peter Pan*, *Chronicles of Narnia*, and *Star Wars, Revenge of the Sith*) adapted the dinosaurs developed for the BBC television series *Walking With The Dinosaurs* for use in live performance. *Walking with the Dinosaurs Arena Spectacular* (*WWTD*) premiered in Melbourne in 2007, and subsequently has toured 206 cities across the Australia, North America, Europe, and Asia and attracted audiences of more than 7 million people (AKA 2013). The production uses a combination of animatronics, remote-controlled puppets and marionettes, and live human actors in costumes to stage over twenty different species of dinosaurs. Building on the success of this spectacle-driven production, Global Creatures (the parent company of Creature Technology Company) collaborated with DreamWorks Theatrical to produce a stage adaptation of the animated film *How To Train Your Dragon* (*HTTYD*). The production originated in Australia in 2012 and has just completed a tour of North America. Finally, Global Creature's musical stage adaptation of *King Kong* based on the 1933 feature film, is scheduled to preview May 2013. Global Creatures has emerged as a leader in the production of large-scale animatronics, and the forthcoming production marks a shift away from arena spectacles and more firmly in the direction of live theatre. While some academics and theatre artists loath to permit them entrance, animatronics are no longer limited to theme parks or Madame Tussaud museums. Automated and tele-operated presences are taking their place alongside human actors in stage musicals and live performances, shaping our conception of live entertainment, and raising important questions about embodiment and agency of technological actors and a machine's ability to generate a performance or work of art. Autonomous and semi-autonomous machines not only warrant our attention, but also invite scholarly investigation of their methods of representation.

The use of animatronics in contemporary productions reifies the important connection between traditional puppetry and engineering technologies. Global Creatures develops their shows together with puppeteers, and for the past several years Victoria College for the Arts in Melbourne has been host to the National Puppetry and Animatronics Summit. Recognizing the synergies between these two fields, the summit brings together artists and engineers to discuss methods of animation and to debate issues concerning machines in performance. The summit proceedings are not published, but I have corresponded with some of the summit directors and participants, including Peter Wilson (puppetry consultant on *HTTYD* and director of puppetry for the forthcoming *King Kong*), Annie Forbes (Terrapin Puppet Theatre), and Philip Millar (Global Creatures engineer). These artists all spoke to the profound relationship between puppetry and animatronics, and the summit's continued success indicates that the fields of engineering and puppetry have much to learn from one another.

To demonstrate how a puppeteer's approach to the task of recreating animal movement fundamentally differs from that of traditional animatronics, I focus on two landmark productions that are credited with re-introducing puppetry to popular theatre audiences: Disney's stage adaption of the animated feature film *The Lion King* (1997), and the National Theatre's adaptation of Michael Morpurgo's novel *War Horse* (2007). The artful approach to creating and animating animal-inspired puppets by Julie Taymor (*The Lion King*) and Basil Jones and Adrian Kohler of Handspring Puppet Company (*War Horse*) can be read against the approach for automating animatronics in *WWTD* and *HTTYD* that focus primarily on mechanical reproduction of animal motions and behaviors. Although both productions feature hybrid bodies that combine human actors with the technology of the puppet, Taymor and Handspring represent two wholly different aesthetic styles. Representations of animal characters are not rooted in precise mimicry, but rather in the principles of abstraction, stylization and control which approximate Deleuze and Guattari's conception of becoming-animal and Maurice Merleau-Ponty's notion of the phenomenal body. The hybrid figures constitute a type of human-machine interaction, where human operators incorporate the technology of the puppet into their own bodies, and through this assimilation achieve an altered kinesthetic awareness. The actor's assimilation of technology approximates Merleau-Ponty's conception of the phenomenal body, which locates the body as the site for the primary knowing and experiencing the world. The hybrid figures are also constitutive of "cyborg theatre" as defined by new media scholar Gabriella Giannachi.[40] The human-puppet hybrid body forces the human performer to

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[40]In *Virtual Theatres*, Giannachi defines cyborg theatre as "primarily concerned with the modification and augmentation of the human, yet it is also about the enmeshing of the human with the environment, whether in the 'real' world or in the simulated world of the World Wide Web." Drawing on Donna Haraway's 1985 *Cyborg* Manifesto, which posits that Cyborgs, as creatures of

acquire a new body image based on expanded tactile, kinesthetic, and visual inputs. This arrangement promotes fluid and intuitive interaction between the human and the technological apparatus, and can function as a model for designing more intuitive control mechanisms for animatronics.

BECOMING-ANIMAL

I have already demonstrated how the history of automata—from the classical mechanical theatres constructed by Heron through present-day animatronics—embody the lineage of automation technologies from pneumatic and hydraulic powered systems to the mechanically-driven motions and electronic technologies. Technological developments enabled automata to evolve from passive agents capable only of mechanically reproducing imitative behaviors to situated devices able move and interact in the world and exhibit a wider range of gestures and expressions. The mechanistic lineage of animal-inspired automata and robots parallels that of human-inspired machines. Animal-inspired figures designed to abstract and represent the human experience present a different set of problems than humanoid

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fiction and social reality, are able to "bridge the gap between the real and representation, between social reality and fiction" (46), Giannachi connects liminal figures of the cyborg and the automaton, tracing cybernetics scholar Norbert Weiner's conception of the history of automata as responses to the specific concepts of the body in relation to machines. According to Giannachi, cyborgs, robots, and automata are examples of complex figures that provoke and shape our relationship with technology. While this concept lies beyond the scope of the given study, which focuses on the aesthetics of autonomous machines, I am aware of the connections between this study and Giannachi's work and am interested in developing this research further.

robots—how to best design non-humanoid objects that evoke both human and animal characteristics and provoke identification. Whether or not these performing objects are designed to realistically resemble animals, the quality of movement is essential in creating compelling mimetic creatures. How automata and robots move and operate in the physical world determines how successfully they can create illusions of liveness and provoke the intentional stance. To understand this process, we must first consider the relationship between human beings and animals, and how anthropomorphic tendencies have changed together with the rise of modernism and technological developments.

In Chapter Two I briefly mentioned de Solla Price's essay *Automata and the Origins of Mechanism* which considers the creation of human and animal-inspired automata in relation to the history of technology and the origins of mechanistic philosophy. The author cites several examples of classical, Renaissance, and Enlightenment-era automata in the shape of animals: astronomical representations found in Egyptian tombs, Heron of Alexandria's singing birds, Islamic water clocks constructed between 800AD to 1350AD, and the first "monumental astronomical clock" constructed for the cathedral in Strasbourg which featured an automation of a bird figure where "the complicated arrangement of strings and levers became a reasonable simulacrum for the musculature and skeleton of a real bird" (18). While the development of automata in general prompted philosophical consideration of consciousness (mechanism versus vitalism, abstract versus concrete movement), animal-inspired automata provoked this question more readily as philosophers and theologians debated the existence of the soul, and what (if anything) divided the human being from the animal. De Solla Price locates this mechanistic philosophy/rationality split by reading Thomas Aquinas' treaty on theology alongside animal-inspired automata from the thirteenth century:

> […] St. Thomas Aquinas, stated emphatically in his *Summa Theologica* (Qu. 13, Art. 2, Reply obj. 3, Pt. II) that animals show regular and orderly behavior and must therefore be regarded as machines, distinct from man who has been endowed with a rational soul and therefore acts by reasons. Surely, such a near-Cartesian concept could only become possible and convincing when the art of automaton-making had reached the point where it was felt that all orderly movement could be reproduced, in principle at least, by a sufficiently complex machine. It is remarkable that at this very time the figures of apes became popular as automata—they had been used *inter alia* by the Islamic clockmakers—by being endowed with an appearance similar to that of man but behaving as a "beast-machine." This is probably the line that led to such literary and philosophical devices as the Yahoos of Jonathon Swift, beasts shaped like men but without rationality; it is also the line that made philosophically important the emergent possibility of exhibiting mechanically many manifestations of apparent rationality. (19)

The urge toward mechanistic explanations of biology continued with Descartes' attempt to explain bodily and neural mechanisms in *Treatise on Man* (1663), and Julien Offray de la Mettrie's similar attempts in *L'Homme Machine* (1748). These two works sought to define human behavior and biology within the framework of machines, and it is no coincidence that these essays were synchronous with the development of the humanoid automata of Vaucanson and Jacquet-Droz discussed in the previous chapters. One of the most popular automata of the period was Vaucanson's duck automata, which through a combination of mechanism and clever trickery created an illusion to mimic the anatomical functions of ingestion, digestion, and defecation (Mazlish 179). As de Solla Price suggests, animal-inspired automata played a crucial role in the development of complex mechanisms that simulated and reproduced lifelike motions, and also functioned to distinguish human behaviors and motions from that of animals.

Attempts to simulate and mimic the mechanistic properties of animal movement continued during the modern period, and resulted in profound shifts in how animals were conceived philosophically and aesthetically in cultural and industrial landscapes. Akira Mizuta Lippit traces the definition of the term *anthropomorphism* in the modern period, suggesting that humanity's relationship with animals and our tendency to anthropomorphize objects shifted with the rise of modernism. Lippit's assessment is central to understanding relational artifacts and Delueze and Guattari's concept of *becoming animal*, and is worth quoting at length:

The Oxford English Dictionary places the first known use of the word *anthropomorphism* with the meaning "attribution of human traits to animals" in the second half of the nineteenth century. (Until this referential shift, the word was used to indicate mistaken attributions of human qualities to deities). It was during the nineteenth century, with the rise of modernism in literature and art, that animals came to occupy the thoughts of a culture in transition. As they disappeared, animals became increasingly the subjects of a nostalgic curiosity. When horse-drawn carriages gave way to steam engines, plaster horses were mounted upon tramcar fronts in an effort to simulate continuity with the older, animal-powered vehicles. Once considered a metonymy of nature, animals came to be seen as emblems of the new, industrial movement. Animals appeared to merge with the new technological bodies that were replacing them. The idioms and histories of numerous technological innovations, from the steam engine to quantum mechanics, bear the traces of an incorporated animality. James Watt and later Henry Ford, Thomas Edison, Alexander Graham Bell, Walt Disney, and Erwin Schrödinger, among other key figures who contributed to the industrial and aesthetic shifts of the late nineteenth and early twentieth centuries, found uses for animal spirits in developing their respective machines, creating in the process a fantastic series of hybrids. Cinema, communication, transportation, and electricity

> drew from the actual and phantasmatic [sic] resources of dead animals. Technology, and more precisely, the technological instruments and media of that time, began to serve as virtual shelters for displaced animals. In this manner, technology and ultimately the cinema came to determine a vast mausoleum for animal being. (124-125)

In chapter three I briefly mentioned Walt Disney's 1940 animated feature film *Fantasia* in relationship to Depero's automated mechanical theatre, suggesting that Depero's vision of metamorphosing actors and transforming landscapes anticipated spectacle-driven theatre productions which are based on animated feature films of the late twentieth and early twenty first centuries. For Depero, puppetry was the inspiration that caused him to imagine these worlds, but it also provided the means for exploring how animated worlds might be bodied forth on the live stage. During the twentieth century, animation and film proved to be an artistic playground for generating images of animals and other anthropomorphic creatures. This "incorporated animality" included the generation of fantastical hybrid creates that combined elements of the animal world with human stories and psychology. Disney animated films are examples of fantastical animal hybrids—in animation, animal characters served as proxies for human characters, and like Aesop's fables, their stories are not animal stories but human ones.[41] This mode of representation

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[41] When asked to distinguish his work with puppets from Aesop's Fables and Disney animations, puppeteer Adrian Kohler says "I suppose the thing about Aesop's Fables, or Mickey Mouse, is that

continues to the present day and informs the current generation of animated films, although at present there are far more players in the commercial film industry: DreamWorks Animation, Pixar, and LucasFilm Animation are just a few of the hundreds of animation studios that develop and generate content for television, film, and video gaming.

The opening of Disneyland in 1955 presented the challenge to develop methods for bringing the animal-inspired characters to life. Thus began the process which Rebecca-Anne Do Rozario has called "Reanimating the Animated"—be which she means the adaptation of character/animal hybrids originally conceived in two dimensional environments to the three dimensional stage in theatre performance. (Do Rozario 2004). While Do Rozario is chiefly concerned with the adaption of animated films to stage (of which more later), it is important not to overlook the role of early animatronics in the adaption of animated characters into situated and embodied agents. In an effort to simulate and automate the motions of characters originally conceived in animated environments (an extraordinarily difficult task given that many of these stories involve the metamorphosis of animals into humans), Disney engineers adopted then-contemporary technologies of industrial robots for use in rides and installations (*Life* 1967), and created a research department devoted entirely to that purpose: audio-animatronics (Malmberg 2010). I contend that Disney's efforts to represent animals through mechanical

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they're really people. They're not real animals; they simply use the shape of the animal to add some kind of texture to what is basically a human argument. Whereas working with the horses in War Horse has meant that we've got to learn how horses think, how horses are different from humans" (*The Magical Life of Objects*, 2011, 13). I maintain that although they are anthropomorphic, these figures constitute representations of animals, and are no more or less "real" than the simulacra of a puppet horse. Both rely on imaginative processes of the spectator to complete the becoming-animal.

reproduction (animatronics) predisposed scholars to dismiss future representations of animals as crude imitations not worthy of scholarly consideration. This bias has perhaps contributed to the reluctance to consider animatronics as compelling theatrical devices. Efforts by Disney, Dreamworks Theatrical, and other production companies to create animal-inspired figures on stage through traditional puppetry and animatronics invites the opportunity to consider how artists have moved beyond purely mechanical reproduction to create more dynamic representations of animals.

Despite Disney's influence in shaping our aesthetic experience of animals for nearly one hundred years,[42] the numerous "fantastic hybrids" realized through the various media of film, animatronics, and puppetry have largely been dismissed by critical scholarship on the grounds that these simulacra are sentimental, fictionalized representations and do not constitute meaningful representations of animals. The narratives of Disney animated films, which are rooted in fairy tales and mythology, have drawn much ideological criticism based on their representations of gender, race, and ethnicity. When Disney Theatrical ventured beyond theme parks to perform in more established theatre settings (first in 1994 with the adaptation of *Beauty and the Beast* and in 1997 with *The Lion King*), scholarly consideration of these productions focused not on the artistic contributions but rather on the commodification of culture and critiques of mass consumption and capitalism (Budd and Kirsch 2005). With few exceptions, these theatrical productions failed to generate any critical discourse concerning their aesthetics or

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[42] Disney Brothers Cartoon Studio, the forerunner to Walt Disney Animation Studios, was founded in 1923 (Wells 1998).

methods of representation. Such omission misses an opportunity to engage with the topic of mimesis and representation of animals onstage, and perpetuates the disciplinary bias against certain artistic works based on their methods of production. Just as historians of technology have been reticent to assign significance to ingenious mechanical devices of antiquity on the basis that they are nothing more than frivolous toys (de Solla Price), theatre scholarship risks overlooking the important contributions that these productions make to shaping an aesthetics of animals and technology on stage.

Paul Wells writes about choreographic principles in animation, noting in the dynamics of movement a narrative strategy that is directly connected to theatrical staging and dance. Because animation prioritizes movement (that is, beyond the restrictions of character), "narrative is often played out purely through the movement of the body as it is represented in the animated film" (Wells 112). Given the importance of movement, one would expect that movement would play a central role in the adaption of animated films to the live stage. While this is true of the characters for the stage adaptation of *The Lion King* and *War Horse*, it is less true for productions that feature animatronics where the focus is overwhelming on mimetic, rather than kinetic, strategies. The representations of animals in *The Lion King* and *War Horse* offer an interesting perspective into the Deleuzean notion of becoming-animal, and the hybrid bodies of the human/puppets prompt consideration of the phenomenal body. In these instances, puppetry merges the body of the performer with technological apparatus to create a representation or image of an animal. The result is a liminal creature that exists somewhere between species and between animate-ness and inanimate-ness. Like the Futurist and Bauhaus mechanical costumes, these figures are related to puppets, robots, and cyborgs, and shape our notions of agency, hybridity, and copresence. The puppet is the intermodal experience that models our experience of other forms of technology and prosthetics merging with the living human body.

Before continuing, it is important to understand exactly what Deleuze and Guattari mean by becoming-animal, how this post-structuralist concept has functioned as a philosophical tool for understanding representations of the animal in literary and cultural theory. The term was first introduced in the study *Kafka: Toward a Minor Literature*, and is discussed in further detail in *A Thousand Plateaus: Capitalism and Schizophrenia.* Deleuze (a philosopher) and Guattari (a psychoanalyst), cite instances of literary texts, music, modernist painting, and even B movies as examples of how artists ("sorcerers") create states of identity suspension in their works. The concept of becoming-animal posits that human and animals enter into a process of identification or *copresence* with one another. This concept is useful for understanding how a puppeteer's approach to the task of recreating animal movement fundamentally differs from that of traditional animatronics. For Deleuze and Guattari, becoming-animal (which the authors insist does not result in a subject but rather a state of being) culminates in the formation of a *rhizome*, or image of thought, where one is able to contemplate the multiple identities of animal and the human. This concept continues to impact contemporary art practice and theory: "Deleuze and Guattari's concept of becoming-animal (*devenir-animal*) holds a special place in tying any creative reimagining of the human so closely to that of the animal. The real radicalism of the concept lies not in its reframing of the question of living subjects and their identities, but rather in its charting the possibilities for experiencing an uncompromising sweeping-away of identities" (Baker 68). We can understand becoming animal as processes of identity suspension marked by gestures towards the "other than human." For Deleuze and Guattari, the animal is aligned with creativity, and notes the shift away from the "traditional use of animals as little more than remote ciphers for human meanings" towards new complex assemblages that suggest the question of interrelatedness of animals (Baker 68). If we permit de Solla Price's conception of animal-inspired automata as "tangible manifestation of the triumph of rational, mechanistic explanation over those of the vitalists and the theologians" (de Solla Price 10), then we might read becoming-animal as a recuperating of the animistic principles of vitalism or the Bergsonian *élan vital.*[43] In other words, becoming-animal involves something more than mechanical reproduction or precise mimicry, but an effort to uncover the essence of the animal and to enter into negotiation with that essence. I propose this was precisely the investigative notion that undergirded experiments at the Bauhaus and Schlemmer's recuperation of "that which can *not* be mechanized" (Gropius 18).

Although Deleuze and Guattari are primarily interested in deconstructing notions of identity, their concept of becoming-animal can be understood in terms of an aesthetic project grounded not in the imitation of animals, but rather in

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[43] See discussion of Georg Stahl's "Theoria medica vera" (1707) and Henri Bergson's "Creative Evolution" (1907) (Porter 2003).

exploring moments where the human and the animal enter jointly into the composition of the other. Using literature, music, and painting as reference points (the authors cite *Moby Dick* as the becoming-animal *par excellence*), the authors define becomings-animal almost exclusively in terms of kinetic movement and perception. While the essay meditates on a wide range of becomings (*becoming-animal*, *becoming-woman*, *becoming-child*) their primary effort is to refute the psychoanalytic tradition of reading human-animal relationships and assemblages in Oedipal terms, focusing instead on the act of becoming-animal as the "relations of movement and rest, speed and slowness, emitted between particles" (303). For the authors, becoming-animal does not happen through imitation or identification with an animal (as is the case with Turkle's relational artifacts), but is instead a process of negotiation that occurs at a molecular level:

> Starting from the form one has, the subject one is, the organs one has, or the function one fulfills, becoming is to extract particles between which one establishes the relations of movement and rest, speed and slowness, that are *closest* to what one is becoming, and through which one becomes. This is the sense in which becoming is the process of desire. This principle of proximity or approximation is entirely particular and reintroduces no analogy whatsoever. It indicates as rigorously as possible a zone of proximity or *copresence* of a particle, the movement into which any particle that enters that zone is drawn. (300)

> That is the essential point for us: you become animal only if, by whatever means or elements, you emit corpuscles that enter the relation of movement and rest of the animal particles, or what amounts to the same thing, that enter the zone of proximity of the animal molecule. You become animal only molecularly. (303)

When the human and animal enter into *copresence*, the result is not a subject (there is only becoming) but rather the formation of a *rhizome*, or image of thought, where one is able to contemplate multiplicities and assemblages, a "block of becoming."[44] The authors are interested in the process of becoming-animal and identity suspension and not necessarily in representations or imitations of animals. To clarify this distinction, they use the example of the tarantella dance, which given the dance's prominence in theatre scholarship seems particular apt:[45]

> The tarantella is a strange dance that magically cures or exorcises the supposed victims of a tarantula bite. But when the victim does this dance, can he or she be said to be imitating the spider, to be identifying with it, even in an identification through an "archetypal"

[44] "For if becoming animal does not consist in playing animal or imitating an animal, it is clear that the human being does not really become an animal any more than the animal "really" becomes something else. Becoming produces nothing other than itself. We fall into a false alternative if we say that you either imitate or you are" (262).

[45] The depiction of the tarantella dance in Henrik Ibsen's *A Doll's House* has been the subject of much scholarly analysis.

> or "agonistic" struggle? No, because the victims, the patient, the person who is sick, becomes a dancing spider only to the extent that the spider itself is supposed to become a pure silhouette, pure color and pure sound to which the person dances. One does not imitate; one constitutes a block of becoming. Imitation enters in only as an adjustment of the block, like a finishing touch, a wink, a signature. But everything of importance happens elsewhere: in the becoming spider of the dance, which occurs on the condition that the spider itself becomes sound and color, orchestra and painting. (336)

The concept of becoming-animal is chiefly considered with the processes of identity suspension of the human being, and not necessarily with how animals are imagined or represented by humans. However, because becoming-animal is a process wherein the human body enters into negotiation with the animal so the human identity is temporarily suspended, the liminal quality of this interaction (which for Deleuze and Guattari is motivated through movement) approximates the process of becoming in puppetry. Becoming-animal is a process of mutual identification, and while it is not the goal, mimesis is a central aspect of this process.

Puppetry embodies a similar process of becoming: the human operator enters into negotiation with an inanimate object through movement, with the desire to animate the object and bring forth a *certain kind of life*. In this process, the puppeteer subsumes her ego in order to assume the properties of the puppet, similar to the way a dancer of the tarantella subsumes her ego in becoming-spider. As with the dance, this negotiation happens principally through movement. It is this process, which we might call *becoming-puppet*, which enabled Kleist to see in the marionette the emergence of a soul. When the puppeteer places "himself in the center of gravity of the marionette" (Kleist 23) and learns to yield himself to the motions and momentum of the puppet, we might say that the puppet and operator have established a *copresence*. Seen this way, we recognize immediately that the question is not whether theatrical productions that stage animal-inspired characters constitute legitimate instances of becoming-animal in the strictest Deleuzean sense (although this would be an interesting point to consider further). Rather, we can use the concept of becoming-animal to understand how the puppeteer animates life differently than purely automated figures. In other words, we can use puppetry as a model for reconciling the mechanistic and animistic principles tendencies with regards to automated motion and animal-inspired robots. From this, engineers might develop animal-inspired animatronics that are more expressive and responsive and provoke the intentional stance.

Deleuze and Guattari's concept of becoming-animal can be understood in relation to Merleau-Ponty's notion of the phenomenal body: while becoming-animal is a mode of identity suspension, it hinges on the interaction with another body, the animal "silhouette" that merges with the corporal body of the human. For Merleau-Ponty, consciousness arises through movement and the phenomenal experience of the body: "not a matter of 'I think that' but of 'I can'" (137). It is through the experience of the body through movement, he claims, that we ultimate come to know and inhabit the world: "Our bodily experience of movement is not a particular case of knowledge; it provides us with a way of access to the world and the object…My body has its world, or understands its world, without having to make use of my 'symbolic' or 'objectifying function'" (140). Merleau-Ponty challenges mechanistic theories of the body by arguing that motility—which can be defined as the mental image of the body in space formed not through visual or aural perception but from the physical sensations of bodily movement— is the foundation of intentionality and consciousness (137). Motility is not "a handmaid of consciousness, transporting the body to that point in space of which we have formed a representation beforehand," (139), but rather, consciousness is how the body inhabits time and space, and "the cultivation of habit" is the "rearrangement and renewal of the body image" given our physical experience of the body in the world.

> The body is our general medium for having a world. Sometimes it is restricted to the actions necessary for the conservation of life, and accordingly it posits around us a biological world; at other times, elaborating upon these primary actions and moving from their literal to a figurative meaning, it manifests through them a core of new significance: this is true of motor habits such as dancing. Sometimes, finally, the meaning aimed at cannot be achieved by the body's natural means; it must then build itself an instrument, and it projects thereby around itself a cultural world. At all levels it performs the same function which is to endow the instantaneous expressions of spontaneity with "a little renewable action and

> independent existence." Habit is merely a form of this fundamental power. We say the body has understood and habit has been cultivated when it has absorbed a new meaning, and assimilated a fresh core of significance. (146)

For Merleau-Ponty, the body image is the means through which humans arrive at a total awareness of their posture and movement in the "intersensory world," it is a "way of stating that my body is in the world," (101) and this image brings together the tactile, kinesthetic, and visuals contents of the body and the surrounding space into a unified field of awareness. The significance of Merleau-Ponty's phenomenal body to the present study is how a human adopts instruments or technological apparatus to expand their awareness and experience of the physical world (i.e. "when the meaning aimed at cannot be achieved by the body's natural means"). The most well-known example of this phenomenon is the blind man's stick, which the man adopts as a prosthetic tool for knowing the world in a way that he could not otherwise. The man quickly learns to grasp the motor significance of the stick, and the stick becomes a part of his motility:

> The blind man's stick has ceased to be an object for him, and is no longer perceived for itself; its point has become an area of sensitivity, extending the scope and active radius of touch, and providing a parallel to sight. In the exploration of things, the length of the stick does not enter expressly as a middle term: the blind man is rather

> aware of it through the position of objects than the position of objects through it. The position of things is immediately given through the extent of the reach which carries him to it, which comprises besides the arm's own reach the stick's range of action. (143)

Merleau-Ponty's concept of the phenomenal body and its emphasis on being-in-the-world "cleared the path for a new application of the term 'embodiment' as it is used today in cultural anthropology, cognitive science, and theatre studies" (Fischer-Lichte 83). The philosophical notion of the embodied experience has been used to interpret the use of digital technologies in contemporary performance,[46] but it is also a useful framework for identifying the phenomenological aspects of puppetry and becomings-animal.

To represent animals onstage, a puppeteer uncovers the essential movements and characteristics of the animal, and creates technological tools that render these motions by extending the scope, radius, and quality of the human-centered movements. The puppeteer learns to use prosthetics as expressive tools, and, like the blind man's stick or the restrictive Futurists and Bauhaus costumes, the prosthetics alter the motility of the performer and his/her embodied experience of the world. The technology influences the performer's experience in the world on a kinesthetic level, forcing the human into a closer alliance with the essence or "silhouette" of the animal. This process is what enables animal-inspired puppets to

[46] See Broadhurst 2012.

transcend mere imitation and instead constitute a type of becoming. Typically, the design and control mechanisms for animatronics have prohibited this type of negotiation between puppeteer and puppet (the Deleuzean "block of becoming"). Animatronics are stuck in a mimetic trap, and fall into what Deleuze and Guattari call the "false alternative" which says "that you either imitate or you are" (263). This may partially explain why it is so difficult for animal-inspired robots to stimulate the spectator's imagination and evoke agency.

While I recognize that the staging of animals *The Lion King* and *War Horse* are primarily concerned with mimetic representations of animals and the mapping of human stories onto animal characters, I believe that the formal aspects of these productions suggest an aesthetics that is rooted in kinetic (and not mimetic) behaviors. The resulting representations are less precise than mechanical reproductions of animatronics, and yet more complex than an actor in an animal suit. The hybrid figures occupy a liminal space wherein we might uncover significant processes of creating believable and compelling simulations of animals on stage. I do not suggest that a stage adaption of Disney's *The Lion King* opens up new perspectives on what it means to be an animal in the African savannah, but *War Horse* does shift the subject of performance to the animal, furthering the perspective developed in the novel which urges the spectator to adopt a critical stance from the perspective of the animal. I believe that it is premature to dismiss these representations as "crude imitations" simply because they are modeled on animated feature films, or because animal characters are employed to tell human stories. Reluctance to acknowledge these live stage productions that bring the human, the animal, and the technological into relationship reflects the value-ridden judgments that often color critical studies of commercially successful and spectacle-driven productions.

The Lion King and *War Horse* utilize the techniques of traditional puppetry to animate animal characters; the animal character emerges from composite assemblages that rely on physical alliances between human operators and the puppets. Rather than masking the control system or occluding the body of the human performer, these productions foreground the human-animal hybrid by exposing the control mechanisms and avoid mimicry-based approaches in favor of abstract design. In both productions, the movements of the puppeteers are tightly coupled to those of the puppets. In Deleuze and Guattari's terms, these becomings-animal are not imitative but rather emerge from the human effort to negotiate with the puppet through movement. The technology of the puppet effects the movement and kinetic behaviors of the actor, forcing them to move in anti-naturalistic and anti-imitative ways and creating a *rhizome*, or block of becoming, from which an image of the animal emerges.

The relationship between animal and human is negotiated through the prosthetics/technology of the puppet, and puppetry can be a tool for the "imaginative and metaphoric integration" that allows for "reciprocal response strategies" which Parker-Starbuck identifies with cyborgean performance. This alliance is facilitated by technologies which, like the blind man's stick, expand the actor's kinesthetic awareness and force them into a physical negotiation with the puppet: in *The Lion King*, the actors' bodies merge with the puppets to form the literal silhouette of the animal bodies, and in *War Horse* puppeteers don harnesses to control the movements from inside the puppet, powering horse-leg motions with their human legs. This technological configuration promotes the process of becoming-animal by affecting the movement of the actor, affecting the subjective experience of the actor and the spectator's perception of the representation. Actor puppeteer Finn Caldwell, who played the role of the horse Topthorn's "heart" in the original production of *War Horse* describes the experience thus:

> The first three puppeteers are in the horse. The fourth puppeteer is the actor that's playing with it, and that doubles the reality of the horse. When someone's treating you like a horse, your conscious mind goes away, you just start being animal. And that's made much more apparent by the fact that when you're puppeteering, you're looking at the puppet, so it's much more difficult to be aware of other actors around you. (Millar, M. 96)

The identity suspension which Caldwell describes appears directly linked with the physical act of animating the puppet from within. Although puppetry may use imitation as a starting point, the animal character does not result from the actor's mimetic efforts to "play a horse," rather the character of the horse emerges entirely through movement (which stands in contrast to relational artifacts which try to emulate human psychology). In *War Horse*, each puppet requires a team of three operators to operate it (one as the heart, one as the hind, and one outside the puppet directing the head and neck). The puppeteers must work collectively to find a vocabulary of movement that communicates the essential characteristics and idiosyncratic traits for each animal character, which are communicated entirely through movement.

In the next section, I describe in detail how puppeteers engage in processes of becoming-animal in their representation of animal characters, and discuss three essential characteristics that might be applied to the design and control of animal-inspired robots. These processes are anti-illusionistic (because of the processes of binocular vision discussed in the earlier chapters), and the representation of animals is not rooted in mimicry or precise mechanical reproduction but arises from the physical interactions between actor and object, puppeteer and puppet, human and technology, to create another type of representation—or *a different kind of life*. Deleuze and Guattari: "For if becoming animal does not consist in playing animal or imitating an animal, it is clear that the human being does not 'really' become an animal any more that the animal 'really' becomes anything else. Becoming produces nothing other than itself." In the active negotiation between puppeteer and puppet, there is only the state of becoming. In puppetry, the representation of animals is not tied to anatomically correct figures that precisely reproduce motions but rather emerges from the animating force of the human operator breathing life into the puppet.

A TALE OF TWO PUPPETS

In any puppet, the movement must be more persuasive than the form.

-Mervyn Millar

This section presents a discussion of two works of fiction adapted for the live stage that use puppetry to bring fictionalized, animal-inspired characters to life. Theatre history provides numerous theatrical forms and performances of becomings-animals that we might choose from. I focus on Disney's adaptation of the animated feature film *The Lion King* and the National Theatre's adaptation of Michael Morpurgo's novel *War Horse* because the physical scale of the productions and their viability as global touring productions seem most relevant to the study of animatronics in live performance. Both productions rely on traditional and innovative forms of puppetry such as Malian *bamana* puppets, Japanese *bunraku*, shadow puppetry, glove puppetry, and rod puppetry to create animal-inspired characters. Although both productions are rooted in the principles of abstraction and stylization, they demonstrate different aesthetic orientation—Taymor's designs foreground the hybridity of the human/animal cyborg, while the *War Horse* puppets resist the aesthetic merging of puppeteer and puppet by clothing puppeteers as human characters in period costumes. Despite their different aesthetic approaches, both productions visually foreground the act of animation by exposing "the mechanics"—or the act of animation— and the success of these representations hinges on the puppeteer's ability to capture the essential movements and kinetic behaviors of the animal. While these motions are rooted in mimesis, they are not generated through pure mechanical reproduction but are achieved by locating motions that approximate and highlight the essential characteristics of the animal. Finally, in both productions the control mechanisms for the puppet are tightly coupled to the body of the human performer (as opposed to the indirect control mechanism used for marionette choreography), forcing the puppeteer to incorporate the technology of the puppet and forge a new kinesthetic awareness based on the expanded tactile and visual inputs the puppet provides. This awareness promotes fluid and intuitive interaction between the human and the apparatus.

Disney 1997 stage adaptation of *The Lion King* is based on the 1994 animated feature film which tells the coming-of-age story of Simba, a lion who struggles to find his place in the world after the murder of his father. Despite the weighty themes, the story is interspersed with levity and slapstick comedy a features many upbeat choral numbers. Julie Taymor directed the production and together with Michael Curry designed masks and puppets to give stage life to the animated characters. The stage production departs slightly from the film: South African composer Lebohang Morake contributed musical arrangements (including lyrics in Swahili) to Elton John's and Tim Rice's score, new scenes were added for character development, and the gender of one of the leading roles was switched in an effort to strengthen the female presence in the play. Since its premiere, the musical has solidified its place as one of the most popular stage musicals in the world: the show has been translated into five languages (Japanese, German, Korean, French, Dutch), and has been performed in thirteen countries on five continents (Cerniglia and Lynch 3).

Although the production has undergone some changes to suit local customs and traditions, the use of puppetry and choreography is largely consistent across productions. Taymor's written accounts of the production's development (Taymor 1997; Schechner 1999) provide valuable insight to the design process and her unique aesthetic approach. Taymor's concept of the "double-event"— where the spectator simultaneously perceives the story that is being told and *how* the story is being told—is vital to understanding how a puppeteer imagines and generates expressive choreography to create illusions of life on stage. It is not dissimilar from States' conception of binocular vision, and Taymor's commitment to "exposing the mechanics" makes a strong case for acknowledging binocular vision in productions that feature inanimate objects posed to simulate life.

War Horse is a stage adaptation based on the children's book of the same name by Michael Morpurgo which tells the story of the First World War as seen through the eyes of a horse, Joey, and his friendship with his human owner, Albert. Joey is sold from the family farm in Devon to serve on the front lines as a British Calvary Horse. Although the story is populated by human characters, there is no mistaking Morpurgo's goal of depicting the atrocities of war from the animal's neutral perspective. Joey is unquestionably the play's protagonist, and his journey gives a "horse's eye view" of the suffering and violence of WWI: over the course of the play Joey is captured by the Germans, used to pull ambulances, and guns, and convalesces on a French farm during winter. In the play, we observe Joey as foal, animated by three actor/puppeteers who operate the horse puppet externally in the *bunraku* style, through his growth into a slightly larger-than-life-size horse operated in a new configuration of three puppeteers (two within the puppet, one without).

The play was developed at England's Royal National Theatre and premiered in 2007. Directed by Marianne Elliott and Tom Morris, the National Theatre commissioned South African puppeteers Basil Jones and Adrian Kohler of Handspring Puppet Company to develop the horses and other animal puppets used in the production. Handspring's approach to puppet motion are well documented (Jones and Kohler 2011; Millar 2006 and 2007) and these accounts are central to understanding the process of creation and generations of animal movements. Like Taymor, Millar documents the production's development from initial design stages through multiple development workshops, providing insight into approach to generating puppet motion.

Equally important to understanding Handspring's aesthetic approach is Basil Jones' essay on puppetry and authorship (in Taylor 2010) which challenges the established hierarchy between the written text and the sensory experiences created by the performances. Jones asserts that the "authorial process of a play is of a multi-generational semiotic system with numerous authors, and including the authority of the audience," (260) and considers the unique phenomenological experience of the audience in productions that feature puppets and performing objects. Although speaking of puppetry, Jones' concept of the spectator's authorial role is essentially a restatement of Shklovsky's acknowledgment of the pivotal role of the observer/spectator in the work of art, and an elaboration of States' conception of art as “a certain perspective on a subject.” Jones’ acknowledgment of the authorial role of the spectator affirms Fischer-Lichte’s model of theatre performance as an autopoietic feedback loop. Irrespective of how we choose to name it, these conceptions all point toward a general understanding of the unique phenomenological experience that undergirds theatre performance in general, and the act of animating inanimate objects in particular.

From the written accounts of their artistic and authorial processes, we come to understand that for these puppeteers all aesthetic and practical decisions are informed by consideration of the phenomenological experience of the audience. They each begin with the question, “How will the audience experience the objects in performance?” and the design and control mechanisms grow from this understanding. For Taymor and Handspring, decisions regarding how thoroughly to expose the mechanics or mask the illusion (or rather which mechanics to mask and which to expose in order to create the illusion) inform the overall design considerations and ultimately influence how the audience responds or interacts with the objects onstage. Jones:

> Now let us look at the phenomenon of the performed puppet play from the point of view of the audience. What happens to actors armed with words when they are sharing the stage with a puppet? [In *War Hose*] the audience quickly developed an affinity and fascination with the horses. They clearly want to understand what the horse is feeling and thinking and as a result, they become

> avaricious readers of horse semiotics. Whatever the horse puppeteers do (from ear twitching, flank shivering and eye-line alteration, to whinnying, nickering and blowing), the audience hungers to interpret.
>
> The audience thus experiences a strong feeling of empowerment. They feel themselves to be in a new interpretive territory concerning the meaning of animals within the context of a theatrical event. There are no rules for such forms of interpretation and thus the puppeteers give to the audience an *interpretive authority* that is not often imparted in more conventional forms of theatre. And so, as generators of meaning, it could be argued, the audience take up an authorial role. The intensity of this interpretive focus has an unexpected result: the audience are so intently decoding the visual text that they may experience sections of the performance where the auditory dimension of the play is, as we say, bleached out. In a very real sense, the puppets are stealing the limelight. (261)

Reviewing the production in *TDR*, Ralf Remshardt declares that "one doesn't come to *War Horse* to see the humans. The true secret to the production's continued success is undoubtedly the realization of the horses and other animals" (Remshadt 273). Jones highlights the fundamental distinction between live theater and other types of entertainment, which is the interpretive role that the audience plays through their imaginative and metaphoric integration. Whether it is through actively seeking and reading of the puppet's motions and vocalizations, or the unconscious observation of the more subtle moments of stillness (Jones refers to this as the power of "breathed stillness"), the development of puppet motions and control systems stem from the tacit acknowledgment of the audience's authorial and interpretive role. Jones:

> This philosophy acknowledges the puppet's lack of self-consciousness and invites the audience into a narrative space that lives alongside and may supersede the verbal text. It is because of the intensity of this moment that the spoken text is often washed out by a kind of existential glare of the life that the puppet is living at that moment, on stage. The existence of this phenomenon, where the puppet seems to offer its own simple moment to moment 'being' as the Ur-narrative to the audience, is why we as puppeteers make our claims to authorship. (263)

If the conceit of puppetry hinges on this Ur-narrative of the continual struggle for the inanimate object to live on stage, then in order for a puppet—or any inanimate object— to be perceived as alive, "the movement must be more persuasive than the form" (Millar, M. 60). We can summarize the method for puppetry thus: first determine what the puppet does (or should do), and only then consider what it can (or should) look like. In the effort to create realistic simulacra, animatronics and other animal-inspired robotics often appear to have been conceived in the reverse order. If we accept that movement is essential (and we might argue that movement is the puppet's strongest means of communication), then any effort to create artificial forms that simulate life should proceed from this methodology.

The Lion King and *War Horse* were developed over a period of several years and multiple development workshops that brought together playwrights, puppeteers, actors, musicians, and choreographers. After studying the development of these productions, some patterns begin to emerge that underscore the connections between puppetry, animatronics, and robotics. The first is that each production involved significant design and redesign of puppets—a process that involves building prototypes and considering not only how to best represent the animal, but which actions communicate the essential character traits. In many instances, designs for puppets were completely redesigned and sometimes eliminated from the production after the opening. For example, the red-billed hornbill Zazu in *The Lion King* was originally to be performed by a masked actor (similar to the other principle characters); when it was clear that the design choice did not work, Taymor and Curry reconceived their approach and instead designed a hand-operated rod puppet perched on the actor's forearm. Similarly, the 2007 premiere of *War Horse* featured a puppet in the role of the young French girl Emilie, but since 2008 the role has been performed by an actress, ostensibly to bring a different quality of warmth and vitality to that segment of the play (Millar, M. 9). These examples illustrate the approach of puppeteers and the technical and aesthetic adjustments that inform the work: for puppeteers, it is not just a matter of automating motion, but uncovering which processes are most suitable for automation and fit with the overall aesthetic of the production.

To focus my discussion of puppet methodology, I have chosen three elements which I perceive as essential to puppetry and provide a formal methodology for developing more interactive animal-inspired animatronics: 1) identification and development of techniques for reproducing essential movements; 2) the acknowledgment of binocular vision and stylization in design and choice of control mechanism; and 3) the development of intuitive control systems which tightly couple the movement of the puppeteer with that of the puppet. I suggest that developers of entertainment use this methodology to create animatronics that are more expressive and responsive, and more likely to be provoke the Intentional stance and evoke agency.

Essential Movement

Taymor's and Handspring's puppets each have a distinct aesthetic: Taymor's aesthetic bears the signs of Asian puppetry (inspired by her study of Japanese puppetry and her extensive work with southeast Asian forms), while Handspring's aesthetic displays the varied influences of African puppetry (inspired by the company's South African roots and their collaboration with the Malian Sogolon Puppet Theatre on the *Journey of the Tall Horse*). These artists draw on a variety of traditional and innovative puppet forms to inform their unique aesthetic approaches to movement. One significant difference is evidenced by their conception of where to place the puppeteer: Taymor's puppets are frequently visual hybrids of human actors and animal puppets. In *The Lion King* an actor's limbs are often costumed and designed as animal limbs (rather than simply externally powering the motion). Conversely, Handspring's aesthetic typically relies on puppeteers who operate the puppet from outside, in the style typically associated with *bunraku*, but for large scale animal puppets, Handspring chooses to place the operators inside the puppet. For example, the giraffe puppet in *The Lion King* grows out of the body and silhouette of the human (Figure 12), whereas the Handspring giraffe designed for *Journey of the Tall Horse* was animated by two puppeteers hidden within the front and hind quarters of the animal (Figure 13). This reveals two approaches to movement:

> As I experimented with how an actor's body could be incorporated into the long legs and neck of a giraffe, what evolved was a figure created by an actor on four stilts. Nothing is hidden. One is aware that the stilts are attached to the actor's arms and legs and that the giraffe's neck and head rest as a tall hat on the performer's head, so the actor's face is visible. The fact that I could achieve the semblance of the giraffe silhouette was a plus, but the fact of seeing the dancer as part of that image became the fun and became the point. I wanted the audience to marvel at what a human being can do through true technical prowess. (Taymor 30)

The merging of the giraffe form with the human form is an example of cyborgean form which both modifies and augments the human body, and the hybridization of the two forms draws attention to the fragility of this liminal arrangement. Like the blind man's stick, the stilts force the actor into a different kinesthetic awareness and embodiment in the world, which in turn informs the actor's movements. This approach to movement had aesthetic implications: the stilts force the actor to adopt a delicate gait, calling to mind not only a real giraffe's motions but also foregrounding the physical negotiation between the human and the puppet and constituting a Deleuzean block of becoming by establishing "the relations of movement and rest, speed and slowness, that are closest to what one is becoming and through which one becomes" (Deleuze and Guattari 300). Forced to adapt to the form of the giraffe by embodying artificial prosthetic limbs, the human identity is temporarily altered or suspended and replaced by a liminal copresence with the animal.

Handspring's approach to representing a giraffe in *The Journey of the Tall Horse* represents a different type of becoming-animal, where the identity of the human puppeteer merges with the technology of the puppet in a slightly different way: their giraffe was operated by two actors on stilts that coupled their own legs to the giraffe's legs, and used their arms to operate mechanisms for controlling the tail, ears, head, and neck (Millar 57). The puppeteers are subsumed within the body of giraffe (only their legs are visible) and they control the puppet motions from within. This arrangement physically couples their movements with that of the giraffe, creating a relation of movement that is based on kinetic motions rather than imitative behaviors. This configuration approximates that used to animate the puppets in *War Horse*, although given the structural requirements—which dictated that the puppets carry human riders—Handspring chose to add a third puppeteer to automate the head and neck from outside of the puppet.

Figure 12. Taymor's giraffe in *The Lion King* incorporate the silhouette of the human puppeteer.

Figure 13. Handspring's giraffe for Journey of the Tall Horse featured two operators inside, resulting in a more naturalistic-looking giraffe.

Despite their different aesthetics and control mechanisms, Taymor and Handspring both acknowledge the necessity of creating convincing movement. Kohler refers to this as building a puppet "from the inside out," that is, determining what structural and practical requirements are needed, and then stepping back to ask "What does it actually look like, can we bear the aesthetic it's proposing?" (Millar, M. 57).

Taymor explains her approach to puppetry and movement using the term "ideograph," and Millar writes about Handspring's experimental approach that involves working with puppets parts towards the development of more intricate and articulated designs. Although their processes differ, the puppeteers have a similar goal: to uncover the essential movement characteristics for a given character, to eliminate all extraneous movements, and to design a system that allows for the maximum amount of expression with the smallest amount of effort (the fewest puppeteers and the least physically-demanding system of automation). Taymor's name for this process is working with ideographs, (a process informed by her study with Jacques Lecoq at the *L'Ecole de Mime* during the 1960's), which refers to the process of uncovering the "essence" or the "abstraction" of a character. She describes ideographs as "boiling it down to the most essential two, three brush strokes" (Schechner 37):

> In the visual arts, an example of an ideograph would be a Japanese brush painting of a bamboo forest: Just three or four quick brush strokes capture the whole. In the theater, an ideography is also a pared-down form—a kinetic, abstract essence of an emotion, an action, or a character. […] Lecoq enjoined us to create ideographs of colors and materials, to "do red," "do blue," "be ice," or "be steel." […] The idea was not to imitate ice or steel or joy but to reveal the essential kernel of the subject without the distracting details. A haiku. (Taymor 140)

Taymor's concept of ideographs can be likened to Handspring's work with what they call "unadorned" puppet elements—in this case tail, ears, puppet legs, or partial puppet heads—which is a part of the iterative process of uncovering the most fundamental, essential characteristics for portraying the animal movements and character traits. In some cases, working with unadorned elements was a practical consideration: in the case of *War Horse* the stage simply could not accommodate an entire brigade of horses, riders, puppeteers, and actor, therefore not all of the horses would be represented in full. When experimenting with the foal puppet for Joey, the puppeteers realized that a smaller-scale puppet simply could not accommodate two human operators inside, and they worked with the unadorned puppet to explore different configurations and representations. This process led to an exciting discovery concerning movement and character:

> We try the simplest image of a horse that we can make—just a head, then a tail to join it. Someone grabs some short lengths of two-by-one timber to use as skinny, straight legs, and it's one of the great serendipitous moments to the development. The kneeless legs make the foal's walking elongated, clumsy, fragile and awkward. Next to [the horse's mother] this smaller figure looks vulnerable, naïve, and helpless. There are three puppeteers hunched over this partial image, but its expressive movement is strong enough to let them shift into the background. (Millar, M. 61)

In this case, the process of identifying essential, fundamental movements led to the discovery of a motion that evoked projections of character, age, and even the emotional state of the horse (Figure 14). These character traits are juxtaposed by the other puppet used to represent Joey, which is slightly larger than a full-size horse, and whose motions are more articulated and able to convey more subtle movements (Figure 15). Kohler, who designs the puppets, "works with accurate anatomical proportions to help the movement of the joints echo those of the real animal, but his skill is to be selective about which joints are there, and how they are positioned for the operators" (Cashill). The horse's anatomy is only a point of departure for thinking about creating and automating motions, but it is not a rigid form. The process of generating and automating motions begins with translating horse motion into puppet motion, and then working with the anatomy of the horse to bring about these movements, even if they are not anatomically correct.

Figure 14. The puppet representing Joey as a foal is less articulated than that of the older Joey (below), and the resulting movements are evocative of certain characteristic and personality traits.

Figure 15. The full-size Joey puppet is operated by two actors inside the puppet, and a third actor who controls the head and jaw outside of the puppet. The puppet's "skin" is made from thin polyester material which is partly transparent under theatrical lights. The decision to stretch the "skin" underneath the cane-frame is anti-naturalistic and reinforces the sculptural quality of the horse (Millar, M. 60).

Millar writes that the unadorned puppet-approach is used even after prototypes have been developed and continue to play a role in determining what the mechanics of the full puppet will look like: "We still refer back to the simplest ways of representing a horse, adding in separate horse-puppet legs or heads to create partial horse images. Kohler is used to making partial puppets, and [director Tom] Morris' invitation is always to 'think about what it does, rather than what it looks like'" (58). The physical arrangement of the three actors controlling a single horse puppet encourages the processes of identity suspension introduced by Kleist and integral to Deleuze and Guattari's becoming-animal: the three individual human actors relate with the puppet by means of movement and rest, and in this action they also enter into relationship with one another. The image of the horse emerges from this negotiation, appearing through an assemblage of actions, motions, and pieces of jointed materials. Through this process, the actors' own individual identities are temporarily suspended and become aligned with each other's and also with that of the horse. Millar (who operated the puppet of the foal Joey in the original production) says this arrangement allows the puppeteers to "enter the mind of the horse a little more, and we will be attuned to this way of reading the action because of the emphasis on puppetry. The movement of puppets is one of their strongest means of communication" (31).

It is sometimes the case that even movement that was previously considered "essential" movement can seem too much. For *The Lion King*, Taymor and Curry developed custom masks for Scar and Mufasa with animatronic features: the masks were attached to harnesses worn above the actor's heads and were controlled using a cable hidden in the costume sleeve.[47] The masks could rotate 360 degrees and were equipped with moveable mouth, eyes, and eyebrows. These animatronic features meant that the mask could be employed in a variety of configurations, preserving the vertical lines of the human actors while also allow for a horizontal shape (aided by the use of prosthetic limbs). The prosthetic limbs were held in the hands of the actors, could be used either as human props (weapons for Mufasa; a cane for Scar), but when used horizontally, the prosthetics became the fore limbs that created the animal silhouette. Like Joey's kneeless legs, these prosthetics suggested certain character traits: Scar's cane becomes a third leg, "implying

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[47] Taymor's decision to "expose the mechanics" has its limits: in order to create compelling illusions it is necessary to mask some of the mechanical control and apparatus.

perhaps that he lost the fourth in the same fight that mangled his face" (Taymor 53). However, during development workshops, the animatronic masks ultimately proved too distracting. Taymor:

> While [the animatronics] lent more expression to the mask, ultimately the moving parts seemed extraneous. They undercut the mask's power and mystery, making it distractingly banal and busy. The actor's own face could provide the necessary facial expressions, while the masks, as in traditional mask theatre, would seem to change expression by how the actor moves. (118)

Ultimately, Curry and Taymor decided on a redesign of an animatronic mask where the range of motion was determined in relationship to the actor's head and more limited range of motion. The new design accounted for the silhouette of the mask and the silhouette of the actor's head, and the extension of the mask was "scaled to find the length of the mechanical struts that will achieve the desired range" (Taymor 121). The mask was built out of carbon graphite and weighed only thirty one ounces, and the movements could be operated by a lever worn on the hand.

Taymor's "ideographs" and Handspring's "unadorned puppets" are methods for creating expressive movement that artfully and convincingly animates inanimate objects. Although mimesis is the point of departure, these approaches constitute a more complex process than mechanical replication of movement or a human actor pretending to be animal. Rather, much like the *Imitate, Simplify, Exaggerate* methodology discussed in the previous chapter, these approaches translate animal motion into conceivable, human-powered puppet motion. While the approaches are not entirely synonymous, they demonstrate an essential aspect of puppetry: the effort to strip away all extraneous movement in the effort to uncover the essential quality of movement. We might draw a parallel between this process and Boccioni's theory of dynamism, Schlemmer's ideas of plays based on pure-movement, or Sokolov's concept of "true movement" which frees the puppet from any similarity to the human form. These processes are aligned in their commitment to capture and render the essence of an object through movement alone. It is necessary to recognize this task in contradistinction to the mechanical reproduction of movement.

Binocular Vision

The Lion King and *War Horse* are productions that are self-consciously theatrical and purposefully expose the underlying mechanics and artifice of puppetry. In these productions, the effort is not to mask illusions, but rather to call attention to the artificial nature of the illusion. I have already introduced Taymor's notion of the "double event," an acknowledgement that the spectator is "engaged by both the method of storytelling and by the story itself" (Taymor 129). While Taymor and Handspring both emphatically extol the artifice of puppetry, we recognize by the discussion above that it is neither necessary nor desirable to expose *all* of the mechanics: animatronic cables are hidden in costume sleeves and actors are subsumed underneath costumes that mask their human shape. However the success of these productions lies partly in how they repeatedly call attention to the act of animation, reminding the audience that the source of power is not inside the object but outside it. Although an audience may not know exactly how the effects are achieved, they are privy to the dialectic that exists between the puppet and the human character, and this opens up an interpretive—perhaps even authorial—space. In this heightened space spectators move between being deeply immersed in the artifice and distanced from it. This constant shift back and forth along these planes, forcing the audience to perceive the object's functional utility and aesthetic function, the real and the imagined world, and the inanimate and animate nature of the puppet, is essential to performance. Any successful animation of inanimate objects hinges on this dialectic. The becoming-animal emerges from the human artist who subsumes her ego in order to achieve a presence other-than-human, while the inanimate object works against its inanimate status in a struggle for life. Adrian Kohler and Basil Jones have suggested that this Ur-narrative underlies all of puppetry:

> *Jones*: Puppets always have to try to be alive, it's their kind of Ur-story onstage, that desperation to live.
>
> *Kohler*: […]An actor struggles to die onstage but a puppet has to struggle to live, and in a way that's a metaphor for life.

> *Jones*: So every moment that it's on the stage it's making this struggle.
>
> (Jones and Kohler 2011)

The decision not to hide but to expose the mechanics (or some of the mechanics), and the effort to evoke animal motions and behaviors without precisely replicating them, reinforces binocular vision which is central to theatrical illusion. If engineers wish to develop animal-inspired robots that are expressive, they can learn to stage machines in such a way that translates animal motion into puppet motion, and incorporate the notion of binocular vision so as to acknowledge the artifice of the experience. In the next section, I discuss an example of robotic performance that combines animatronics with traditional marionette puppetry, demonstrating how this approach can function even when the mechanics and sources of automation are masked or hidden from view.

Intuitive and tightly coupled control mechanisms

Puppet motions are controlled by human operators, and in order to develop fluid motions that result in compelling and artistic movement, puppeteers must develop intuitive methods for controlling these figures and interacting with them onstage. For single-operator puppets, this can be achieved with rods that link the motions of the puppeteer with that of the puppet kinematically, or by using attachments points that connect the puppeteer directly to the puppet by cables or pulleys. This ensures that the movement of the human operator is tightly coupled to that of the puppet, and means that the puppeteer remains firmly in control of the puppet's motions. The task becomes increasingly complex with large, multi-operator puppets, such as life-sized horses or elephants, because puppeteers often cannot rely on verbal or visual cues to coordinate their actions and must learn to communicate with one another through movement and tactile engagement with the puppet. For both single-operator and multi-operator puppets, operators must develop their faculties of peripheral vision and learn to coordinate the effort and timing of their movements with their fellow puppeteers and actors onstage. Taymor refers to this intuitive process as a "dialogue that takes places between the mask carrier and the mask itself" (in Schechner 36), while *War Horse* puppeteer Finn Caldwell speaks of an "impulse-based" acting approach. Both descriptions articulate a puppeteer's task of subsuming their identity and entering into physical negotiation with the puppet/prosthetic/performing object. This process is vital to creating compelling movement, and requires much rehearsal and refining of operator techniques, as well as fine-tuning the puppets themselves.

The technical requirements of productions like *The Lion King* and *War Horse* dictate that professional actors must be trained as puppeteers during relatively short rehearsal periods. Although both productions were developed in workshops that spanned several years, the final casts of actors were only assembled seven or eight weeks prior to the premiere of each show. Furthermore, both productions quickly secured touring engagements and multi-city runs which required additional casting. As such, the productions trained actors who had little to no prior experience with puppetry, and could not rely on the lifetime of expertise and heuristics that inform many puppet productions. Given the physical demands on the performers, several teams of puppeteers are required to meet the needs of even a single-site engagement. For example, the original production of *War Horse* featured three different sets of three actors to play the roles of Joey and Topthorn in rotation, and each of these teams were required to develop and deliver performances that were largely consistent in each performance (Millar, M. 9). The designers of the puppets must take this challenge into account and originate designs that have a certain amount of intuition built into the control mechanism.

In the previous chapter, we learned that the indirect control of marionettes makes these puppets difficult to control precisely and to generate refined motions. *War Horse* and *The Lion King* puppets feature a much more direct-control orientation, which enables more refined and expressive movements. For *The Lion King*, some puppets utilize aspects of the *humanette*, an articulated puppet body which is controlled directly by the limbs of the actor: Pumba (a warthog) is operated using cables attached to the actor's legs to trigger the motions of the hind leg movement; the hyena characters use masks that extend out in front of the actors and are controlled by the movement of the actor's own head; the cheetah puppet has cables to synchronize the puppet's head movements with that of the actor's; and Timon (a meerkat) is operated by a puppeteer standing directly behind the less-than-human-sized puppet and uses rods to control the puppet's hands. In each of these designs, the motion of the human actor is not mapped directly onto the puppet (that is, the actors do not move as though they are imitating animals), but only tightly coupled to those of the puppet. This renders even subtle movements— such as a head turn or gaze direction— fluid and promotes intuitive interaction between the operator and the puppet.

The coupling of the actor's movements with the puppet's motion also provides more opportunities for moments of stillness, which Taymor and Handspring both cite as essential to puppet physicality. Taymor:

> One of the keys to puppetry is stillness. Too much movement from a puppet forces the physicality to become general and unfocused. The actor must learn to make quick, small moves that contrast with long luxurious ones, and to alternate motions with stasis. The individual movements become the pauses, the commas, and the exclamation points in the character's phrasing. At the same time, energy levels must remain high and consistent. If an actor's kinetic intensity drops, the puppet loses energy. […] The challenge for the actor was to bring his puppet to life—to get "blood" flowing into every digit, into the legs, into the head, so that the audience sees and feels the life force inside this inanimate object. (144)

The tightly-coupled control mechanism (which echoes Deleuze and Guattari's zone of proximity or *copresence*) enables the actor to develop a subtle and expressive vocabulary of motion that animates the puppet in a believable and compelling way. Through this physical connection, the actor imbues the puppet with a life-force that is more subtle and evocative than that which can be achieved by an operator tele-operating a robot remotely. This is not because the audience can see the face of the actor but rather because the movement emerges from an intuitive and tactile feedback loop between the actor and the puppet, and the puppet is physically designed in such a way that responds to this linkage.

The creation of subtle movements in large-scale, multi-operator puppets presents a greater challenge where the coordination and control mechanisms of multiple puppeteers is required. Millar explains the change in animating the *War Horse* puppets is not in the large scale movements but in coordinating the subtlest motions— such as breath— during performance:

> The three operators, 'head', 'heart', and 'hind'—each have technical expertise to pick up during the rehearsal and training process to work the leg, neck, tail, and ear joints. Heart and hind operators share the weight of the aluminum-reinforced frame (and that of the rider) and can effect subtle changes of position by altering their leg and body position. The subtlest movement of all—the horse's breath—is created in this way, *but the real challenge for these performers is to subsume their ego in one single consciousness and translate their analysis of horse movement into something emotional and natural*. Being accurate is only the beginning of the journey of performing these characters. (Millar in Cashill, my emphasis)

In order to operate the horses, the puppeteers must learn to take into account things like weight distribution and how much strength and effort to use to execute certain motions. Because the operators are physically joined with the puppet, they are able to make decisions about the use of force, speed, and timing based on the tactile information communicated through the technology of the puppet. The prosthetic not only functions like the blind man's stick that expands the kinesthetic awareness of the single operator, but it is also used as a tool for communication *between* the operators. The puppet becomes the mode of communication and the means through which the actors communicates. Puppeteer Finn Caldwell says that this arrangement forces an entirely different type of acting, one based on "impulse but not intention," where the acting is based on short term goals centered entirely on movement (Millar 95). Millar explains how puppeteers learn to make decisions jointly:

> With the three puppeteers in each horse breathing together and concentrating on complementing each other's activity, they need to employ certain tricks of logic to work out how to respond to the scene they are in. One is the 'monkeys' approach, in which the horse actors try to filter out the language of the scene by using the analogy of a person in a room with monkeys. Even if the 'monkeys' are screaming at one another, the horses can tell whether they are themselves under threat and respond accordingly. It's another way of helping to

> focus on peripheral vision, displayed emotion, and body language. (95)

To translate Millar's and Caldwell's concept of impulse-based acting into engineering terms, we night say that the puppeteers are involved in a collectively-based decision making process that approximates subsumption architecture, where control systems are built to "let the robot operate at increasing levels of competence" (Brooks 1986, 14). Subsumption architecture works from a "bottom-up" design, and was conceived as a way for designing robust systems capable of independently navigating their environment in "unconstrained" settings.

As we will see in the next section, traditional animatronics in theatre productions have been limited by their inability to generate subtle movements like the ones mentioned above, and this can partly be attributed to the methods of tele-operation which bear no resemblance the intuitive and fluid control mechanisms found in puppetry.

REANIMATING THE ANIMATED

In order to understand how puppetry might inform the development of entertainment robots, we must consider the challenges involved with the design of animatronics and their use in live performance. Relational artifacts such as the Paro Seal, Sony AIBO, and other animatronic animals used decoratively in event spaces are developed as applied products; that is, they are designed with specific goals and uses in mind. Sherry Turkle, a clinical psychologist and the director of the MIT Initiative on Technology and Self, has written extensively about the efficacy of these relational objects and their use in therapeutic and social settings (Turkle 2005, 2006a; 2006b). These objects are evaluated on their use as relational objects, where machine pets or animal-inspired robots function as proxies for human beings and are conceived as sentimental objects on which humans may project their feelings and emotions. Because these robots use models of human-to-human interaction as their inspiration, they never move beyond lifelike imitation and mimicry and do not demonstrate principles of becoming-animal. They are also inherently limited as theatrical performers, as they are not designed with this purpose in mind.

The case for mechanical theatrical performers is stronger for large-scale animatronics. Given the trend of adapting animated films for live performance, it is reasonable to assume that tele-operated animatronics are the most likely of animal-inspired robots to benefit from puppetry-inspired design choices. Since 2007, the international entertainment group Global Creatures has produced two spectacle-driven arena productions that feature a host of large-scale animatronics: *Walking with the Dinosaurs Arena Spectacular* (*WWTD*) and *How to Train Your Dragon* (*HTTYD*). In June 2012, the company will premiere a musical stage adaptation of *King Kong* at the Regent Theatre in Melbourne. The show is directed by Daniel Kramer, with book by Craig Lucas (author of the Tony-nominated plays *Prelude to a Kiss* and *The Light in the Piazza*) and score by Maurius de Vries (a frequent collaborator of Andrew Lloyd-Webber and contributor to the musical *Love Never*

Dies). Global Creatures is a pioneer in the use of large-scale animatronics in live performance, and this production signals their foray more firmly into the realm of theatre.[48] The show will feature a six-meter tall animatronic figure in the shape of a silverback gorilla, and puppeteer Peter Wilson has described to me the techniques used to animate it as "a combination of marionette- automation and voodoo [puppeteering]" (Wilson 2013). While it is too early to predict a trend in the use of large-scale animatronics in live theatre, these productions present the occasion to consider how puppetry and traditional animatronics might inform one another to create new types of theatrical illusions.

Creating believable robots onstage is a challenge because engineers are relying on the methods for representing animals used in film and television which favor realism and verisimilitude. In adapting these robots for use in live performance, the designers fail to fully consider the different phenomenological stance that theatre provokes (binocular vision). The engineers for *HTTYD* and *WWTD* seem to have approached the task of automating motion in contradistinction to that of puppetry: What should the puppet look like, and how can we make that thing move? In short, by failing to acknowledge the imaginative and interpretive role the audience plays in live performance, the productions rely on ultra-realistic design choices that are technically very difficult to manage and ultimately limited in their range of motions. Animal-inspired robots that are designed for entertainment purposes are locked in a

[48] Carmen Pavlova, CEO of Global Creatures, was formerly an executive produce for the Really Useful Company, and was the director of the International Production Department for Stage Entertainment.

cycle of design and aesthetic traps that rely on more sophisticated motors and levels of technology to realistically reproduce the anatomic movements of the animals on which they are based. The task for engineers, then, should not be to develop robots that perform exactly as animals do, but rather to design systems capable of creative and dynamic movement that create the illusion of animal behaviors. As Meyerhold said, "Not to copy, but to create."

Large-scale, animal-inspired robots have been employed successfully in film and television, but adapting these large machines for use in live performance poses a unique set of challenges.[49] In order for animatronics to reach the level of artistry that puppets have demonstrated, the machines must be mobile, expressive, and interactive. They should also be lightweight, able to navigate the stage safely and swiftly, and demonstrate a wide range of expressive behaviors. Because animatronics require several human operators to operate them, the control system should support fluid and intuitive interaction between the operator and puppet. The challenge of satisfying even some of these conditions in a stage production is significantly harder because of the conditions of live theatre. As Hoffman has rightly argued, it is easy to edit subtle motions such as gaze direction in post-production for a film or television sequence, but on stage it is very difficult to control the precise gaze of an animatronic figure. In live theatre, a subtle motion such as eye contact can be instrumental in creating and sustaining the illusion of life.

[49] Sonny Tilders, the Creative Director of Global Creatures, designed and built animatronics for feature films such as Peter Pan, Chronicles of Narnia, and Star Wars, Revenge of the Sith.

Large-scale animatronics often require multiple operators: one operator is usually seated in a chassis inside the puppet driving the motions with a joystick or similar control mechanism, and several other operators animate gestures and sounds from offstage or from the back of the auditorium. Coordinating these efforts is exceedingly difficult because the operators are physically separated from one another and do not share a perceptual model of the world based on the puppet's perspective. Because the performing objects are physically decoupled from their operators—by which I mean there is not a strong correlation between the physical effort of the operator and the resulting puppet motion—it can be difficult for operators to develop an intuitive sense for operating and controlling subtle and expressive motions. Furthermore, because the goal of these high-tech puppets is to realistically mimic movements, the objects require more motors to automate each separate motion, which in turn requires more human operators to control them. This mimicry-based approach makes the robots heavy and difficult to control, and suggests why animatronics so often fail to create convincing or compelling theatrical illusions. The essential features of puppetry described above offer a method to avoid this.

Like humanoid robotics, animal-inspired robots can be either tele-operated (direct-control) or fully automated figures. In both cases, the figures are heavily stabilized and because of the machinery involved they are cumbersome to work with. The combination of motion control challenges, weight, and safety concerns makes it difficult to create compelling theatrical illusions—the objects either appear flat and one-dimensional (think of the animatronics on Disneyland rides) or they appear ultra-realistic looking but are incapable of demonstrating a wide range of expressive motion. For example, the dragon character Toothless featured in *HTTYD* is stabilized by a giant mount connected to the dragon's tail and physically roots the puppet to the ground (Figure 16). A separate "flying" Toothless appears only in scenes where flying is required, and the lighter puppet is controlled by automated marionette strings from above (Figure 17). The lightweight model is used in the air, but the more expressive, interactive puppet is too heavy to be airborne. The heavy mounts used for dragons and dinosaurs in *HTTYD* and *WWTD* are constant reminders of the artifice of the construction. No matter how realistic the object looks, the robots will never achieve lifelike behavior and perform exactly as "real" animals would. The mounts are painted to blend in with the stage floor and do not embrace the binocular vision of the theatrical experience; they are crude efforts to hide the mechanics in an effort to preserve the illusion. Taymor and Handspring developed methods for staging animals through the principles of essential movement, acknowledgment of binocular vision, and tightly-coupled control systems. These techniques could be applied to animatronics used in live theatre productions.

Figure 16. The animatronic dragon Toothless in *HTTYD* is stabilized by a mount attached to the puppet.

Figure 17. A separate, lightweight puppet is used in flying sequences, and is operated by strings in the style of a marionette.

WWTD developed technologies for controlling multi-operator puppets, combining techniques from traditional puppetry and tele-operated robotics. Many puppets are controlled using the "voodoo rig" offstage (Figure 18). Voodoo puppeteering is a term coined by engineers at Global Creatures to describe the remotely-operated control system that uses computer interfaces, vision and sound technologies, and joystick operated mechanisms to control puppet motion and choreographic sequences (Paynter 2009). Each animatronic figure is controlled by two or three puppeteers, sometimes with an operator seated in a chassis inside the puppet, and several offstage puppeteers who control the movement of the ears, eyes, tail, and vocalizations using a specially designed keyboard. All of the inputs are entered into a computer which drives the actions remotely. In the *WWTD* touring production in Copenhagen, I witnessed a voodoo puppeteer operate a small, baby brontosaurs mounted on wheels via remote control. The puppeteer, who communicated with the other puppeteers through his head-set, stood beside me in the audience to control the motions of the puppet using a joystick device not dissimilar from the type of control used to automate a remote-controlled car. *WWTD* also featured a marionette-inspired pterosaur puppet suspended from a stationary position in the grid. Although the robot remained in a fixed location, the engineers created the illusion of a flight by combining a pulley system to animate the wings with a digital-projection of a moving landscape in the background.

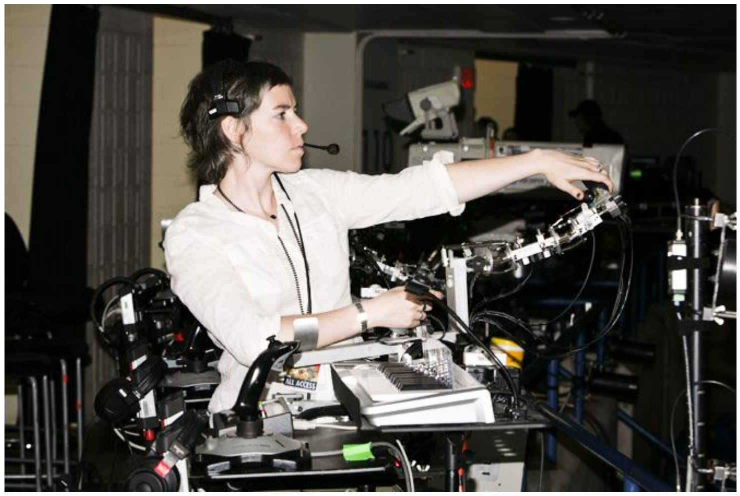

Figure 18. A Global Creatures puppeteer operates the dinosaur tele-remotely using a “voodoo rig,” the top hand operates the head and neck, and the bottom hand operates the body and tail (Paynter 2009).

The pterosaur flight technique is not dissimilar from Disney Research’s early experiment with a single-string butterfly marionette described in the previous chapter, although the pterosaur was more articulated—the puppet featured an animatronic head with an articulated jaw that could open and close. This scene was one of the most visibly arresting moments of the show. Although the mechanics of the control were visible, the sequence captured the essential characteristic of the dinosaur’s motion—inviting the audience to contemplate the magnificent motion of large, powerful wings that appeared to sustain flight. In a production that was otherwise lacked dynamic or spontaneous motions, it was a rare moment to contemplate the power, size, and elegance of these creatures.

HTTYD is a much more technically ambitious project that features twenty three lifelike dragons with wingspans that measure up to forty six feet, and scenes which call for five dragons to fly simultaneously while supporting human actors.

Unlike the pterosaur, the dragons are capable of proxemic and gestural movement, and are each operated by nine pulley strings. The flying dragons share the stage with a cast of circus artists and acrobats that perform against a "high-tech wall-to-floor immersive projections system" which measures more than 20,000 square feet (Waddell 1). The size and weight of the show are a consideration for the production's touring potential. The original production (which premiered in Australia) was too big to fit in many North American venues and the producers were forced to adjust the "weight and size" of the show (which presumably means modifying the choreography to include fewer robots). Even after changes, the show is still not able to fit in all of the venues. Despite efforts to construct lighter-weight dinosaur and more nimble control systems, the size and weight of current-generation animatronics are still significant challenges for mounting touring productions.

Peter Wilson, a puppetry consultant on *HTTYD* and the director of puppetry for *King Kong*, says that one of the biggest challenges facing animatronics is the loss of the immediate human connection: "If we as an audience cannot connect though the eyes and breath of our puppet, we feel removed from any empathy and emotional connection to the character" (Wilson 2013). Even if the animatronics are equipped with ultra-realistic motions and gestures, each degree of freedom requires a separate actuator which is in turn controlled by a separate operator. Despite the sophisticated control systems such as the "voodoo rig," simple motions like simulating breath and more complex motions like gaze direction—which are vital to indicating expressive and responsive behaviors and evoking the intentional stance—

are extraordinarily difficult to automate because they are mediated through a control system that often does not provide any tactile feedback to the puppeteer/s who direct these motions. The technical apparatus prevents multiple puppeteers from subsuming their ego into one single consciousness the way *The Lion King* and *War Horse* puppeteers collaborated.

To address this challenge, I suggest the development of a gesture-based control system that tightly couples the interaction of the operator's motions with those of the puppet. The system could include sensory feedback such as the use of force, direction, and timing in such a way that would link and coordinate the operator's motions with those of the puppet. Furthermore, these inputs could be coordinated with visual sensors to help the puppeteers to develop perceptual models, providing them with a more intuitive sense of the spatial dimensions of the stage and the other actors. A gesture-based control system could help to coordinate the efforts of multiple operators animating a single puppet, allowing puppeteers to interact with one another more fluidly, emulating the kinesthetic perception of traditional puppet configurations and aligning the operator's motility more in line with that of the performing object.

In addition to a gesture-based control system, I would argue for an aesthetic approach to animatronics that acknowledges the binocular vision inherent to puppetry. Such an approach would mean less focus on the mechanical reproduction of motions and more attention devoted to identifying the essential movement characteristics for a given animal or character. Just as Kohler's horse puppets modified the neck joints to create a wider range of motion than is anatomically possible, so could engineers adopt more abstract or creative approaches to designing animal robots. While this may lead to animatronics that are not as realistic-looking, it could possibly lead to motions and behaviors that strengthen the autopoietic feedback loop that connect the puppet, operator, and spectator. *The Lion King* and *War Horse* puppets demonstrate that even when the mechanics are exposed, such objects can still be perceived as intentional systems and evoke agency. By shifting the focus from mimesis to kinesis, we arrive at an image that is more artistic and perhaps ultimately more compelling because it invites the spectator to be part of the act of creation.

CHAPTER VI

SUMMARY OF FINDINGS

Hans Christian Andersen's fairy tale *The Nightingale* tells the story of an emperor who falls in love with the beautiful song of a nightingale. The emperor is so taken with the bird's mellifluous music that he captures the bird and keeps it in captivity at court. Admirers come from all over the world, and one visitor presents the emperor with a gift of a mechanical bird in the likeness of the real animal. The automaton is decorated with precious jewels, and the clockwork mechanism hidden inside produces a variety of songs that entertain the court. The emperor grows to love the mechanical creature even more than the real bird, who is eventually banished. What's more, the mechanical music is considered even more pleasing because the automaton keeps perfect time and its behavior can always be predicted. "You can understand it, you can open it up and see how human minds made it, where the wheels and cylinders lie, how they work and how they all go around," the Master of the Music exclaims (Andersen 90). After years of use, the mechanical bird breaks and can only be played once a year. The emperor falls gravely ill, and on his deathbed he longs for the comfort of the nightingale's song. But there is no one there to wind the bird up, and the bird cannot sing without being wound. At that moment, the real nightingale appears at the window, singing its sweet tune that restores the emperor's health. The bird's song sends the messenger of death on his way (his purpose unfulfilled) and the nightingale agrees to visit the emperor as long as he lives.

This fable, written in 1843 as the sun was setting on what Kang calls the "Golden Age of Automata," nicely illustrates why the promise of robotic performers is so alluring, and why the reality is so often disappointing. The possibility of robotic actors or autonomous machines that move and interact in the real world offers an image of technological prowess that stimulates our imagination and propels the human proclivity for creating artificial life. However, as Andersen's nightingale and Ovid's story of Pygmalion remind us, the ability to create the living likeness of an animal or human being is not the same thing as creating life. The spirit or essence of a being is a far more difficult thing to replicate than its outward physical attributes or internal motor functions, and yet it is this essence that most emphatically signals the appearance of life. As Vaucanson's flute player and Ishiguro's *Geminoid F* have shown, the creation of artificial life cannot be achieved merely through ultra-realistic physical attributes or through mechanical reproduction alone: something *more* is needed. Pygmalion's statue was brought to life through the divine power of Aphrodite, and in Andersen's tale only the real nightingale could heal the emperor. In AI research, scientists are looking for that "new stuff" or "special juice" that will allow them to move beyond mechanical reproduction towards a more profound understanding of living systems (Brooks 2002, 190). Whether it is indeed a substance or a mathematical formula that will lead to a better understanding of biological systems, it is clear that until researchers uncover this missing element, attempts to simulate life will remain just that: simulacra.

The physical constraints of the real world and the enormously complex engineering tools required to replicate outward forms and inner mechanisms of human and animal-inspired robots make it very difficult for robots to display characteristics of liveness that stimulate our imagination or generate notions of the sublime. It also makes it very difficult to argue that such robots are creative in the same way that human beings are creative. However, as I have suggested throughout this study, if we can identify which aspects of creativity and performance are most vital to live performance—and in particular to the representation of human and animal forms—then we can begin to consider methods for developing robots that appear more creative and interactive. Such an understanding will also provide a framework for evaluating machines used in live performance to understand how they function aesthetically.

In Chapter Three I discussed Fortunato Depero's collaboration with the Ballet Russes on an adaptation of Andersen's fairytale called *Le Chant du Rossignol* (*Song of the Nightingale*).[50] Although the production was never produced, Depero's work on the project led him to conceive of a theatre without human performers and populated entirely by mechanical figures and marionettes:

> Having just finished the costumes and scenery for the Russian ballet, a thought came to my mind: in order to gain a wider geometric expression, the freedom to change the proportion of costumes to people and settings to characters, it would be necessary to abandon the use of human performers, and to replace them with a "living"

[50] Although Depero had completed a substantial amount of the work on the Le Chant du Rossignol, the ballet was never produced, partly because of Diaghilev's extended financial commitments, (see Berghaus 300-305). However, his work with the Ballet Russes prompted Depero to explore puppet theatre further.

> automaton, meaning a new kind of marionette, liberated from natural proportions, in a style full of invention and fantasy, capable of delighting us with its paradoxical and astonishing mimicry. (Depero in Jurkowski 1998: 55)

What strikes me as paradoxical about Depero's decision to abandon human actors in favor of artificial ones is that it is orthogonal to the moral of Andersen's tale. However, when we consider the efforts of artists like Depero and Prampolini, as well as contemporary efforts by Disney, Handspring Puppet Company, and Global Creatures to give life to fantastical creatures on stage, we see how theatre artists have used techniques of traditional puppetry and robotics to liberate the stage from the "natural proportions" of human actors in the search for new methods of representation. These forms are rooted in—but not governed by—mimicry. But mimesis is only the point of departure. How the representations move and interact with their environment is essential to acknowledging provoking the intentional stance and evoking agency.

Despite the enduring interest in automata and mechanical theatres, experiments by the historical avant-garde to create autonomous art figures, and more recent productions that feature robots and other animatronics, theatre scholars have not given full consideration to the possibility of technology-as-performer. Furthermore, the use of animatronics in live productions has been all but ignored by contempoary theatre scholarship. Given the number of spectators that frequent these spectacle-driven productions, this omission speaks more to a disciplinary bias than to their small circle of influence. Autonomous and semi-autonomous robots are taking their place alongside human actors in live performance, and their presence is shaping present and future audience's conceptions of live entertainment. These technological players raise important questions concerning embodiment, agency, and a machine's ability to generate a performance or create a work of art. Here I have argued that autonomous and semi-autonomous machines warrant our attention and necessitate scholarly investigation of their methods of representation.

This study lies at the intersection of several fields—including theatre, engineering, computer science, puppetry, visual art, and philosophy—and considers the question of agency and intentionality of inanimate objects. In the cognitive sciences, agency and intentionality are discussed chiefly in terms of the perception of mental states between human beings (relational psychology), while AI research focuses on the human perception of mental states in artificial agents (the Turing Test, Dennett's intentional stance). In the humanities, scholars have traditionally considered the relationship between agency, intentionality, and performativity of machines by considering the historical representations of automata—both real and fictionalized—in their cultural contexts. While there is some overlap, it can be difficult to find common ground across science, engineering, and the humanities for discussing methods of representation and an object's ability to evoke agency.

Two recent studies—Reilly's *Automata and Mimesis on the Stage of Theatre History* and Kang's *Sublime Dreams of Living Machines*—ostensibly consider the performance history of machines and robots in connection with contemporary digital culture and machine-based performances, however the studies end long before the dawn of the digital age and do not consider automata and robots created during the last half century (precisely the time when machines started to move autonomously). These works provide detailed descriptions of automata and offer valuable readings of the interrelationships between nature, art, technology and cultural history. Together with Harold Segel's comprehensive study of puppets, robots, and modernism in *Pinocchio's Progeny*, these works provide a solid foundation from which we can formulate theories of technological bodies in performance. However they only mark the beginning of an understanding of the human proclivity for staging artificial life and simulacra. Here I have made the case that this topic merits further research and indicated which avenues might be pursued for considering technology-as-performer.

Given the ontological link between puppetry and robots, I used a puppet-centered approach to construct a phenomenological understanding of machines in performance. I began by considering two interrelated questions: 1) Does robotic performance constitute a creative act? and 2) How can engineers use puppetry to develop robots that better exhibit behaviors that are identified with creative performance? Using States' concept of binocular vision and Dennett's concept of intentional systems, I argued that robots and other inanimate objects evoke agency by developing expressive and responsive behaviors. These behaviors can be achieved primarily through movement, and contrary to conventional practice, I proposed that movement is more crucial to provoking the intentional stance than physical resemblance or photographic realism. In other words, kinesis is the new mimesis.

In Chapter Two I argued that technological objects can suspend our disbelief in ways similar to that of a human actor portraying a character, or the way a puppet acquires life in the hands of a skilled puppeteer. Recognizing the theatrical implications of the Turing Test, an enduring but elusive benchmark for defining and assigning intelligence to artificial systems, I proposed two necessary conditions for a robot to originate a performance and persuade a human observer of its creativity: expressivity and responsiveness. On the basis of Dennett's concept of intentional systems, I proposed that these features provoke the intentional stance and enable an inanimate object to evoke agency.

In Chapter Three I identified performances by the historical avant-garde as proto-robotic performances that contributed to artistic awareness and exploration of autonomous acting machines. Citing specific experiments by Futurist and Bauhaus artists such as Marinetti, Prampolini, Depero, Schlemmer, and Moholy-Nagy who endeavored to create new modes of production and perception during the Machine Age, I demonstrated the importance of movement and physical expression to the creation and simulation of autonomous machines. Lacking the technological tools to realize their artistic visions, these artists used puppetry as a tool for actualizing autonomous art objects. Their productions challenged the traditional actor-spectator dynamic by making performances more interactive through more flexible and dynamic stages and prefigured autonomous acting machines by joining human actors with performing objects and mechanical devices. These avant-garde experiments led to new conceptions of the mechanized body and the mechanical performer, and interrogated the impact of new technologies through formal exploration. Although the productions did not feature robots *per se*, they investigated the phenomenological aesthetics of machines through a synthesis of design, engineering, and artistic expression.

In Chapter Four, I considered the design and control of human-inspired robots from antiquity to the present, identifying how engineers have traditionally approached the task of automating human-inspired motion and creating mechanical simulacra of human beings. From the human-shaped automata of the Renaissance and Enlightenment periods onward, engineers have typically generated motions by mimicking the functional anatomy through automated or tele-operated means. This approach results in robots that bear a strong physical likeness to human beings but whose motions are rigid and mechanical. Citing the most advanced human robotics such as the *Geminoid F* and *Geminoid DK*, I showed how the functional-anatomy approach to movement leads to motions that are dull and predictable and limit a robot's ability to create convincing or compelling performances. I identified this challenge as a kinematic version of the Uncanny Valley.

Citing my work on the *Pygmalion Project*, I outlined a theory for automated motion based on the principles of traditional puppetry and binocular vision. I proposed that using the principles of abstraction, stylization, and intuitive control creates motions that are more artful than kinematic motions because they engage binocular vision and invoke the spectator's imaginative participation. Binocular vision is a cognitive mechanism that enables the automated motion of the marionettes to avoid appearing uncanny or perfunctory. Furthermore, models for collaborative robots that can sense and respond to their environment emulate aspects of human-powered puppetry such as collaboration, intuition, and control. These features result in a type of emergence where the robots exhibit interactive and spontaneous behaviors—traits that contribute to the autopoietic model for theatre performance. While humanoid-robots do not yet convincingly imitate the creative act (and therefore cannot be said to originate a work of art), the initial findings of the *Pygmalion Project* suggest how the developers of entertainment robotics might use puppet-inspired design choices to develop more dynamic automated motion.

In Chapter Five, I considered the unique challenges of creating and animating animal-inspired robots and outlined how engineers could use puppetry to overcome these challenges. Recognizing the human willingness to accept animals as proxies for human experience, I used Deleuze and Guattari's concept of "becoming-animal" and Merleau-Ponty's notion of the phenomenal body to consider how puppetry's methodology fundamentally differs from that of traditional animatronics. Citing Julie Taymor's *The Lion King* and Handspring Puppet Company's *War Horse* as examples of animal representations that are not rooted in mimicry but in creative movement, I outlined methods that engineers might use for developing more expressive and responsive animatronics: 1) An aesthetic approach to animatronics that acknowledges binocular vision and privileges essential and abstracted movements over mechanical reproduction; 2) A gesture-based control system that more tightly couples the interaction of the operator's motions with those of the puppet, which would include sensory feedback such as the use of force, direction, and timing to better coordinate the operator's motions with those of the puppet.

Citing the recent trend of adapting animated feature length films for live performance, such as DreamWorks Theatrical's *How To Train Your Dragon* and Global Creature's forthcoming *King Kong*, I proposed that developers of animatronics might learn from puppetry to create more intuitive interfaces for operating and controlling robots—in particular large-scale, animal-inspired robots. I anticipate that these methods will lead to more compelling animatronics that are more likely to provoke the intentional stance and evoke agency. There are indications that engineers are beginning to incorporate such methods in their practice. Philip Millar, a Global Creatures engineer who designs and builds animatronics, says that the two most significant challenges facing animatronics at the moment are the high cost of design and manufacture and the "unrealistic expectations from producers as to what animatronics are capable of doing" (Millar, P. 2013). Puppetry provides methods that are "cheaper, faster, more versatile, more easily built and repaired, available to many more people, amenable to a more varied range of approaches, (and) generally more versatile and flexible" (Millar, P. 2013). Peter Wilson, the puppetry director for *King Kong*, has indicated that the control mechanism they are using in the production combines marionette automation and voodoo puppeteering to render the large scale movements and the small-scale expressions (Wilson 2013). Interestingly, the company known for developing some of the most realistic-looking animal robots is employing engineering techniques that have powered traditional puppetry since antiquity. The *mechane* of ancient Greece that created the illusion of flight finds a modern-day corollary in automated marionette platforms. While the object of representation may change, the basic laws of mechanics and the imaginative and metaphoric integration that enables us to suspend our disbelief and delight in illusion continues to function as it has throughout theatre history.

This study has focused primarily on embodied agents, that is, puppets and robots that are embedded and situated in the real world rather than digital avatars or presentations in virtual environments. While the effects of digital computing and processing on live art is well-documented (Messaris 2006; Tribe 2006; Bay-Cheng 2011) and beyond the scope of this study, it is worth considering how current and future digital technologies might be used to develop a gesture-based control system that is more responsive and intuitive. In Chapter Five, I advocated for a gesture-based control system that measures force, direction, and timing to better coordinate the operator's motions with those of the puppet. In traditional puppetry, the human operator incorporates the technology of the puppet into his/her own body, and through this assimilation achieves an altered kinesthetic awareness which promotes fluid and intuitive interaction between the human and the technological apparatus. While digital technologies have been used successfully in animating and rendering three-dimensional objects in film, television, and video gaming, these efforts continue to use photographic realism as their model (Prince 31). This has led to development of more interactive technologies for gaming (the Microsoft Kinect console discussed in Chapter Four is one example). Building on these modeling and graphics tools, researchers at Microsoft have developed the *KinEtre Project*, a three-dimensional modeling system that uses a small, hand-held camera to scan inanimate objects and render them immediately in a 2D environment to be animated by a human using only their gestures and movements (Moore 2012). Echoing the multi-operator puppets in *War Horse* and *How to Train Your Dragon*, the authors have experimented with multi-operator animations, using two humans to animate the figure of a digital horse (Figure 19). While the *KinEtre Project* is still in experimental phase and does not yet have a direct product application, it presents an innovative approach to digital puppetry and computer animation (Sturman 1998). The researchers use the tool to "breathe life into static objects" (Moore 2012), and their results have implications for tele-presence and human-computer interaction research. Despite these potentials, the software is limited because (as with voodoo puppeteering) the human operators still have no tactile or haptic feedback from the system: the operators rely solely on visual, rather than tactile feedback to animate motions of the avatar.

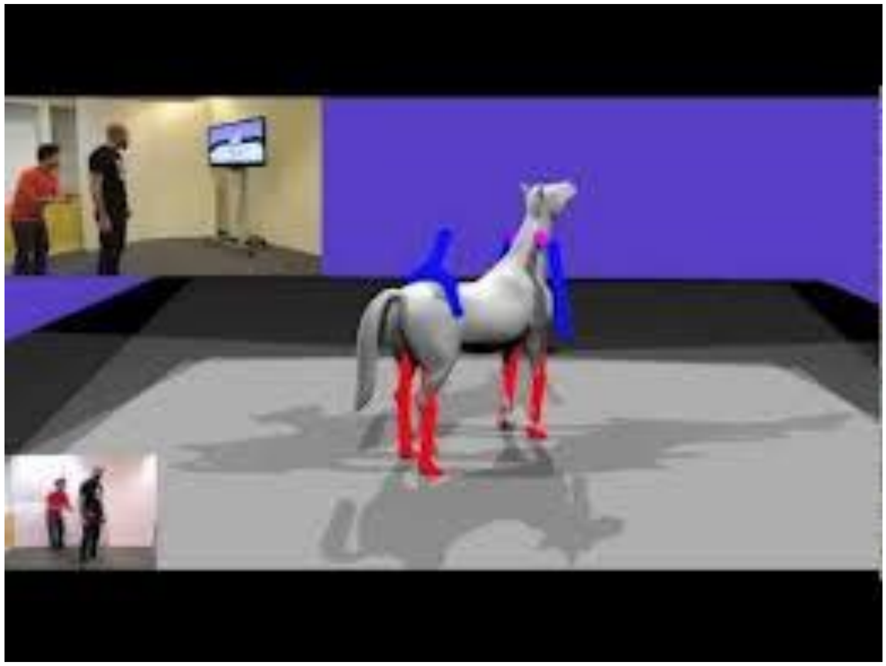

Figure 19. A video still from the KinEtre Project (Microsoft Labs) uses a three-dimensional model to animate objects in virtual environments. The "puppeteers" animate the objects using only visual feedback. (For video see Moore 2012).

One potential application of a system like *KinEtre* would be to combine the modeling and animation capabilities of the system with haptic or force-feedback technologies, such as those used in computer simulations and the remote control of tele-robotics. The *KinEtre* software could be used to develop a new kinesthetic model for the human user based on the animated avatar to emulate the direct-control of traditional puppetry. According to Philip Millar,

> There is no more direct and effective means of controlling a puppet than direct physical contact. Failing that, a control system must offer some sort of feedback, whether visual or force feedback. With many animatronic puppets, some form of remote control system is essential

> whether because of size, weight or position of the puppet. Only very well-designed systems can come close to matching the fluid interaction of traditional forms of control. (Millar 2013).

Combining a visual animation system (like that developed for *KinEtre*) with the haptic or force-feedback technologies used in tele-robotics could result in a gesture-based control system for animatronics that emulates the direct-control mechanism in puppetry. Combined with sensing technologies on the puppets, such a system might come closer to matching the fluid interaction of traditional puppetry and breathe more "life" into robotic actors. This is an exciting avenue for further research, and would provide an opportunity for puppeteers and engineers to learn from one another.

Theatre and performance studies scholars have long sought to identify and define the most essential and fundamental aspects of our medium, and to define the essence of our field. Historically, theatre has been defined in terms of what happens between stage and spectators, between actor and audience. Performance scholar Christopher Balme refers to this essence as intertheatrical communication, where theatre distinguishes itself from other art forms or media as a "special form of face-to-face communication" (Balme 83), and Fischer-Lichte has described theatre as a "fundamentally open, unpredictable process" between the stage and the audience (39). While the recognition of theatre as an interactive process between artist and spectator may have been necessary to accommodate the impact of the digital revolution and new technologies that jeopardized the physical presence of the human performer (Balme), it also addresses the imaginative and metaphoric integration that is unique to live performance. In her study *The Theatre of the Bauhaus*, Melissa Trimingham expresses this essential quality of theatre thus:

> The yearning of an audience to be deceived, its illogical willingness not only to enter a space of spatial transformation but to accept all kinds of obvious and not so obvious tricks, devices, and suggestions, seems to argue for a deep felt human need, a desire to glimpse the unknown, the irrational, a Bergsonian sensation of being "wholly in flux" that can never be explained by our rational selves. Immanuel Kant in his *Critique of Pure Reason* knew he could never prove a transcendent reality, yet felt that the very human capacity to conceive its existence was significant in itself; it seems indisputable that the experience of watching theatre constantly offers us some tantalizing limitation and possibility. Whilst Kleist offers us the sublime object in theory, performance actively exposes it on stage. It makes its attempt to realize the sublime—momentarily, fragmentarily, sometimes unsuccessfully but always hopefully—through the embodied live experience of the performer, object, and audience. (126)

Robots and puppets are connected on an epistemological level as well as ontological—they represent ways of knowing the world and coming into interaction with the life of objects. They provoke the desire to be deceived, and as liminal objects that hover between the animate and inanimate, they also portend a glimpse the unknown. Puppeteers and developers of entertainment robots are connected by the desire to give life to these inanimate forms, and to stimulate the imagination through methods of representation that are inventive and fantastical. The mirror they hold up to nature is not a plane mirror but a curved and shifting one—it is a mirror that produces magnified or distilled images that reflect aspects of the human experience but are not of it. They provide visions of the world from which we are partly or wholly free, and enjoin us to contemplate the world we know through the lens of a world that is not ours. This notion underlies both puppetry and the theatrical impulse, and robots are gradually learning how to play their roles.

Through my study of historical and contemporary stage productions and engineering practice I have concluded that within every object, there exists a potential for movement, and this movement expresses the object's core essence. Puppeteers have demonstrated a profound ability for drawing out this movement, working together with an object to communicate its essence while gesturing to the life-force that lies within it. Engineers can learn from puppeteers how to locate and elicit this essential movement, and this may result in machines that engage our imagination and stimulate notions of the sublime.

WORKS CITED

Automata. Web. 25 Feb. 2013

AKA. *King Kong Live On Stage*. TM and Global Creatures. 2012. Web. 25 Feb. 2013.

AKA. *Walking with the Dinosaurs*. Global Creatures and BBD Worldwide Ltd. N.D. Web. 25 Feb. 2013.

Ackerman, Evan. "Video Monday: Rat Heart Robots, Cheap UAV's, and Disney's Humanoid. *IEEE Spectrum Online*. 26 November 2012. Web. 26 Feb. 2013.

Andersen, Hans Christian. "The Nightingale." Andersen's Fairy Tales. New York: Penguin Young Readers Group, 1991. Print.

"Anyone for Yo-Ho-Ho? Disneyland's Big New Pirate Ride." *Life* 15 Sept. 1967: 138 142. Print.

Ashford, Emily. "Robotics: Specialized Machines Inspired by Biology." *McCormick Magazine* 2011: 28--31. Print.

Balla, Giacomo and Fortunato Depero. "Futurist Reconstruction of the Universe 1915." *Futurist Manifestos*. Trans. Robert Brain. Ed. Umbro Apollonio. London: Thames and Hudson, 1973. 197-200. Print.

Balme, Christopher. "Surrogate Stages: Theatre, Performance and the Challenge of New Media." *Performance Research* 13.2 (2008): 80-91. *EBSCO Host*. Web. 25 Feb 2013.

Baugh, Christopher. *Theatre, Performance, and Technology*. New York: Palgrave Macmillan, 2005.

Bay-Cheng. *Mapping Intermediality in Performance*. Amsterdam, Netherlands: Amsterdam University Press, 2010.

Bedini, Silvio. "The Role of Automata in the History of Technology." *Technology and Culture* 5.1 (1964): 24-42. *JSTOR*. Web. 14 Jan. 2013.

Bell, John. *Puppets, Masks, and Performing Objects*. Cambridge: MIT Press, 2001. Print.

Berger, John. *About Looking*. New York: Pantheon Books, 1980. Print.

Berghaus, Günter. *Italian Futurist Theatre, 1909-1944*. Oxford: Clarendon Press, 1998. Print.

Bernstein, Nikolai. *The Coordination and Regulation of Movements*. Oxford: Pergamon Press, 1967. Print.

Boccioni, Umberto. "Absolute Motion + Relative Motion = Dynamism." *Futurist Manifestos*. Trans. Robert Brain. Ed. Umbro Apollonio. London: Thames and Hudson, 1973. 150-154. Print.

Boden, Margaret A. *The Creative Mind: Myths and Mechanisms*. 2nd ed. London; New York: Routledge, 2004. Print.

---. *The Philosophy of Artificial Intelligence*. Oxford England; New York: Oxford University Press, 1990. Print.

Bogatyrev, Petr. "The Interconnection of Two Similar Semiotic Systems: The Puppet Theatre and the Theatre of Living Actors." *Semiotica* 47.1 (1983): 47. Print.

Breazeal, Cynthia L. *Designing Sociable Robots*. Cambridge, MA: MIT Press, 2002. Print.

Broadhurst, Sue. "Merleau-Ponty and Neuroaesthetics." *Digital Creativity* 23:3-4 (2012): 225-238. Web 25 Feb. 2013.

Brooks, Rodney. *Flesh and Machines: How Robots Will Change Us*. New York: Pantheon Books, 2002. Print.

---. "A robust layered control system for a mobile robot." *Technical Report*. Cambridge, MA: Massachusetts Institute of Technology (1986). *ACM Digital Library*. Web. 25 Feb. 2013.

Brustein, Robert. "The Lion Queen." *New Republic* 218.5 (1998): 25-26. *Academic Search Premier*. Web. 25 Feb 2013.

Budd, Mike and Max Kirsch. *Rethinking Disney*. Wesleyan University Press: 2005.

Burnham, Jack. *Beyond Modern Sculpture*. New York: G. Braziller, 1968. Print.

Calenda, Antonio and Maria Signorelli. "I Piccoli di Podrecca." *I Quaderni del Teatro* 60:1 (April 2000). Web. 25 February 2013.

Card, Stuart K., Thomas P. Moran, and Allen Newell. *The Psychology of Human-Computer Interaction*. Hillsdale, N.J.: L. Erlbaum Associates, 1983. Print.

Cashill, Robert. “War Horse’s Animal Magnetism, Part 2.” *Live Design Exclusive Insight* (2011). *Business Source Complete*. Web. 24. Jan 2013.

Carroll. C. “Robots Get Real.” *National Geographic* 220.2 (2012): 66-85. Print.

Causey, Matthew. *Theatre and Performance in Digital Culture*. London; New York: Routledge, 2006. Print.

Chen, I. Ming, Shusong Xing, and Song Huat Yeo. “Robotic Marionette System: From Mechatronic Design to Manipulation.” *Proceedings of IEEE International Conference on Robotics and Biomimetics* (2005): 228-233. *IEEEXplore*. Web. 25 Feb. 2013.

Craig, Edward Gordon. *On the Art of the Theatre*. London; New York: Routledge, 2009. Print.

de Solla Price, Derek. “Automata and the Origins of Mechanism and Mechanistic Philosophy.” *Technology and Culture* 5.1 (1964): 9-23. *JSTOR*. Web. 24 Feb 2013.

Deleuze, Gilles and Felix Guattari. *A Thousand Plateaus*. London: Continuum, 2004. Print.

Dennett, D. C. “Intentional Systems.” *The Journal of Philosophy* 68.4 (1971): 87-106. *JSTOR*. Web. 18 Jan. 2013.

Depero, Fortunato. “Colori.” *Futurist Performance: Includes Manifestos, Playscripts, and Illustrations*. New York: PAJ Publications, 1986. Print.

Duchamp, Marcel. *Salt Seller: The Writings of Marcel Duchamp*. New York: Oxford University Press, 1973. Print.

Eckersley, Nicole. “Sayonara: Android-Human Theatre.” *ArtsHub*. Web.18 Dec, 2012.

Egerstedt, Magnus, Todd Murphey, and John Ludwig. “Motion Programs for Puppet Choreography and Control.” *Hybrid Systems: Computation and Control*. Springer-Verlag (2007): 190-202. Print.

Epstein, Robert, Gary Roberts, and Grace Beber. *Parsing the Turing Test*. New York: Springer, 2008. Print.

Fischer-Lichte, Erika. *The Transformative Power of Performance*. New York: Routledge, 2008. Print.

Forbes, Annie. "Re: Puppets and Animatronics Summit." Message to the Author. 29 Jan. 2013. E-mail.

Franchi, Stefano, and Guven Guzeldere. *Mechanical Bodies, Computational Minds*. Cambridge, MA: MIT Press, 2005. Print.

Friedman, T. "The Robot Made Me Do It." *New York Times*, 25 August 2012. Print.

Freud, Sigmund. *The Uncanny*. Trans. D. McLintock. New York: The Penguin Group, 2003. Print.

Ghedini, F., and M. Bergamasco. "Robotic Creatures: Anthropomorphism and Interaction in Contemporary Art." *IEEE International Symposium on Robot and Human Interactive Communication* (2010): 731-736. *IEEEXplore*. Web. 25 Feb. 2013.

Gianacchi, Gabriella. *Virtual Theatres*. New York: Routledge, 2004.

Goldberg, RoseLee. *Performance Art: From Futurism to the Present*. New York: Thames & Hudson, 1988. Print.

--. *Performance: Live Art 1909 to the Present*. London: Thames and Hudson, 1979. Print.

Goodman, Nelson. *Ways of Worldmaking*. Indianapolis: Hackett, 1978. Print.

Gropius, Walter. The Theater of the Bauhaus. Transl. Arthur S. Wensinger. Middletown, CT: Wesleyan Univeristy Press, 1961.

Gross, Kenneth. *Puppet*. Chicago: University of Chicago Press, 2006. Print.

Guizzo, E. "Geminoid F Gets Job as Robot Actress." *IEEE Spectrum Online*. (2010). Web. 5 Nov. 2012.

Haraway, Donna. "The Cyborg Manifesto." *The Feminism and Visual Culture Reader*. London, UK: Routledge, 2010. 587. Print.

Hanson, D. "Why We Should Build Humanlike Robots." *IEEE Spectrum Online*. Web. 18 Dec. 2012.

Hero. *The Pnuematics of Hero of Alexandria*. Tran. Joseph Gouge Greenwood. Ed. Bennett Woodcroft. New York: American Elsevier, 1971. Print.

Hoffman, Guy et al. "A Hybrid Control System for Puppeteering a Live Robotic

Stage Actor." *Proceedings of IEEE International Symposium on Robot and Human Interactive Communication* (2008): 354-359. *IEEEXplore*. Web. 26 Feb. 2013.

"How To Train Your Dragon Live Spectacular." Global Creatures and DreamWorks Animation. ND. Web. 25 Feb 2013.

Hu, J., Wang, J. and Sun, G. "Self-Balancing Control and Manipulation of a Glove Puppet Robot on a Two-Wheel Mobile Platform." *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems* (2009): 424-425. *IEEEXplore*. Web. 25 Feb. 2013.

Hultén, Pontus, and Palazzo Grassi. *Futurismo & Futurismi*. Milano, Itlay: Bompiani, 1986. Print.

Huyssen, Andreas. *After the Great Divide*. Bloomington: Indiana University Press, 1986. Print.

Ishiguro, H. and MacDorman, K.F. "The Uncanny Advantage of Using Androids in Social and Cognitive Science." *Interaction* Studies. 7.3 (2006): 297-337. *IEEEXPlore*. Web. 25 Feb 2013.

Johnson, E. and Murphey, T. "Dynamic Modeling and Motion Planning for Marionettes: Rigid Bodies Articulated by Massless Strings." *Proceedings of IEEE International Conference on Robotics and Automation* (2007): 330-335. *IEEEXplore*. Web 25 Feb. 2013.

Jones, Basil and Adrian Kohler. "Handspring Puppet Co.: The Genius Puppetry Behind War Horse." *TedTalk*. Mar. 2011. Web. 25 Feb. 2013.

Junzhi Yu, et al. "Development of a Biomimetic Robotic Fish and its Control Algorithm." *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics* 34.4 (2004): 1798-810. *IEEEXplore*. Web. 25 Feb. 2013.

Jurkowski, Henryk. *Aspects of Puppet Theatre*. London: Puppet Centre Trust, 1988. Print.

---. *A History of European Puppetry, Volume I*. New York: Edwin Mellen Press, 1996. Print.

---. *A History of European Puppetry, Volume II*. New York: Edwin Mellen Press, 1998. Print.

---. "Transcodification of the Sign Systems of Puppetry." *Semiotica* 47.1 (1983): Print.

Kac, Eduardo. *TelePresence and Bio Art*. Ann Arbor, MI: University of Michigan Press, 2005.

Kang, Minsoo. *Sublime Dreams of Living Machines*. Cambridge, MA: Harvard University Press, 2011. Print.

Kaplin, Stephen. "A Puppet Tree: A Model for the Field of Puppet Theatre." *TDR* 43.3 (1999): 28-35. Print.

Kemp, Wolfgang. "The Work of Art and its Beholder." *The Subject of Art History: Historical Objects in Contemporary Perspectives*. Eds. Mark A. Cheetham, Michael Ann Holly, and Keith P. F. Moxey. Cambridge, UK; New York: Cambridge University Press, 1998. Print.

Kirby, Michael, and Victoria Nes Kirby. *Futurist Performance: Includes Manifestos, Playscripts, and Illustrations*. New York: PAJ Publications, 1986. Print.

Kleist, H. "On the Marionette Theatre." Trans T. Neumiller. *The Drama Review* 16.3 (1972): 22-26. *JSTOR*. Web. 25 Feb 2013.

Kober, J., Glisson, M., Mistry, M. (2012) "Playing Catch and Juggling with a Humanoid Robot." *Disney Research*. 2012. Web. 25 Feb. 2013.

Kott, Jan. "Bunraku and Kabuki, Or, About Imitation." *Salmagundi* 35 (1976): 9-109. Print.

Kroos, Christian, et al. "Evoking Agency: Attention Model and Behavior Control in a Robotic Art Installation." *Leonardo* 45.5 (2012): 401-407. *Project Muse*. Web. 25 Feb 2013.

Langdon, M. "Walking with the Dinosaurs [Robot Dinosaurs]." Engineering & Technology (17509637) 4.12 (2009): 44-47. *Academic Search Premier*. Web. 25 Feb. 2013.

Langer, Susanne K. *Feeling and Form*. New York: Scribner, 1953. Print.

Laurel, Brenda. *Computers as Theatre*. Reading, MA: Addison-Wesley, 1991. Print.

Law, Alma H., and Mel Gordon. *Meyerhold, Eisenstein, and Biomechanics: Actor Training in Revolutionary Russia*. Jefferson, N.C.: McFarland, 1996. Print.

Lee, Miles. *Puppet Theatre*. London: Faber and Faber, 1958. Print.

Lemon, Lee T., and Marion J. Reis. *Russian Formalist Criticism*. Lincoln: University of Nebraska Press, 1965. Print.

Levi-Strauss, Claude. *The Savage Mind*. Chicago: University of Chicago Press, 1962. Print.

Malmberg, Melody. *Walt Disney Imagineering*. New York: Disney Editions, 2010.

Martin, P., Johnson, E., Murphey, T. and Egerstedt, M. "Constructing and Implementing Motion Programs for Robotic Marionettes." *IEEE Transactions on Automatic Control* 56.4 (2011): 902-907. *IEEEXplore*. Web. 25 Feb. 2013.

Mazlish, Bruce. "The Man-Machine and Artificial Intelligence." *Mechanical Bodies, Computational Minds*. Eds. Stefano Franchi and Güven Güzeldere. Cambridge, MA: MIT Press, 2005. Print.

McCarren, Felicia M. *Dancing Machines*. Stanford, CA: Stanford University Press, 2003. Print.

McKnight, Heather and Gray, M. "Acting Lesson with Robot: Emotional Gestures." *Proceedings of ACM/IEEE International Conference on Human-Robot Interaction* (2012): 407. *IEEEXplore*. Web. 25 Feb. 2013.

Meĭerkhol′d, V. Ė., and Edward Braun. *Meyerhold on Theatre*. Rev ed. London: Methuen Drama, 1998. Print.

Merleau-Ponty, Maurice. *Phenomenology of Perception*. Tran. Forrest Williams. New Jersey: Routledge & Kegan Paul, 1962. Print.

Messaris, Paul, and Lee Humphreys. *Digital Media: Transformations in Human Communication*. New York: Peter Lang, 2006. Print.

Millar, Mervyn. *The Horse's Mouth: Staging Morpurgo's War Horse*. London: National Theatre in association with Oberon, 2007. Print.

Millar, Philip. "Re: Research Inquiry." Message to the author. 1 March 2013. E-mail.

Moholy-Nagy, Laszlo. "Theatre, Circus, Variety." *The Theater of the Bauhaus*. Ed. Walter Gropius. Middletown, CT: Wesleyan University Press, 1961. Print.

Mori, Masahiro. "The Uncanny Valley." *Energy* 7.4 (1970): 33-35. Print.

Moor, S. "Microsoft's KinEtre Animates Household Objects." *IEEE Spectrum Online*. Web. 7 Nov. 2012.

Moravec, Hans. *Robot: Mere Machine to Transcendent Mind*. 1998.

Murphey, Todd, and Magnus Egerstedt. “Choreography for Marionettes: Imitation, Planning, and Control.” *IEEE International Conference on Intelligent and Robotic Systems*. San Diego, CA (2007): Print.

--and Johnson. E. “Control Aesthetics in Software Architecture for Robotic Marionettes.” *Proceedings of American Control Conference* (2011) 3825-3830. *IEEEXPlore*. Web. 25 Feb. 2013.

Ovid. *Metamorphoses*. Tran. A. D. Melville. London: Oxford University Press, 1986. 232-234. Print.

Parker-Starbuck, Jennifer. “Becoming Animate: On the Performed Limits of “Human.” *Theatre Journal* 58.4 (2006): 649-668. *Academic Search Premier*. Web. 25 Feb. 2013.

---. *Cyborg Theatre*. Palgrave Macmillan, 2011. *Palgrave Connect. Web 26 Feb 2013*

Paynter, Ben. “Robodinos: What Could Possibly Go Wrong?” *Wired Magazine*, 20 July 2009. Web. 25 Feb. 2013.

Pavis, Patrice. *Languages of the Stage*. New York: Performing Arts Journal Publications, 1982. Print.

Porter, Roy. *Eighteenth Century Science*. New York: Cambridge University Press, 2003.

Potts, Alex. “Dolls and Things: The Reification and Disintegration of Sculpture in Rodin and Rilke.” *Sight & Insight*. Eds. E. H. Gombrich and John Onians. London: Phaidon Press, 1994. Print.

Prince, Stephen. “The End of Digital Special Effets” *Digital Media*. Eds. Paul Messaris and Lee Humphreys. New York: Peter Lang, 2006. 31. Print.

Proschan, Frank. “The Semiotic Study of Puppets, Masks, and Performing Objects.” *Semiotica* 47.1 (1983): 3-44. Print.

Reilly, Kara. *Automata and Mimesis on the Stage of Theatre History*. New York: Palgrave Macmillan, 2011. Print.

Roach, J. “Up Front: Kinesis is the New Mimesis.” *Theater Journal* 40.1 (2010):1-3. Print.

Roads, Curtis. *The Music Machine*. Cambridge, MA: MIT Press, 1989. Print.

Rothfels, Nigel. *Representing Animals*. Bloomington, IN: Indiana University Press, 2002. Print.

Salter, Chris. *Entangled*. Cambridge, MA: MIT Press, 2010.

Sand, George and Virginia Vaughan. *The Snow Man*. Boston, MA: Roberts Bros., 1871. Print.

Saygin, Ayse Pinar, Ilyas Cicekli, and Varol Akman. “Turing Test: 50 Years Later.” *The Turing Test: The Elusive Standard of Artificial Intelligence*. Ed. James Moor. Boston MA: Kluwer Academic Publishers, 2003. Print.

Schechner, Richard. “Julie Taymor: From Jacques Lecoq to the Lion King.” *The Drama Review* 43.3 (1999): 36-55. *Project Muse*. Web. 25 Feb. 2013.

Schlemmer, Oskar. Letters and Diaries. Ed. Tut Schlemmer. Trans. Krishna Winston. Middletown, CT: Wesleyan University Press, 1972.

---. “Man and Art Figure.” *The Theater of the Bauhaus*. Ed. Walter Gropius. Middletown, CT: Wesleyan University Press, 1961. Print.

Seawright, James. “Phenomenal Art: Form, Idea, and Technique.” *On the Future of Art*. Eds. Arnold Toynbee and R. Solomon. New York: Viking Press, 1970. Print.

Segel, Harold. *Pinocchio's Progeny: Puppets, Marionettes, Automatons, and Robots in Modernist and Avant-Garde Drama*. Baltimore, MD: Johns Hopkins University Press, 1995. Print.

Shin, Hyun Joon, Jejee Lee, and Sung Yong Shin. “Computer Puppetry: An Importance-Based Approach.” *ACM Transactions on Graphics* 20.2 (2001): 67-94. *IEEEXplore*. Web. 25 Feb 2013.

Shklovsky, V. “Art as Technique.” *Russian Formalist Criticism*. Eds. Lee T. Lemon and Marion J. Reis. Lincoln: University of Nebraska Press, 1965. Print.

Solon, Olivia. “There is No Point to Making Robots Look and Act Like Humans.” (2011). *Wired Magazine*. Web. 18 Dec. 2012.

States, Bert O. *Great Reckonings in Little Rooms: On the Phenomenology of Theater*. Berkeley: University of California Press, 1985. Print.

Steels, Luc, and Rodney Allen Brooks. *The Artificial Life Route to Artificial Intelligence: Building Embodied, Situated Agents*. Hillsdale, N.J.: L. Erlbaum Associates, 1995. Print.

Sturman, David. "Computer Puppetry." *IEEE Computer Graphics and Applications* 18.1 (1998): 38-45. *IEEExplore*. Web. 25 Feb. 2013.

Taylor, Jane. *Handspring Puppet Company*. New York: David Krut Publishing, 2009. Print.

Taymor, Julie. *The Lion King: Pride Rock on Broadway*. New York: Disney Enterprises, 1997. Print.

Terada, Kazunori et al. "Reactive Movements of Non-Humanoid Robots Cause Intention Attribution in Humans." *Proceedings of the 2007 IEEE/RSJ International Conference on Intelligent Robots and Systems* (2007): 3715-3720. *IEEEXplore*. Web. 25 Feb 2013.

"Theatre of Robots." *Engineered Arts*. 2012. Web. 25 Feb 2013.

Tillis, Steve. "The Art of Puppetry in the Age of Media Production." *Puppets, Masks, and Performing Objects*. Ed. John Bell. Cambridge, MA: MIT Press, 2001. 173-185. Print.

---. *Toward an Aesthetics of the Puppet*. Westport, Connecticut: Greenwood Press, 1992. Print.

Topey, Peter. *Disembodied Performance*. Master's Thesis. MIT, 2009. Web. 26 Feb. 2013.

Tribe, Mark, and Reena Jana. *New Media Art*. Köln; London: Taschen, 2006. Print.

Trimingham, Melissa. *The Theatre of the Bauhaus*. New York: Routledge, 2011. Print.

Turing, A. M. "Computing Machinery and Intelligence." *Mind* 59.236 (1950): 433-460. Print.

Turkle, Sherry, et al. "Encounters with Kismet and Cog: Children Respond to Relational Artifacts." *Digital Media.* Eds. Paul Messaris and Lee Humphreys. New York: Peter Lang, 2006. 313. Print.

---. "Relational Artifacts with Children and Elders." *Connection Science* 18:4 (2006): 347-361. *IEEEXplore*. Web. 25 Feb. 2013.

---. *The Second Self*. Cambridge, MA: MIT Press, 2005. Print.

Vaucanson, Jacques de. “An Account of the Mechanism of an Automaton, Or Image Playing on the German-Flute.” *Medicine, Science, and Technology* (1742). Print.

Veltrusky, Jiri. “Man and Object in the Theatre.” *A Prague School Reader on Esthetics, Literary Structure, and Style*. Ed. Paul L. Garvin. Washington: Georgetown University Press, 1964. 83. Print.

---. “Puppetry and Acting.” *Semiotica* 47.1 (1983): 69. Print.

Waddell, Ray. “Slaying Dragons.” *Billboard* 124.22 (2012): 9. *Business Source Complete*. Web. 24 Jan. 2013.

Wakabayashi, A., Motomura, S., and Kato, S. “Communicative Humanoid Robot Control System Reflecting Human Body Movement.” *Proceedings of International Symposium on Micro-NanoMechatronics and Human Science* (2011): 122-127. *IEEEXplore*. Web 25 Feb. 2013.

Wegner, Daniel et al. “Causes and Consequences of Mind Perception.” *Trends in Cognitive Sciences* 14.8 (2010): 383-8. Print.

Weizenbaum, Joseph. *Computer Power and Human Reason: From Judgment to Calculation*. San Francisco: W. H. Freeman. Print.

Wells, Paul. *Understanding Animation*. London: Routledge, 1998. Print.

Wiener, Norbert. *Cybernetics: Or, Control and Communication in the Animal and the Machine*. Cambridge, MA: MIT Press, 1965. Print.

Wiles, David. *Greek Theatre Performance*. Cambridge, UK: Cambridge University Press, 2000. Print.

Wilson, Peter. “Re: Puppets and Animatronics Summit.” Message to the author. 29 Jan. 2013. E-mail.

Wood, Gaby. *Edison's Eve*. New York: Alfred A. Knopf, 2002. Print.

Wright, Alex. “What a Mechanical Performance! Bravo!” New York Times. July 5, 2012. Web 25 February 2013.

Yamane, K., Hodgins, J. and Brown, H.B. “Controlling a Marionette with Human Motion Capture Data.” *Proceedings of IEEE International Conference on Robotic and Automation* (2003): 3834-3841. *IEEEXplore*. Web. 25 Feb 2013.