From Mechanical Metamorphosis to Empathic Interaction: A Historical Overview of Robotic Creatures

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Humans have had a long history of fascination with building intelligent machines that depict themselves or move animatedly. This article explores the history of robotic creatures like Egyptian figurines, Greek mechanical inventions, 18th century ingenious automata, and modern kinetic mise-en-scène and robotic artworks. Several interactive robots showed the potential for emotional interaction between humans and machines. In the context of human-robot interaction, empathy with robots requires further discussions on the interaction design.

Keywords: history of robots, automata, kinetic scenography, robotic art, empathic interaction

Introduction

The history of robotics research has narrowed slightly over the past 50 years (Kumar, 2010; Mason, 2012). Humans have been fascinated with building machines that perform human-like and animalistic behaviors or computing cosmic phenomena with mechanical designs since the ancient civilizations. The description of the *Mechanical Theater* in the Hero of Alexandria corpus attested to the performing mechanism over a millennium in Europe (Boas, 1949). The metamorphosis myth was widely known through the *Metamorphoses*, written by Ovid in the Roman Empire. One of his embellished characters, Pygmalion, represented the automaton myth (Anderson, 1972).

After Descartes, the predominance of rationalism as a background nourished the development of diverse automata among craftsmen, artists, and theologians. Jacques de Vaucanson demonstrated a mechanical duck pecking and digesting in France (Delve, 2007), while Wolfgang von Kempelen invented an interactive game machine with animated automata dubbed the *Chess Automaton* in 18th century Germany (Serexhe, 2007; Weibel, 2007).

These anthropomorphic machines were on the cutting edge of popular performance at the closing belle époque (Kumar, 2010). The long tradition and fascination with automata revived kinetic art forms and finally reached robots in the 1960s. Robots were introduced on the transformative stage as newly-invented performers paralleled with cybernetics (Demers & Horakova, 2008; Ghedini & Bergamasco, 2010). The Canadian director Robert Lepage performed kinetic mise-en-scène and expressed unique mechanical metamorphoses on the stage (Dixon, 2007). His collaborator, Louis-Philippe Demers, also showed the possibilities of machines with emotional interactions in art museums and theaters.

Humans have an ability to feel empathy with machines (Kozima, Nakagawa & Yano, 2004; Skogerson, 2001). This emotional interaction was developed far from the neolith figurines in the Greek mechanism to the current robotic theaters and robotic characters in Disney theme parks. The field of robotic entertainment is explored through a retrospective overview from ancient dolls to modern robotic performances based on historical materials and artworks focusing on the mechanical design and emotional interactions between humans and machines.

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Figure 1. Toy Milling Servant, 1300~1200 BC. Photo © Rob Koopman

Inspiration from the Past

Robotics are not just marvels of technological improvement but are widely imagined by writers, filmmakers, and cultural reporters. Their expectations have always exceeded the potential ability of robotics (Csikszentmihályi, 2006). Such literary imaginations and overt expectations of artificial machines are not only derived from literature, films, and theater plays, but also from ancient civilizations. The inspiration to build an anthropomorphic machine came from figurines with jointed arms as well as other articulated dolls from ancient Egyptian mausoleums, as a form of proto-automata (Fig. 1). The Egyptian developed a high sophistication trumpet mechanism of the anthropomorphic figure around the first millennium B.C. (Price, 1964). This mechanical design favored evocative demonstrations related to the power of the pharaohs.

In spite of this fascination with simulating humans, the tradition of articulated puppetry subsisted almost ten centuries in stasis (Price, 1964). The other mechanical inspiration in ancient Greece was the development and simulation of the astronomical mechanism, which was equipped with bronze gears like clock technology (Marchant, 2010). The origin of the astronomical representation in the Occident derived from the star-map vault of Egyptian tombs and theoretical models in Babylonia (Price, 1964).

The Antikythera Mechanism

The Greek interpreted patterns from the Babylonian astronomy as mechanical models merged into the Ptolemaic analysis and Pythagorean mathematics (Price, 1964). This preserved idea was found in the Aegean Sea in 1901 concealed in a wooden box approximately two hands wide without a title or name (Fig. 2). This was entitled the *Antikythera Mechanism* and consisted of more than 30 bronze gearwheels with millimeter scale clearances (Marchant, 2010). Greek inscriptions appeared on the cover of the front wheels to indicate the sun, moon, and zodiac (Marchant, 2010). The mechanism, built in the 1st or 2nd century B.C., allowed concentric rotations by a human hand and could display the 365 days of the year, 12 signs of the zodiac, and the directions of the five known planets using individual dials (Marchant, 2010). It is assumed that the elaborate mechanism might work perfectly, using a pin-and-slot mechanism that enabled one gearwheel to drive another around a slightly displaced axis (Marchant, 2010). While this hand-held planetarium represents the first mobile computer (Price, 1974), articulated figurines were reborn as mechanical automata in 1st century B.C. Roman-Alexandria (Price, 1964). The embedding of the cosmic and animate technological aspects was organized by the Hero of Alexandria in the first century A.D. (Price, 1964).

Figure 2. *Antikythera Mechanism*, ca. 100 B.C. Left image shows the front face of the original artifact of the salvage from the wreck. Right image made by computer graphic restoration.

Photo © Tony Freeth

The Mechanical Theater

Although the *Antikythera Mechanism* displayed as an inanimated apparatus, this artifact proved a rich background for the potential for building animated figurines of the era. The mechanics and physics of Ctesibius was integrated by Hero (Peppé, 2002), who published more than six books including *Pneumaica*, *Automata*, *Mechanica*, and *Belopoetica*, which were relevant to the mechanism in the middle of the Greco-Roman age. Hero's Works were rediscovered after being translated into Latin and German in the later Renaissance period (Boas, 1949). He invented various mechanical models using the hydraulic and geared elements in order to teach his pupils and to entertain the populace (Peppé, 2002; Scotchmer, 2004). His ingenious designs remained in the corpus as a part of the complete collection in Germany (Schmidt, 1899).

The part of the book related to robotic creatures, edited by Schmidt, is depicted by the mechanical theater that illustrates various mechanisms to perform mechanical spectacles (Fig. 3). He developed a ten-minute long mechanical play implemented by the knot driven rope algorithms using diverse elements (e.g., mechanisms of cogwheels, pulleys, levers, inclined plates, axles, and even large drums to make thunder sounds). According to the *Die Automatentheater* in the German edition of Hero's corpus (Schmidt, 1899), he designed a mechanical parade with figurines that opened doors on the architectural model. He also illustrated revolving axles under the stage that would move the mechanical dolphins. His mechanical design at the time was like a magician performing for the audience (Schmidt, 1899). However, Hero's mechanical theater was the actual entertainment, involving a mechanical metamorphosis on the stage representing the philological illustration of the Western world. His ingenious development was severed by medieval theology and was stagnated from the end of the Renaissance up to the 18th century (Boas, 1949; Price, 1964; Scotchmer, 2004). During this period, there were a few remarkable mentions of automata, amplified by two theologians: Albertus Maginus, who made a mechanical man with a brazen head, and his pupil St. Thomas Aquinas, who stated that the empathy machine was inspired from animals (Price, 1964). Some of the studies to build anthropomorphic mechanisms continued in the Middle East, known as Al-Jazari's automata (Kumar, 2010), whereas European stayed almost one millennium in the theological frame.

Figure 3. Illustrations from *Automata Theater* by Hero of Alexandria in the book *Herons von Alexandria* edited by Wilhelm Schmidt in Leipzig in 1889. Captured images from the book.

The Development of the Human-Automaton Interaction

Hero's and Vitruvius' works were increasingly translated for European countries (Boas, 1949) after the improvements in the clock mechanism in the Renaissance (Price, 1964). These influences could be found in the Strasbourg clock with the automated manikins and the clock tower in Prague with the mechanical parade of figurines (Price, 1964). Another aspect of the mechanical entertainment was reintroduced by Jacques de Vaucanson and Wolfgang von Kempelen as the automaton in the 18th century (Peppé, 2002; Weibel, 2007).

The Automaton

Vaucanson created three different automata in Paris from 1738 to 1739, which greatly astonished the populace and impressed monarchs like King Frederick of Prussia (Delve, 2007). His first android automaton was a flute player utilizing levers, valves, and bellows (Delve, 2007). Although it was like a technological descendant from Hero of Alexandria and the Egyptian trumpet playing mechanism, Vaucanson's automata mechanically simulated human musicians and a digesting duck (Delve, 2007). His aim was not only to build marvelous replications of humans or animals, but also to precisely embody the biological organ mechanisms (Delve, 2007). Therefore, his mechanical duck made of gilded copper could imitate eating, drinking, digesting, and excreting as well as mimic the stretching body of a real duck (Delve, 2007).

A couple of decades later, the Austro-Hungarian inventor and artist Wolfgang von Kempelen combined interaction with automata inspired from the fear of intelligent machines or of the uncanny (Serexhe, 2007; Weibel, 2007). While Vaucanson represented human activities through machines, Kempelen supplemented the anthropological abilities (e.g., speaking and gaming) into

(a) a replica of the original

(b) the secret of chess game

Figure 4. Wolfgang von Kempelen, A Replica and Illustration of the *Chess Automaton* 1770.

automata (Weibel, 2007). His legendary anthropomorphic machine, the *Chess Player* (or the *Chess Automaton*) was first presented to Empress Maria Theresia, his sponsor, and the aristocracy in Hapsburg around 1770 (Fig. 4).

The Interactive Game Machine

After the death of Kempelen in the early 19th century, the first interactive game automaton travelled from Germany to other countries (Weibel, 2007). The *Chess Automaton* astonished Europeans and stimulated discourse about the difference between humans and machines, which was a new interaction in mechanical intelligence (Serexhe, 2007). It was designed for playing in chess matches against a mechanical chess player for an appreciative audience (Weibel, 2007).

According to one of the reports about the *Chess Automaton* in England (Hatchard, 1819), spectators could participate in a chess game with the automaton chess player, who dressed in traditional Turkish attire. The automaton always started each game with a white chessman and could play against his opponent like a skillful chess master. The automaton could precisely place a chess piece in a particular square every time. When a human opponent makes a mistake, such as moving a Knight as if it were a Castle, the automaton recognizes the error and immediately moves the Knight back to its former position with an unsatisfied reaction (Hatchard, 1819). Spectators were unacquainted with such mechanical sorcery, so the machine's anthropomorphic behavior baffled them and increased their suspicion of artificial intelligence.

Depending on other reports on the *Chess Automaton* (Evans, 1905), some spectators assumed a human chess player was concealed in the chest that was connected to the Turkish android. The invisible assistant, who seemed to be a chess expert, was hired by the exhibitor Maelzel in order to control the automaton. However, Evans (1905) states, "it was believed that the automaton was really operated by ingenious mechanism." The *Chess Automaton* represented mechanical intelligence before the development of artificial intelligence and robotics. Moreover, it was assumed to be an interactive game system that displays the mechanical phenomenon, which engrosses its participants and spectators. Thus, Kempelen achieved the principal objective of building a mechanical human, or a robot. It is a debatable whether his creation can be recognized as a primeval robot or merely an entertainment mechanism. However, Kempelen succeeded in creating an obstinate character that spectators might believe as a living automaton, although it was secretly controlled by human intelligence (Weibel, 2007).

Mechanical Metamorphosis in Modern Art Forms

In the 20th century, automaton was transmuted into mechanical art forms like kinetic art, robotic art, and kinetic mise-en-scène beyond commercial entertainment or robotics laboratories. Although the Czech novelist Karel Čapek produced the famous play *R.U.R. (Rossum's Universal Robot)* as the originator of the robot in 1920, the actual robot appeared in the late 1950s (Kac, 1997; Kumar, 2010). The decade falling between the late 1950s to the early 1960s was important to the proliferation of robots, not only in scientific research with the first industrial robot, but also in the art scene where modern artists experimented more with new media. This decade was the cultural intersection where the machine-age era was closed and the new information-age era began (Shanken, 2002).

Kinetic Art, Robotic Art, and Cybernetics

One of the most renowned art critics, Pontus Hultén, directed an influential exhibition called *The Machine: As Seen at the End of the Mechanical Age* that included mechanical artworks from Leonardo Da Vinci to collaborations between contemporary artists and engineers (Shanken, 2002). He also curated retrospective exhibitions of kinetic sculptures by Jean Tinguely, who developed ingenious kinetic artworks in the 1950s (Hultén, 1955). Hultén (1955) stated that Tinguely's meta-mechanics altered conventional engineering simply by involving the irregularities in motion without computation. Tinguely's kinetic art represented not only artistic machinery but also anthropomorphic machines, which can be found in the *Métamatic* series of the late 1950s. These machines generated different automatic drawings each time through unbalanced rotations. His most spectacular performance was the *Homage to New York*, which destroyed itself within 28

(a) construction

(b) performance

Figure 5. Jean Tinguely, *Homage to New York*, Museum of Modern Art, New York, 1960.
Photo © Cloud farm

minutes by explosions at the garden of the Museum of Modern Art in 1960 (Reichardt, 1987; Fig. 5). It showed the demise of mechanical life with a metaphor for “metallic suicide” (Reichardt, 1987).

Robots were introduced as an art form in the *Cybernetic Serendipity* exhibition at the Institute of Contemporary Art in London in 1968 (Shanken, 2002). Nam June Paik and Shuya Abe presented the first art robot *K-456* in 1964, where a humanoid artwork walked on the street and was hit by a car in New York (Kac, 1997; Fig. 6). Additionally, Edward Ihantowicz exhibited a big scale robot, *The Senster*, which could interact with spectators at Philips in Eindhoven from 1970 to 1974 (Kac, 1997). In the art scene, there were early imaginations and prediction on robotic existence before Čapek’s definition of the robot. The avant-garde artist Francis Picabia mentioned a robotic existence to Paul B. Haviland, an art critic, in magazine *291* on September 1915, where Picabia stated, “We are living the age of the machine. Man made the machine in his own image. She has limbs which act; lungs which breathe; a heart which beats; a nervous system through which runs electricity. The phonograph is the image of his voice; the camera the image of his eye. The machine is his ‘daughter without a mother’” (Reichardt, 1987, p. 368).

The Emergence of Robotic Art

During Modernism, numerous artists tried to develop automated machines. They extensively explored robotics in order to develop a new medium to express the hybrid of robots, media, systems, life forms, and context (Kac, 1997). The significance of robotic art is required in the new aesthetic dimension of modeling behavior and developing unprecedented interactive communications in physical spaces (Kac, 1997). Kac and Antúnez Roca (1997) declared that “Robots belong to a new category of objects and situations disruptive to the traditional taxonomy of art (p. 4).”

After the introduction of *K-456* by Nam June Paik and machine suicide by Tinguely, the Survival Research Laboratories (SRL) astonished spectators with aggressive machines that could pretend to attack an audience (Ghedini & Bergamasco, 2010). Since 1979, Mark Pauline and the SRL performed with dangerous robotic machines. The *Robot* was assembled by grafting a mechanical exoskeleton to the dead body of a rabbit in order to generate a reverse walking motion at the show *An Unfortunate Spectacle of Violent Self-Destruction* in 1981 (Kac, 1997). Contrary to Kempelen’s fear of mechanical intelligence in the 18th century (Weibel, 2007), their robotic performances revealed that the fear of mechanical behaviors seemed to be out of control. In the

(a) robot K-456

(b) robot K-456 hit by car

Figure 6. Nam June Paik and Shuya Abe, *Robot K-456*, 1964. Photo © Peter Moore

(a) the performance

(b) writing a word with the third hand

Figure 7. Stelarc, *The Third Hand*, 1981. Photo © Stelarc

same year, Stelarc performed *The Third Hand* in Tokyo (Fig. 7). This transplanted robotic hand, which was activated by the electric signal from his abdomen and leg, attached to his right arm and could write out “THE THIRD HAND” by following the movements of his right hand (Kac, 1997). The SRL and Stelarc tried to combine mechanical components with flesh in order to evoke the uncanny to frightened spectators. Their performances were traced to the avant-garde in the 1960’s, when Nam June Paik appeared like an artistic shaman with new media rather than traditional mise-en-scène.

Mechanical Metamorphosis in the Theater

The kinetic mise-en-scène can be historically traced through scenography from the Renaissance, Wagner’s statement of the *Gesamtkunstwerk*, the Bauhaus designs for immersive theater, and closely to the Czech director, Josef Svoboda in the 1950s (Dixon, 2007). Svoboda projected kinetic scenery on multiple screens to show enchanting illusions and spectacular scenes on the stage of *Laterna Magika* in Prague (Dixon, 2007). Such visual illusion and kinetic scenography was widely proliferated across art genres in the 1960s.

Robert Lepage is one of the directors who inherited the fusion of image projection and kinetic stage from Svoboda’s experiment (Dixon, 2007). Lepage trained in dramaturgy and scenography at the Conservatoire d’Art Dramatique in Quebec from 1975 to 1978 and later founded the production company *Ex Machina* in 1994 to bring thematic significance of technology to contemporary audiences (Allain & Harvie, 2006). The title of his company originated from the Latin *Deus ex machina*, referring to the Greek theatrical technique that God ultimately solves problems at the climactic moment of drama and descends through the mechanical crane, which was known as an invention of Hero. Three years later, he opened the theater *La Caserne* and renovated the former fire station with optimized theater space and technical workshops. Hence, he could completely present kinetic mise-en-scène in the *La Caserne* since the *Geometry of Miracles* in 1998 (Allain & Harvie, 2006).

Lepage tried to explore the spatial metamorphoses of space using the scenographic mechanics rather than the traditional dramaturgy of characters and plots (Dixon, 2007). For example, his Hamlet differs from Shakespeare’s protagonist in *Elsinore* due to the transformative stage and kinetic mise-en-scène. He deconstructed the original story of Hamlet and devised mechanical technologies to tell the story differently (Dixon, 2007). He transformed prosaic objects into technological metamorphoses. For instance, an ironing board appears as a gym bench and then as

Figure 8. Robert Lepage, The revolving stage of *Der Ring des Nibelungen*, Metropolitan Opera, 2012. Photo © The Wagnerian

an MRI scanner while a washing machine window becomes the portal to a manned spaceship in *The Far Side of the Moon* (Dixon, 2007).

Lepage's kinetic scenography caused an uproar after the premiere of *Der Ring des Nibelungen* in New York's Metropolitan Opera in 2012 (Fig. 8). He equipped a giant machine with 45 tons of 24 rotating planks to lift actors vertically and project video images. Anthony Tommasini of the New York Times criticized his mechanical opera in stating that it consisted of juvenile and intrusive details rather than dignified ways (Tommasini, 2012). Such hostile reviews reflect the opposite of mechanized stages and also derive from the traditional criticism given by Aristotle against the *Deus ex machina* in ancient Greece (Worthington, 1990). In addition to journalistic sarcasm, robotic artworks were often described by other artists as dysfunctional machines and funny assemblages in comparison to those in engineering labs (Ghedini & Bergamasco, 2010). Thus, the critical demeanor and the anti-machine philosophy have continued over two millennia.

Human-Robot Interaction in the Art Scene

Since the Neolithic period, all machines were operated by human hands. From the stone axe to the haptic surgical robots, the *Antikythera* celestial instrument to the smartphone, and the mechanical dolphins in Hero's theater to the rotational planks in Lepage's opera, machines were always operated by humans. When audience observe such a mechanical scenery in the theater, they might not distinguish the mechanisms those are operated by manual control or by an interactive system. In many robot demonstrations by robotics institutions, spectators may not have the chance to interact directly with a robot. Normally, robots are introduced by operators or a presenter that only focuses on technological improvements and new functions.

Dalsgaard and Hansen (2008) suggested that an interactive artifact needs to consider the interchangeable roles, which can be explained by the relationship between the spectator, user, and performer. When a user interacts with a system observed by other spectators, the user temporarily becomes a performer (Dalsgaard & Hansen, 2008). The changing of roles by robots will need to be explored further where robots perform and interact with humans in the physical space.

If a robot can pat a human face like a lover or the blind, then the user can empathize with the machine. Humans have an ability to imagine the machines as if they are living (Kozima, Nakagawa & Yano, 2004; Skogerson, 2001). The robotic artist and stage designer Louis-Philippe Demers presented various robotic works relating these two interaction factors between robots and humans where robots are living performers and empathetic machines.

Robotic Species on the Stage

Demers began his artistic career in robotic performance in theater, collaborating with Bill Vorn and Lepage's *Ex Machina* from the experimental play *Zulu Time* in the La Caserne in Quebec since 1999. They developed the shell structure of an airport as the stage, and five different robots to perform with actors. "It was one of the most technologically sophisticated and scenographically heavy metal performance ever staged" (Dixon, 2007). The robots acted not only as mechanical props with supporting roles but occupied several parts of the stage as robotic actors collaborating with human actors.

The long fascination for *Automata Theater* from Hero of Alexander was entirely fulfilled by Demers with the collaborative performance *Devolution* in 2006 (Demers & Horakova, 2008). For the dance theater, Demers designed 30 robotic machines and prosthetics to explore the relationship between robotic and human performers in the collision and confluence of the two species (Brannigan & Stewart, 2006). His robotic species performed as independent dancers, singers, autonomous lights, and aliens on the stage. The prosthetic apparatus attached to the human dancer but moved as though it were a cultured cauda. The choreographer Garry Stewart joined robotic artist Demers in designing the mechanical co-existence tensions, represented by the uncanny anthropomorphic evolution from metallic artifacts. It simultaneously extracted the zoomorphic potential of human bodies in the *Devolution* (Brannigan & Stewart, 2006). Human performers could dynamically interact with Demers' performing machines (e.g., hanging cubes, walking tables, choir robots, and many other mechanical species; Fig. 9).

Figure 9. Garry Stewart and Louis-Philippe Demers, A scene of *Devolution*, Australian Dance Theater, 2006. Photo © Australian Dance Theater

Empathy with Machines

The other attempt to design intelligent automaton, which Kempelen ceased with the pseudo-interactive machine, also passed down to Demers. Before the *Devolution*, Demers and Vorn in 1998 exhibited the interactive robot installation *La Cour des Miracles* with six different machines that could imitate physical behaviors of strange animals. The installation consisted of *The Begging Machine*, *The Convulsive Machine*, *The Crawling Machine*, *The Harassing Machine*, *The Heretic Machine*, and *The Limping Machine*. They intended to develop them so that the spectator would be empathetic to their characterized machines when they expressed pain (Skogerson, 2001). For instance, *The Convulsive Machine* shakes its spindly metal structure when near spectators (Skogerson, 2001). In this situation, the spectator acquires antithetical emotions from the unfamiliar machine: torture or empathy. If the spectator feels empathy with the machine's pain and steps back, the machine stops the interaction. In actuality, the machine cannot feel real pain from the proximity of the spectators (Skogerson, 2001). Such an unusual situation brings hesitancy about interacting with mechanical existence and also reveals the potential for empathic interaction between human and robot.

In 2012, Demers introduced an anthropomorphic robot that touches and gropes spectators as if it were a blind person (Fig. 9). *The Blind Robot* displays not only blind sensing in robotics, but also identifies humans with its empathy machine (Demers, 2012). When touching a spectator, *The Blind Robot* becomes a living blind person and the spectator has no choice but to embrace the machine's hands. In *La Cour des Miracles* (1998) and *The Blind Robot* (2012), Demers reversed the anthropocentrism into the machine-oriented situation. His robots attempt to control human emotion and transform their mechanical existence into animate beings rather than merely those imitating human appearance. Such an emotional metamorphosis of the machine-beings differs from the conventional robots and their interaction programs.

On the contrary, Ken Goldberg, Joseph Santarromana, and his collaborators developed a web-based telepresence robotic installation called the *Telegarden* in 1995. They installed an Adept robot arm in the small, real garden, where the robot can plant and water flora as a gardener controlled by users on the Internet (Kac, 1997). The connected users of the *Telegarden* could communicate with each other and share the real garden virtually. Although this secret garden appeared only thorough a surveillance camera on the web site, real plants grew with the users' name tags (Kusahara, 2001). The *Telegarden* presented not only the problems of telepresence and teleoperation, but also the communication-based interaction among invisible users rather than the local interactions between robots and humans. A collective interaction reveals the robot as an anthropomorphic performer.

(a) approaching a spectator

(b) touching face

Figure 10. Louis-Philippe Demers, *The Blind Robot*, 2012.
Captured images from the video clip *The Blind Robot* © L. P. Demers

Figure 11. Disney, Lucky the Dinosaur, Hong Kong Disneyland, 2005.
Photo © Disney Wiki

The Empathic Interaction between Humans and Robots

The empathic interaction between humans and robots is not restricted to robotic art or an Infanoid robot but expanded to the industrial robot. Rethink Robotics developed a human-friendly robot, Baxter, for the industrial environment in 2012. Designed to collaborate with nearby human workers and interact with them as an endearing co-worker, Baxter is equipped with a flat monitor representing its face to interact with users (Fitzgerald, 2013). Furthermore, it can display emotional feedback with its eye expressions (e.g., surprise and sadness, while also closing its eyes to users and co-workers). The designers of Baxter planned its user interface to appear simple and intuitive like a child who can learn to do something with guidance by parents (Fitzgerald, 2013). During the learning process, users may feel the anthropomorphic emotion of Baxter. Adding empathic interaction into robots will increase effective communication between humans and robots (Vignemont & Singer, 2006).

Service robots are increasing popular in adventure theme parks, shopping malls, and even in coffee shops close to everyday life. People can encounter an agent robot and order drinks from robotic baristas at Briggo Coffee in the University of Texas (Olsen, 2012). They still appear as automated systems that include an interactive user interface with a touch screen or via mobile phones. In the future, they can acquire empathic interaction with human beings so that they can perceive the varying emotions of a human guest. The robot artist Kenneth Rinaldo (1998) analyzed the relationship between humans and technology in the post-modern era: “In our time, with human cultural development so inextricably intertwined with and dependent on technology, our existence surrounded by a strangely comfortable embryonic sack of chips and wire, it is no wonder that a relationship between technology and phylogeny seems evident” (p. 372). Following his metaphor, the empathic interaction can improve the embryonic environment of the human-robot interaction.

Robots, as entertainment characters, have been continually developed by Disney for shows and amusements in theme parks in the tradition of animatronics (Madhani, 2009). As an example, Lucky the Dinosaur walks around the theme park with its usher and makes appropriate gestures to show surprise, sadness, anger, curiosity, and laughter (Wax, 2008). This pale green robot emulates

the living character in Disney animation (Wax, 2008; Fig. 11). The Walt Disney Imagineering R&D team designed the robotic interaction between the usher and spectators conjoining and exemplified the empathy between humans and machines. Similarly, *Wall-E* appears as a mobile robot like the character from the animation, and he can interact one-on-one with spectators (Wax, 2008). Spectators might feel empathy for the emotional states during the interaction. Contrary to the empathetic interaction with the familiar character, some spectators could feel discomfort, even though they perceive it as a robot. The falling point, where humans hesitate to interact with robots, needs to be investigated further in order to determine how humans perceive emotional borders of the empathic interaction.

Figure 12. A positioning map of robotic creatures in history. © 2014 Chang Geun Oh

Twenty creatures are spread over the graph. The vertical axis indicates a spectrum ranging from abstract design on the bottom toward anthropomorphic or animalistic appearance on the top, and the horizontal axis indicates control methods ranging from manual control on the left and moving toward empathic interaction on the right. The numbers of icons are arranged by their chronological appearance in history (No. 1: Toy Milling Servant, 2: Antikythera Mechanism, 3: Illustration of Rotating Dolphins by Hero of Alexandria, 4: Galatea and Pygmalion in Ovid's *Metamorphoses*, 5: Parade Manikins in Prague Clock, 6: The Digesting Duck, 7: The Chess Automaton, 8: Homage to New York, 9: Robot K-456, 10: The Senster, 11: Rabot by SRL, 12: The Third Hand, 13: TeleGarden, 14: The Convulsive Machine, 15: Lucky the Dinosaur, 16: *Wall-E*, 17: Devolution, 18: The Baxter, 19: The Blind Robot, 20: *Der Ring des Nibelungen*). This graph illustrates the characteristics from the articulated figurine in Egypt and theatrical mechanism in ancient Greece to the animation robots in the current century as created by modern inventors and artists. The empathic interaction between humans and robotic creatures reached a peak on the top right point where the myth of Pygmalion is located.

Conclusion

Robotics has a rich history involving robotic creatures that includes the work of artists and inventors even before the foundation of robotics in the middle of the 20th century. The passage of robots was initially acknowledged as a form of myth and novels by artists and inventors who developed machines that could be physically metamorphosed. This passage was finally headed toward robotics converging upon interactive robots. Originally, artists were believed to create living existences, which was demonstrated by Pygmalion represented as a sculptor rather than as a king of Cyprus in Ovid's *Metamorphoses*; Hero of Alexandria could also be named as the first designer working with primitive robots on the mechanical stage, not only a mechanical engineer of the era; Wolfgang von Kempelen astonished spectators by his pseudo-intelligent automaton as the first inventor of game robots; Nam June Paik proudly marched with the first humanoid on the streets in New York; and Demers finally suggested the machine-centered interaction with empathy through robots with disabilities. Thus, these robotic artists inspired robotics researchers with their enthusiasm and considerable ideas in order to design significant methods in the human-robot interaction field. From this historical perspective, robotics engineers can learn from the numerous artworks that experimented with various expressions of sentiments from objects.

When Pygmalion patted his female sculpture on the bed and dreamed of it transforming into a real woman, *Galatea*, the keen interaction altered the reality. This myth reflects human nature in creating a similar existence in robots. Thus, humans have tried to develop autonomous machines that mechanically depict themselves as intelligent and emotional machines. The similarity between humans and robots depends not only on the anthropomorphic appearance or sophisticated algorithms but also on the capability for empathetic interaction. The interactive robots by Demers and Disney proved the potential of emotional interaction among robots and humans. As shown in Baxter, a human-like feedback is also required in industrial robots so that they become effective collaborators. In addition, the empathic interaction with robots requires more discussion on the interaction design in robotics and cognitive science. There are abundant examples of robotic creatures in history, including art works and creative inventions, which can be rediscovered for further human-robot interaction.

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