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Robots on stage

Henning Christiansen[1,*] & Anja Mølle Lindelof[2,*]

[1]Department of People and Technology & [2]Department of Communication and Arts
Roskilde University, Roskilde, Denmark

Abstract

This article investigates the appearance of robots on stage in contemporary performance. As a convincing demonstration of the relevance of robots – as artefact, concept and metaphor – we take Blanca Li's 2013 dance performance *Robot!* as our starting point. We have distilled five dimensions that provide vocabulary and terminology to characterise different instances of robots on stage with a focus on their expressive character. These dimensions are: Movements, Apparent level of Autonomy & Interaction, Appearance, Massification and Sound

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1. Introduction

25 minutes into the contemporary dance performance *Robot!* the show's protagonist – a 58 cm tall, plastic robot of the label Nao – is introduced as it teams up with a male, human dancer in a passionate *Pas-de-deux*. The Nao is brought on stage in a closed box by the solo dancer: Newly bought – still to be unpacked from its box. New-born – with its visual resemblance to a child, about to explore how to move and come into being. During the sequence, the Nao slowly unfolds into a human-like character as it learns to dance; see Fig. 1. Being interested in the use of robots on stage, this is a great example of a performance that pushes the limits of the performative potential of the Nao robot: Choreographing a compelling human-robot-interaction. Projecting feelings and empathy into the plastic robot. Making the audience go "aahh!" in sympathy with the animate creature on stage.

Interestingly, and perhaps surprisingly, this sequence's convincing interaction is entirely pre-recorded. This sequence has been developed in an iterative process with choreographer Blanca Li in the role of the robot, and subsequently transferring her movements and gestures to the robot and testing with the dancer step by step. During the live performance, the robot replays these patterns and their embedded emotional and communicative cues towards which the dancer reacts in real time. And yet the scene convincingly appears as a tender, mutually emphatic and, to some extent, spontaneous interplay between two equal partners, the robot and the male dancer. According to engineer Thomas Pachoud and assisting

Figure 1. Rehearsing the *Pas-des-deux* of Blanca Li's *Robot!* before performing in Mâcon, 2016.
(Photo copyright © Henning Christiansen 2016)

*Corresponding authors. Email: henning@ruc.dk, lindelof@ruc.dk

choreographer Pascale Peladan (personal conversation), this was the only meaningful way to create this sequence due to both the imperfections and limitations of (the Nao) robot technology and the detailed timing and flow of the show that do not leave a fraction of a second for the robot to wander off. Any interest in robots on stage is confronted with this dilemma between working with the fascinating, autonomous behaviour of robots and the demands of control in show business.

This article proposes a vocabulary and an ontology to characterise robots' appearances in scenic performances. In doing so, we take a dramaturgic point of view on robots on stage. Focusing on dramaturgy – as opposed to using a technical definition of what is a robot – means that we consider how a notion of robot is experienced, and if and how autonomy is enacted on stage. This aim is inspired by the increasing number of robots appearing in staged performances, the intriguing nature of the very subject, and further motivated by our own work in progress design of animating familiar domestic objects for stage performances. The article takes its starting point in *Robot!* which exposes a highly diverse array of staged, robotic gestalts.

Robot! is a dance performance by Bianca Li Dance Company featuring dancing robots and human dancers, accompanied by an on-stage mechanical orchestra. It plays with the ubiquitous presence of technology in our society and the way in which robot technology has gradually moved from research labs and specialised industrial plants. They have become an integral part of people's daily lives in the shape of intelligent copiers, lawn movers, vacuum cleaners, toys, parking assistants, and a horde of self-driving vehicles now readily rolling in. This "uncanny ballet with men and machines," as described by the magazine Elle,[1] stages human-robot relationships through choreographic means of expression. Featuring a dance company of eight highly skilled dancers and the Nao-robot with its specific technical qualities and anthropomorphic character as a main figure, the show allows for subtle explorations of the relationship between robots and humans across its various tableaux. Complementing what we might coin the "main story" about a Nao robot learning to dance, various other types of robotic appearance are on stage during the show, including robot vacuum cleaners, remote controlled moving vehicles, mechanical musicians and humans dressed as cartoon robots. While this variety of appearances all refer to some notion of a robot, they differ with regard to their robotic gestalt and their grade of autonomy, pointing towards an ambiguity in what we perceive as robots on stage.

The question of autonomy is central to any discussion of robots on – or off – stage. A narrow definition of robots would, as [24] suggest, imply that "the exigencies of live performance require robots to move autonomously or semi-autonomously alongside human performers and in coordination with human operators". In order to characterise performing robots from a technical implementation point of view, Lu (2012) suggests a two-dimensional matrix model whose dimensions are *Autonomy* and *Control*. For example, autonomy ranges from the robot being entirely controlled by a human to the robot controlled by an algorithm (e.g., based on artificial intelligence). This view of what a robot is becomes too narrow for our purpose as the *Robot!* performance clearly illustrates. Accepting the show's many notions of a robot on stage and considering the (intended) audience response, we suggest pragmatic as well as dramaturgical reasons for a broader definition. We put forward a many-dimensional matrix and metaphorical vector-space in which each point indicates one particular form of appearance of the notion of "a robot". These dimensions are intended to represent essential, identifiable properties which are more or less orthogonal and all together span a rich and complete space of "robotic" performative opportunities. The application of this matrix is double, serving as a tool for analytical perspectives as well as for explorations into the design of robots for the stage.

Outline

Emphasising the cross-disciplinary interests when studying robots on stage, Section 2 gives an overview of related studies of performing artefacts, focusing in particular on the fields of performance studies and Human Robot Interaction (HRI). Section 3 narrows down our focus towards robots on stage as "performative gestalts" and includes some remarks on how we see the state of the art in robot technology as relevant for the present study. In Section 4, we present our classification matrix and the five dimensions that we have identified on the basis of *Robot!* and other stage performances; we describe each one in more detail and eventually exemplify the dimensions in use. The concluding Section 5 summarises the argument and discusses further issues and perspectives for future work.

2. Studies of performing artefacts

The present study touches upon many different research areas, ranging from robot technology and engineering to performance theory and philosophical treatments of artificial intelligence. We do not intend

[1] *ELLE*, December 13, 2013. Interview with Blanca Li with comments by Sylvia Jorif: *"... étrange spectacle ballet entre des hommes et des machine"*.

to give a complete or representative survey of the vast literature. Instead, we wish to provide as much background as is necessary for contextualising the present study and for making our own starting point clear.

2.1. Robots in performance and in performance studies

As robots in recent years have become increasingly cheaper, more robust and easier to program, they have also become increasingly apparent on stage. Not just on podiums, at fairs, or in RoboCups, but also as part of more traditional artistic practices like contemporary dance, popular music performance and naturalistic theatre. Industry robots are doing synchronised dancing in popular music shows such as Mylene Farmer's Concert Tour (2013) and the Eurovision Song Contest's semi-final (2016). Androids appear as protagonists in naturalistic theatre performances in Hirata Oriza's *Robot Theatre* (2004–), robotic objects as dancing props with agency (e.g., quadcopters in *Sparked* by the Cirque du Soleil, 2014), and a variety of types of robots in dance and theatre performances such as *Robot!* by Bianca Li, 2013 and *School of Moon* by Eric Minh Cuong Castaing, 2016), in opera (e.g., *Death and the Powers*, 2010, developed at MITmediaLab and *My Square Lady*, by the artist collective Gob Squad) as well as in performance installations (e.g., fish-bird-series 2003-2009, by Mari Velonaki). All of these performances include robots in their set-up, but differ in their emphasis on spoken dialogue, movement or sound, and with regard to technological means as well as to dramaturgic purpose. Also, performance has always adopted and played with new technologies. Certainly, including life-like artefacts in performance is not a new phenomenon. We shall here bypass habitual references to ancient Greece and the early stages of automatons and jump to the early industrial age as the background of some of the basic thoughts on human-machine interaction we still identify today, thematically centred around the question whether or not machines may replace "the real". We see well-known examples in the mid 19th century, such as Hans Christian Andersen's fairytale *The Nightingale*[2] from 1843 and the mechanical dancing puppet Olympia in Jaques Offenbach's opera *The Tales of Hoffmann*[3] from 1881. The issue in *The Nightingale* is the experience of a mechanical bird, from the first fascination of its perfection in singing technique, to the boredom and depression due to its lack of heart and variation, and ultimately to the acclaim of the real nightingale and its song. Olympia is the doll that comes alive and enchants Hoffmann so that he falls in love with it/her. The ideas of artificial humans and simulated intelligence were also apparent at that time, cf. Mary Shelley's *Frankenstein*[4] (1818) and Charles Babbage's design of his analytic machine (1820s), traditionally emphasised as the first modern, programmable computer. Even the word "robot" is ascribed to a theatre performance, the 1921 *R.U.R.* by Karel Capek.

In literature, several comprehensive studies seek to systematise the use of new, digital media in performance [e.g., 2, 15]. In his comprehensive overview of the history of performance incorporating (digital) technology, Steve Dixon suggests that "the use of robots constitutes one of the most technologically advanced developments within Digital Performance" [14, p. 271]. The appearance of robots on stage raises the question of how to deal with performing artefacts that disturb with a fundamental understanding of live performance as human agency on stage. Subsequently, robots on stage are often discussed in terms of a broad, philosophical interest in the influence of digital technology on performance, in which the use of robots is aligned with the use of projections and other "artificial" onstage performers or virtual object-figures. The idea of (strong) artificial intelligence challenges traditional notions of performance, based on a notion of liveness that basically implies human beings on stage in front of a live audience. While the experience of dance, music and theatre as something live is valued and celebrated by audiences and practitioners alike, the status and significance of the live in contemporary performance is disputed [e.g., 1, 37]. For performance scholar Peter Echersall "a dramaturgy of robots and object-figures is noteworthy for the ways that it is extending the idea of performance" [16, p. 129], exactly because it blurs the borderline between live and mediated performance, between human and machine. One such example is the *Robot Theatre* by the Japanese duo Hirata Oriza and Hiroshi Ishoriguro. The main goal here is to develop robots that look and act as much like humans as possible, to which end Oriza has developed what he terms an "actroid" – an android robot that potentially can substitute an actor on stage, designed to act like a human by showing strong visual and behavioural likeness, and to act as if it has empathy (see, e.g., Ogawa et al [2014]). In this case, the autonomy or semi-autonomous actions are emphasised, and the focus is merely to investigate the technical means of production. In any experiment in which technological agents are used to replicate, augment or replace human actors in performance, the question of these agents' "proto-subjectivity" becomes

[2]Original title *Nattergalen*. Original text at http://adl.dk; search for the title. English translation at http://andersen.sdu.dk/vaerk/hersholt/TheNightingale.html.

[3]Original title *Les contes d'Hoffmann*; original libretto and English translation at http://www.gutenberg.org/ebooks/15915.

[4]Original text available at http://www.gutenberg.org/ebooks/41445

central [15, p. 113] and raises the basic question to what extent a robot can act?

Another line of artistic inquiry seeks, on the contrary, to underline the materiality of the machinery. For example, the term "metal performance", coined by Steve Dixon, emphasises the symbiosis of flesh and metal. It covers robots as well as cybernetic organisms, "cyborgs", and stage the machination of the human, enhancing the human body through the use of, e.g., medical instruments, prosthetics, robotics or virtual reality systems. Here, the question of autonomy is put forward in a more distinct way, since the extensions of man include the ability of the technology to react in unforeseen ways and to operate through self-generative processes and not completely under the control of the artist, performer or programmer. The important question thus becomes how the technique influences the creative process? For both, a related question is if and how this autonomy or quasi subjectivity becomes visible to an audience and to what extent there is a need to create certain "visual clues" to manage the audience attention in a performance situation [5, 46]. See also the analyses of [8, 10].

2.2. Human Robot Interaction studies and "theatre" as metaphor

The research field of Human Computer Interaction, HCI, considers the design and evaluation of computer systems, experienced through their user interface. Quality measures typically concern how efficiently and satisfactorily a human user can solve given tasks in an interaction with the system. Traditionally, but not exclusively, HCI concerns situations with a user seated in front of a computer system equipped with standard input-output devices such as high-resolution, graphical monitors, keyboards and computer mice. The user commands the system by explicit input (entering text, clicking buttons, etc.), and the system responds in various ways. Human Robot Interaction, HRI, is a subfield of HCI. The interaction between humans and robots – and thus the design and evaluation of such interactions – is more subtle. The relationship is closer to symmetric, as the human and the robot both may take initiatives and communicate through presence and action in physical space. The robot's communicative acts may be aided by anthropomorphic traits such as gestures and facial expressions, and it may be programmed to simulate social skills and to interpret the human's spoken utterances, facial expressions and even body language. The interaction between human and artefacts may resemble a cooperative process between humans with a subtler and partly implicit communication.

For example, [42] propose criteria for design and evaluation of socially assistive robots that involve personality, empathy and other properties inherited from how we would consider a human assistant. This approach is also relevant for understanding less sophisticated and non-humanoid robots, considering how these artefacts are experienced (rather than what they are). It is, for example, not uncommon for users of advanced copiers to associate a certain personality and (lack of) empathy to these artefact, especially when they do not behave as expected. The conference paper [13] investigates the influence of a humanoid robot's body language based on how it is experienced. The annual ACM/IEEE International Conference on Human-Robot Interaction provides a good overview of the area, and concerns roughly equal portions of reports of technological progress and of evaluation methods [see, e.g., 3, 27, 28].

Theatre has often been used as a metaphor in HCI and especially HRI for controlled environments for testing, having a number of "actors" (some human and some robots), each playing a certain "role" [e.g., 7, 25, 35, 36, 40]. From an engineering point of view, such a setup has the advantage that HCI/HRI issues can be tested in isolation and in controlled environments, as the robots' fixed manuscript eliminates the need for, say, convincingly simulated intelligence and ability to improvise.

Such test beds are typically used in experimental laboratories or university settings, with the audience being academic staff and students and the purpose is to test robots as such (technical robustness and/or HRI) or to investigate new dramatic forms [see, e.g., 24]. Or it can be in school (elementary, secondary, ...) settings with pupils and their teachers as actors, technicians and audience. The purpose may be to teach theatre, programming, or a mix [e.g., 23]. This sort of theatre for testing has also been used with humans playing roles as robot, perhaps through remote control – which is a quite cost-effective way of testing new technology without having to actually build it first.

Another and overlapping field is the research field of Social Robotics, as, e.g., manifested by an annual conference series, e.g., the most recent ones [38, 47], and a research journal; [5] see also the recent collection [45].

In some cases, the robots' interpretation of people's doings is important for the show to succeed, in other experimental dance shows it is central for how the show proceeds. In the famous, referenced study by Ogawa et al. [2014], a robot with a very human-like face and body is citing poems to a dying woman. This actroid is seated in a chair, so that the need for human-like body movements (which are quite difficult to obtain) is reduced.

[5] https://link.springer.com/journal/12369

In the *Pas-des-deux* scene of *Robot!* described in the beginning of this article, the robots' interpretation of people's doings may technically speaking be less important, since an illusion of this can be created by professional performers and (for the robot's part) pre-recorded sequences.

3. Prop or performer?

Strong artificial intelligence, as defined by [39], i.e., the machine has a real mind,[6] is a philosophically intriguing idea, which is still far from present day, reactive technology. However, several authors have considered the (ethical as well as artistic) question of whether intelligent computers will be able to create (in a true sense) art [26]. Consequently it has been suggested that in "Robotic Art", the robots constitute the work of art, rather than creating it [29]. Robots on stage are, thus, an inspiring area of investigation as robots perform alongside human performers and non-human props with a natural focus on the act of performing, rather than speculation of whether the robots themselves are "really" creative.

3.1. State of the art in robot technology

The principles of robot technology have not changed in any drastic way in the last few decades. The dominating software paradigm, called behavioural robotics, as formulated by [6], is based on a constantly running sense-decide-act loop, that at any given moment selects a behaviour (or combination of such) that is judged most optimal here and now, e.g., follow-planned-route, avoid-unexpected-obstacle, etc. This paradigm provides a simple but effective sort of autonomy, so a robot can perform certain tasks, while reacting suitably to changes in the environment. Seemingly advanced patterns of conduct can be induced by fairly simple programs. This ranges from practically relevant devices such as robot vacuum cleaners to the seemingly very robust, more or less absurd creatures exposed, e.g., by the company Boston Dynamics.[7] Upon a behavioural software platform, all sorts of decision making and planning software can be added, as, e.g., demonstrated by self-driving cars, but we judge this (currently) less important for robots in performative contexts.

As suggested, interesting appearances of a robot on stage may be achieved also without technically true interaction between robot and human actor, or between robot and audience. Pre-recorded patterns of robot movements and actions may be replayed by software running on top of a behavioural platform that supports the robot's physical presence, e.g., for keeping the balance while walking, getting back on its feet if it unexpectedly falls, etc. This is exemplified in Blanca Li's *Robot!*. Robot movements may be described in dedicated script languages – find a recent collection of papers on this subject in the book "Dance Notations and Robot Motion" [30].

As we see it, the most important development in recent years is that robots become increasingly cheaper, robust and easier to program. The programmable Nao robot that we have mentioned several times, is a good example of this [19]. It comes with a fairly easy to use programming environment, given the illustrative name *Choregraphe*,[8] which is partly graphical and provides a large collection of predefined behaviours. It can also record movements, performed by a choreographer in slow-motion by bending the robot's physical joints, for later playback.

Another exciting development is the emergence of very cheap do-it-yourself hardware components, such as Arduino,[9] by means of which excited amateurs without an engineering degree can tinker together and program their own robots, utilising whatever is available of cheap wheels, motors and batteries. For less than one hundred EURs, it is possible to produce, say, a box-formed, autonomously moving robot having a reversed broom on its top and a few blinking lamps, capable of reacting to an actor's simple gestures.

The Lego Mindstorms kits,[10] introduced initially in 1998 and continually developed, make robot construction and programming accessible to children, and have had the effect of de-mystifying the understanding of what is a robot:[11] it is not necessarily associated with true and dangerous "artificial intelligence", but is typically a simple mechanical artefact controlled by straightforward algorithms.

3.2. Robots as performative gestalts

The reception of robots depends very much on the expectations of the audience as it is imposed by the context of the performance. The studies mentioned sofar most often assume a more or less humanoid robot appearance as this may naturally enhance humans' interpretation of robot behaviour. Recent research concerns another scenically interesting and challenging issue of making non-humanoid robots expressive, related to a study of the receiver's cognitive mechanisms [see, e.g., 4, 17, 22, 31–33, 41].

[6]Most convincingly depicted in Stanley Kubrick's and Arthur C. Clarke's movie "2001, a Space Odyssey" as the visionary HAL 9000 computer.
[7]http://www.bostondynamics.com)

[8]See http://doc.aldebaran.com for details.
[9]https://www.arduino.cc
[10]https://www.lego.com/en-us/mindstorms
[11]... de-mystifying, as opposed to the way robots are often portrayed in movies and journalistic writings.

For example, Gemeinboeck and Saunders [18] have experimented using machine learning techniques to identify expressive patterns of movements, created initially by human performers placed inside flexible "artefactoid" objects. Takayama et al [41] have applied results from studies of animations to make the intentions and reactions of a robot in social contexts easier to interpret by humans. A variant of this is the study of robots appearing as familiar domestic objects, FDO Robots [11], which in addition to expressive movements, also takes into account the audience's expectations of contexts and situations associated with the chosen FDO. FDO robots in performances also emphasise the importance of the human co-actors' pretending an emotional contact with the robot, thus creating an illusion of the robot as a creature having emotions; see Figure 2 for an illustration of this. See also [43] for another appearance of FDO robots in the shape of animated furniture.

Figure 2. Human actor in close and emphatic contact with an FDO robot, whose body is borrowed from an old-fashioned vacuum cleaner.

As suggested in Section 2, there is a variety of situations in which robots appear on stage, ranging from full scale, professional performances for a paying audience over short (entertaining) intermezzi in larger events such as concerts and TV shows, to experimental laboratory or university settings with its audience being academic staff and students [see, e.g., 24] or performance installations in which there is no clear distinction between auditorium and stage [see, e.g., 44] and in which the interaction between performers and audiences is continuously negotiated.

Demers [12] coins the term "machine performers" in order to cover a broad spectrum of inanimate performing artefacts. From a phenomenological and embodied perspective on his own work *The Tiller Girls*, he emphasises how also machine performers need the co-presence of the audience to be fully realised (p. 276). In other words, in robot performance as it appears for the audience in the auditorium, it is not necessarily the question of autonomy that goes first.

4. Five Dimensions to Describe Robots on Stage as Performative Gestalts

Robot! stages, as stated earlier, the relation between humans and modern technology as a continuum allowing for humans acting as machines and machines becoming animated. The show includes different notions of a robot in each of its sequences. Besides the use of Nao robots (that appear approximately 15 minutes out the show's 60 minutes duration) and human dressed like and/or acting robot-like, the show includes among others a self-moving litterbin on wheels, remote controlled play toy tanks, vacuum cleaners and an on-stage orchestra made out of humans sized mechanical instruments.

Following the idea of machine performers calls for a common interest in these robot as performative gestalts. This includes their expressive as well as anthropomorphic character of their robotic gestalta, and it gives special attention to questions like: What are the roles of the robots used on stage – do they play a main character or is it just a supernumerary? Is it a robot playing a human or does it play a role as a robot and by which means are human-like, communicative features created? Is there one robot or are there many? Do they interact with one another or with human dancers? Some of the answers to these questions lie in the making of the robot – its level of mobility, its looks and gestures and the use of exaggerated clues. Others are to be found in the role the robot is playing, in its interaction with other figures on stage and in the way in which an audience is invited to react with empathy or even to project human feelings onto the machine performer. In the case of *Robot!*, the physiognomy of the Nao, with its human baby body shape, its limbs and blinking eyes, matters, but what makes it most believable is the way in which the human dancer treats the Nao and reacts to its movements and gestures.

Below we introduce five dimensions suited for characterising the robots on stage as performative gestalts. These dimensions describe a metaphorical vector-space in which each point indicates one particular form of appearance of "a robot". The other way round, measuring these dimensions of a specific staged robotic appearances serves as a tool to describe it with special regard to its expressivity potential and anthropomorphic features. Our choice of dimensions condense the material presented in the previous sections inspired by the questions raised by the robotic appearances in *Robot!* and the various performances listed in Section 2.1. The particular number of dimensions (and the definitions thereof) are not final, but open to elaboration and discussion. To illustrate each dimension, we visualise its potential value space as an indicative linear scale that orders some selected values. Of course, this can only be a coarse approximation, since our dimensions in most cases contain more complex values than can be ordered in a linear way.

Dimension 1. Movements

The ability to move is often seen as a defining characteristic feature of an artefact called a robot. On stage, movements are among the prime instruments to create an impression of agency, independently of whether the robot changes its position, moves its parts or both. Absence of movements, or limited movement may also be used dramaturgically.

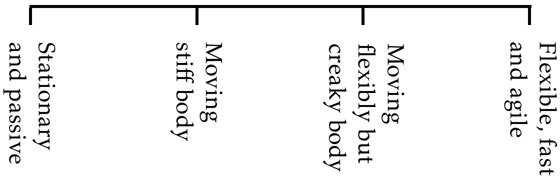
In *Robot!*, the central Nao robot is demonstrated with its many degrees of freedom in its creaky movements: it is dancing in an often clumsy way, it walks, falls occasionally and is able to rise again. In several sequences, most notably in the *Pas-des-deux*, Nao's clumsy movements, small size and doll-like appearance give the impression of a child, appealing to the audience's sympathy. A quite different robot in *Robot!* is a self-moving litter bin on wheels, opening and closing its lid, creating the impression of a mouth ready to eat the litter it is served.

The classical industry robot arm can produce very complex movements, very fast and with high precision; best known is the KUKA mentioned above from 1973 that can rotate around 6 axes. As it has been demonstrated in numerous shows, performances, interactive installations, etc., these robot arms can produce very suggestive human-like dance-like patterns, even though they are typically fixed to the floor and do not at all look like a human dancer. This is demonstrated convincingly in the video[12] from Mylene Farmer's Concert Tour in 2013 mentioned above.

Flying drones or quadcopters can move in three dimensions and tilt or rotate in different ways (called roll, pitch and yaw) with high flexibility and accuracy, although not with the speed of a KUKA robot arm. The lampshades in the *Sparked* video[13] by Cirque du Soleil are made flying by such drones (invisibly to the spectator), and they can react instantly to a human actor's movements, thus creating the impression of a dialogue by movements alone.

[12]https://www.youtube.com/watch?v=wQ3MqPUqCes
[13]https://www.youtube.com/watch?v=6C8OJsHfmpI

Dimension 1, movements. Indicative scale:



In this case, the simplification into a linear scale blurs the distinction between a stationary robot moving its parts (say, a KUKA robot arm), and a robot able to traverse the whole stage space in three dimensions (say, a flying lampshade); both could classify as "flexible, fast and agile". The two middle samples may represent, say, a consumer vacuum cleaner and the Nao robot.

Dimension 2. Apparent level of autonomy and interaction

While the previous dimension is close to being measurable in terms of numbers, the dimension of autonomy and interaction relies on qualitative parametres. As we have discussed, the term "apparent" is important, as a well-planned bluff, perhaps supported by competent human performers, may be at least as convincing as relying on current AI technologies.

A robot may behave in a highly mechanistic way, always giving the same response in similar situations, or it may appear as an active agent that takes its own decisions, or at least showing immediate and perhaps spontaneous reactions.[14]

The *Pas-des-deux* scene of *Robot!* is an eminent example of how a meticulously developed script, executed with accurate precision by a robot, is part of creating a perfect illusion of an autonomous entity that interacts according to its emotional state.

We see interaction and communication tightly integrated with autonomy, as any communicative act reflects a decision of doing that act. Reactivity is a related term: the act of avoiding an obstacle, say, a human, rather than bumping into it, may also be seen as a communicative act, expressing an intention of not harming that obstacle. On the other hand, reactivity is typically applied to mechanistic reactions to changes in its context (cf. its antonym proactivity).

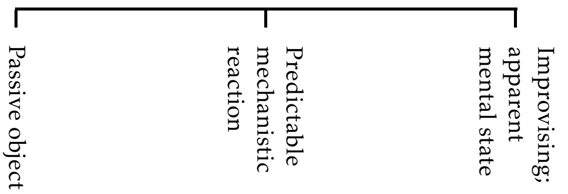
The consumer vacuum cleaner robot that appears in the tumultuous final scene of *Robot!* together with numerous other mechanised artefacts is – technically speaking – the only fully autonomous robot in that performance. However, there is no dramaturgic emphasis on this autonomy, and it is anyhow in the part

[14]It is a well-known trick among programmers of robots and computer controlled artistic installations, that adding a bit randomness and noise – i.e., programmed imperfection – is an easy way to obtain some impression of humanness and intelligence [our own observation; no documentation].

of the spectrum for mechanistically, reactive robots. We may hypothesise that the purpose of including it in *Robot!* is exactly to demonstrate this sort of dumb but useful robots.

Robot Soccer represents an ultimate exposition of genuine robot autonomy, interaction and coordination. As in human soccer, the unexpected and known-to-be-unknown final outcome creates an additional excitement. Robot soccer competitions are in most cases organised as part of technical rather than artistic or scenic events; however, they are experienced by the audience as entertaining and engaging performances.[15]

Dimension 2, apparent autonomy. Indicative scale:



A stance in between the middle and right examples in the scale is represented by the dance performance *School of Moon* from 2016, choreographed by Eric Minh Cuong Castaing. Here children and Nao robots are imitating each other's movements, guided by two professional dancers. The result is a very fine and subtle communication between humans and robots, that seems difficult to create by the bluffing approach we have praised so far.[16] This also points towards the possibilities of different performance genres and the relative ease with which, e.g, improvisational theatre and experimental dance are able to adapt and explore autonomous performative gestalts in the performance situation.

Dimension 3. Appearance: humanoid, abstract or perhaps something else

The perception and reception of an entity on stage as a robot is a combination of different and often coherent properties. For example, the Nao's visual appearance as a small plastic doll with slightly oversized head (this dimension) together with its clumsy way of moving (Dimension 1) may likely be experienced as resembling a child. In order to keep our dimensions more or less independent, Dimension 3 may be though of as what can be deduced from still images of the entity in question.

We have already described several different robots of *Robot!*, including some that are played by human performers. Some robots appear very human-like, such as Hiroshi Ishiguro's seated lady reciting poems in Mirata's "Sayonara" and his showcase of a robot looking exactly as himself. In the other end of the spectrum, we find totally abstract objects used mostly in academic studies such as [18] for which only their movements indicate some sort of agency. An extreme example of such an object may be a box or sphere with no texture at all and a colour of 18% gray. Robots dubbed as "humaniod" come in many variations: the mentioned "very human-like" ones, Nao's abstract (but dramaturgically effective) human-like body, strange devices moving on wheels with the association to a human are created by an animated face shown on a computer screen placed at the top of the device as exercised in several works by Stelarc [20, 21]. An effective and minimalist way to make an artefact give association to something human or an animal is giving it (perhaps a very abstract representation of) eyes: two LED lamps placed in a suitable distance on a robot arm are sufficient, as, e.g., appearing in the video from Mylene Farmers Concert Tour mentioned several times.

Robots may also appear in the shape of familiar domestic objects, say a chair, a table or an old-fashioned manual vacuum cleaner, as already mentioned [11]; there is nothing "robotic" in their visual appearance, but as soon as they start acting, this changes. The visual design of mechanical instruments delivering music throughout most of the *Robot!* performance takes another direction: a relationship to humans is created by the size of the instruments and an occasional hand or pair of lips, but apart from that, they take one form more absurd that the other, something in between creatures from a painting by Hieronymus Bosch and selected rock LP covers of the 1960s.

Overlapping with the previous category are household robots such as the typically flat round consumer robot vacuum cleaners and robot lawn movers, which can appear as themselves, triggering a sort of familiarity. The industrial robot arm is not truly household and most people have never been close to one, but will anyhow likely recognise it, since robots arms have been around for more than half a century and have become a standard icon for modern industrial production methods.

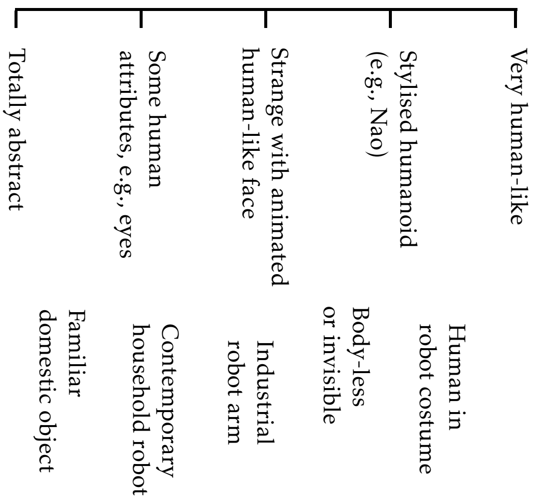
We will also mention human performers – recognizable as such – taking roles of robots. In *Robot!*, we see an ensemble of humans dressed in colourful cardboard box costumes representing a notion of a robot known from comics series and children's drawings, and we see normal looking people whose robotic nature is indicated by exaggerated stiff and "algorithmic" movements (i.e., a value in Dimension 1). An intriguing example of a human acting as a robot is the already mentioned, Olympia of *The Tales of Hoffmann* that is multilayered in the sense that the audience is expected to recognise that

[15] See the official RoboCup webpages http://www.robocup.org for background and links to a videos.
[16] Find more information and videos at http://shonen.info/schoolofmoon/.

a human singer plays the role of a robot playing the role as a human; the robotic layer be may emphasised by the costume (this dimension) – Olympia is often equipped with a winder – and is exercising stiff movements (Dimension 1). The options for visual appearance are endless, and let us end with an extreme example of a robot having no visual body – or rather, the entire stage space is its body; HAL in Kubrick and Clarke's movie "2001: A Space Odyssey" is a frightening example of this.

It is impossible to compress the rich space of visual robot appearances into a meaningful linear scale, so instead we show a line corresponding to "degree of humanoidism" and let those that do not fit in here float in the space, separate from the line.

Dimension 3, appearance. Indicative scale:



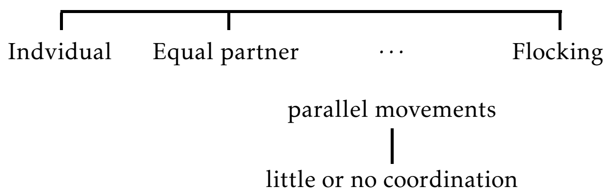
Dimension 4. Massification or individual

Massification is a well-known and recognised parameter in performances and other art forms, and is worth emphasising for robots as well. This goes beyond basic questions such as if there is one or many or if they play a main character, supporting roles or act as supernumeraries. Of course, such traditional terms may apply to robots as well. More interesting to pursue is the dramaturgic potential of robot technology's intrinsic possibility of mass production of totally identical robots, perhaps executing the exact same movements at exactly the same time. Since ancient Greek dramas, the chorus has often played the role of the public opinion; similarly, a chorus consisting of robots rather than people may be chosen to emphasize a mechanistic-stupid pattern of reaction. Identical or almost parallel movements of a few, say two to five, or up to many similar performers create a strong visual effect of parallelism and repetition, emphasising the characteristics of specific movements. This is used in several robot performances such as the (partly) synchronised drones dressed up as flying lampshades in *Sparked* by Cirque du Soleil, and the 32 small robots in Demer's (2016) *The Tiller Girls*. In *Robot!*, following the *Pas-des-deux* scene, four more Nao robots come on stage, facing the audience, and all five strictly identically looking robots attempt to perform the same synchronised dance. Now and then one of them falls, gets up again and finds its way back in line.

Massification also comes in another, apparently less structured way, in which a large number of actors create different patterns of movements. In *Robot!* this happens in the final sequence, where a horde of mismatched robots appears; Naos, a consumer vacuum cleaner; strange, remote controlled wheeled boxes and the mobile litter bin, opening and closing its lid as a mouth. Robots are here accompanied human actors, speeding around like stressed robots suffering from some sort of programming error. There is no synchronization or parallel movements, but massification nonetheless, creating an expressive chaos.

In the other end of the spectrum, the Nao robot appears as protagonist in other sequences of *Robot!*, relying on its special characteristics (especially charm) that makes it different from other pre-fabricated robot brands on the market; for example, it tries itself out as a crooner. In the *Pas-de-Deux* scene that we have mentioned, it appears as one of two equal partner, and the same is the case in another sequence, in which Nao performs a clumsy and failed attempt to seduce an alluring female dancer.

Dimension 4, Massif. or indiv. Indicative scale:



As shown, we indicate the degree of massification by counting with an addition of to which extent a group of robots are coordinated. When characterising this dimension for a given robot, we may also expect an indication of the types of other robots together with which it appears; this is done in Section 4.1 below.

Dimension 5. Sound, including noise, speech and singing

The last dimension we address is sound. For any show, sound plays a constituting role, and this ranges from proper dialogue and singing, over expressive nonverbal sounds to the planned as well as inherent sounds of the machinery, combined in a show's soundscape.

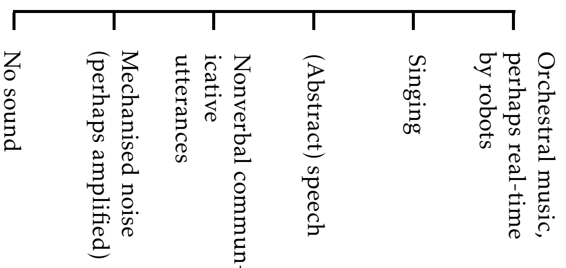
In *Robot!* – as in many dance performances – speech plays only a very small role. Instead it has a continuously changing musical soundscape, partly through loudspeakers and partly by an on-stage orchestra made up by human sized mechanical instruments, whose visual appearance was described under Dimension 3 above. They produce perfectly timed techno-like music relying on mechanical and not synthesizer sound (which makes quite a difference).

While convincing human-like speech is difficult to produce by a computer, it is easy to include recorded sound. When Nao acts as a crooner, loudspeakers transmit the Spanish love song "*Besame Mucho*" as sung a human, deep timbre, sensual female voice. The closest we get to speech in *Robot!* is in the failed seduction scene (see Dimension 4, above) in which the female dancer utters a sort of abstract language composed of words and phrases in different languages and indicative sounds, and Nao replies in a similar way.

Robots and other moving artefacts produce a varying amount of mechanical noise, which may be seen as a problem or may be emphasised and even artificially amplified. In *Robot!*, the sound of five dancing Naos' creaking joints blends into the soundscape. The litter bin mentioned already emits a very distinct metallic "clang" each time its lid closes.

We may suggest the examples of sounds mentioned above order into a scale as follows.

Dimension 5, sound. Indicative scale:



The litter bin's "clang" is an example of what we call a nonverbal communicative utterance.

4.1. Exemplifying the Dimensions as Descriptive and Design Tool

As mentioned in the introduction to this paper, the purpose of our chosen dimensions is two-fold, they should be applicable as a research tool to characterise an existing performative gestalt and as a design tool for novel appearances. Spoken with a mathematical simplicity, both tasks are straightforward: we just have to fill in the five coordinates with values that identify the specific point in 5-dimensional space; done!

We test the dimensions first as a descriptive tool in an attempt to characterise the litter bin of *Robot!*, that has been mentioned several times above. We suggest the following five coordinate values.

1:	Movements	Moves its body slowly forward, changes direction more or less randomly; opens and closes lid.
2:	App. autonomy and ...	Simple responsive, but from time to time experienced a bit cheeky.
3:	Appearance	A Familiar Domestic Object: a medium-sized pedal bin of the sort you can buy almost everywhere.
4:	Massif. or indiv.	Mainly individual; occasionally flocking with cleaning workers, and in the final sequence with lots of diverse robots.
5:	Sound	A metallic, repeated "clang-clang-clang-..." produced by the lid being closed.

This schematic presentation is concise and factual, but it also displays the important anthropomorphic traits of the object in focus. For example, there is an immediate interpretation of what is the front and back of it (that is why we could write above that it moves forward), and a glimpse of a certain personality associated with it appears when it is characterised as "cheeky". Writing down such a description of every instance of the phenomenon robot that appears in *Robot!* will be a good starting point for any thorough and deep analysis of this performance.

Now we make a though experiment of using the dimensions as a design tool. Assume we are involved in the setting of Johann Strauss' operetta *Die Fledemaus*, and we get the idea of animating a central scene object, namely prison guard Frosch's Slivovitz bottle. Frosch is a spoken role, quite often performed by some renowned actor of a certain age with a large element of improvisation; it is very humorous scene, perhaps with a tragic undertone due to Frosch's obvious alcoholism.

Our vision of an animated Slivovitz bottle has a personality that wants to tease and quarrel, but is basically friendly. As a first draft of a design, we fill in the five dimensions as follows.

1:	Movements	Can move back and forth on a specific straight line on a table, moving relatively fast and accelerating very quickly; may occasionally be lifted from the table by a human actor and put back on the same line.
2:	App. autonomy and ...	It reacts spontaneously and instantly to an approaching human hand, sometimes moving away playing hard to get and sometimes allowing the hand to lift it.
3:	Appearance	A Familiar Domestic Object: a bottle labelled *"Slivovitz"* containing a diminishing amount of a yellowish-brownish liquid.
4:	Massif. or indiv.	An individual that is fully aware of its own precious value.
5:	Sound	Occasionally a sound of sloshing liquid (triggered by the human actor's handling of the object).

From this description it is possible to make a first evaluation of the envisioned animated object. A dialogue between actor and technicians may concluded that this is "difficult but doable; if we can make it work, it may create a sensation, so let's give in a try".

5. Conclusion

Inspired by Blanca Li's *Robot!*, this article investigates the appearance of robots on stage in contemporary performance. As a convincing demonstration of the relevance of robots – as artefact, concept, metaphor – this performance unrolls a series of different instantiations and situations of staged robots.

On this basis, we have proposed a classification matrix of five dimensions which may provide vocabulary and terminology to characterise different instances of robots on stage with a focus on their expressive character as performative gestalts. Accordingly, this means that we focus on the intended audience experience rather than on how this experience is produced by technological means. Therefore we include the notion of a robot in a wide sense, ranging from advanced technological artefacts, over simple objects that display some sort of reactiveness or initiative-taking.

Beside references to *Robot!*, the dimensions refer to main developments and discussions regarding, e.g., the level of autonomy, mobility and questions of humanoidization in performance studies and HRI. Such questions highlight potential dilemmas in the study of robots, between the fascinating, autonomous behaviour of robots and the demands of control in show business.

The five dimensions of the matrix – Movements, Apparent level of Autonomy & Interaction, Appearance, Massification and Sound – represent essential, identifiable properties which are more or less orthogonal and that span a rich and complete space of robotic performative opportunities, focusing on robots as expressive gestalts. These dimension indicate a metaphorical vector-space, in which each point indicates one particular form of appearance of a robot on stage.

The applications of the dimensions can serve as an analytical tool investigating the use of robots across performance genres. More importantly, we see the dimensions as a template that may inspire the design of new ideas. Cheaper and easy-to-use technology enables artistic use of robotics in a lot of settings and allows for interdisciplinary collaborations and small-scale students experiments. Ideally, the matrix becomes useful as a tool for researchers, technical developers and performance practitioners to better understand and to invent new ways of including robots in an interdisciplinary collaboration between.

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