The plastic dynamism of the human aesthetic : employing futurist methodologies in the cross-disciplinary design of social robot morphologies

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The Plastic Dynamism of the Human Aesthetic:

Employing Futurist Methodologies in the Cross-Disciplinary Design of Social Robot Morphologies

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"The Plastic Dynamism of the Human Aesthetic" is a critical anatomisation of the aesthetics at play in the morphological design of social robots. The thesis argues for a knowing and consciously engaged approach to the matter and materialisation of non-human bodies in a technologically-driven discipline that is rapidly shaping, and being shaped, by society.

Through a survey of social robot morphologies from the last 25 years, it is shown that roboticists are designing robots for increasingly complex and nuanced social roles. A key aim of designers is to blend intangible human and machine qualities within their designs, yet a lack of formal methodologies for designing social robots is evident. A theoretical analysis of the prominent and problematic aesthetic trends within social robotics challenges the iterated and largely uncontested normative typologies that exist today. Employing methodological practices from fine art, a visual analysis comparing the sculptural work of the Italian Futurists (1900–1916) with contemporary social robot morphologies illuminates remarkable similarities and a prevailing 'futuristic' aesthetic developed by the Futurists that is still largely present in contemporary social robots. By consciously returning to the practices of the Futurists—from which so much futuristic inspiration has been drawn—methods from this period are appropriated to contribute a practice-based methodology for generating new robot morphologies.

It is shown that adopting a diagrammatic approach in the planning stages of social robot morphology design, such as that demonstrated by the Futurists, allows for the hardware, movement and aesthetics of the robot to be considered concurrently. Further, this diagrammatic approach is shown to be both generative and transactional, fostering the codification and transfer of tacit knowledge from within creative disciplines to aid in collaborative multidisciplinary design practices, and generative of designs open to multiple interpretations and potential new morphologies. Reflective practice is engaged to evaluate the artefacts produced as exemplars of the developed design methodology and to argue the importance of interdisciplinary attentiveness to the designed intersection of humans and machines.

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Belinda J Dunstan

25 July 2019

Abstract

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This thesis is dedicated to my mother, Professor Debra Ann Dunstan,
my life-long friend and the strongest woman I know.

As she would say, *"onwards and upwards!"*

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Fortunato Depero, Pencil-woman, 1931, Ink on paper.

Table of Contents

List of Figures

List of Tables

Glossary

Aesthetic (also spelled *esthetic*) refers to the intentional material and physical appearance of the object, and the experience resulting from engaging with the object.

Anthropomorphic having human characteristics; notably, those of the physical human body.

Art | design the terms art and design are used interchangeably, borrowing from one another's methods. The nature of their symbiotic relationship is expanded in section 5.2.

Authentic genuine, original and, in the case of an artwork, true to the intentions of the original artist.

Contemporary belonging to or occurring in the present time.

Cross-disciplinary viewing one discipline from the perspective of another

Embodiment the tangible representation or expression of something in a physical form

HRI human-robot interaction: the field of study of interactions between humans and robots

Humanoid a robot with an appearance resembling that of a human. Although 'anthropomorphic' and 'humanoid' share an etymological origin, within the context of social robotics, both terms have been used interchangeably. Within this thesis, 'anthropomorphic' has been used in reference to characteristics, where 'humanoid' refers to the typology.

Interdisciplinary participants from different disciplines crossing boundaries and creating new knowledge (more integrated than cross-disciplinary).

Morphology the particular form, shape and structure of an object (robot)

Multidisciplinary people from different disciplines drawing on knowledge from their discipline to contribute to a thematically based investigation or single field

Practice (art) inclusive of the working methods, influences, materials, skills, tools and accumulated professional knowledge of an artist

Social Robotics a field concerned with the design and impact of robots interacting with people in social spaces. The definition of a social robot is expanded in section 2.1

Chapter 1

Introduction

In describing the Danish physicist Niels Bohr's development of quantum theory and his discovery of 'quantum leaps', Carlo Rovelli (2014:18) questions "What does this mean? Does it mean that the essential reality of a system is indescribable? …Or does it mean, as it seems to me, that we must accept the idea that reality is *only interaction*?" [emphasis added]. This observation, and indeed the nature of quantum physics reminds us of the immense importance of interaction in the observable universe. As a field, social robotics draws on both the gravitas of interaction, and that of embodiment, which Karen Barad describes as "neither a passive surface for the inscription of culture, nor the biological body" (2007:391), but rather "a prototype of an ethical experience" (Ewa Plonowska Ziarek in Barad 2007:391). At such an intersection, stationed between the interaction of humans with technologically embodied agents, design asks, *how ought this appear?*

In the last two decades the field of social robotics has seen rapid growth, with the development of many variants of 'sociable machines' (Brooks 2004). With a diverse range of functions from museum tour guides (Thrun et al. 2000) to bartenders (Foster 2013), social robots have been developed to fulfil an extraordinary range of roles, including domestic helpers (Sugiura 2009), musical collaborators (Hoffman 2010), and even "friends" (Turkle 2006). As the integration of social robots into the human social sphere has grown to include these increasingly diverse applications, the need to examine robot morphology and movement design from new disciplinary perspectives and to refine their affective interaction capacity has been identified

(Hoffman 2014).

Social robotics is at the nexus of many disciplines concerning humans, robots, design and interaction, and is therefore intrinsically multidisciplinary and complex. Researchers within social robotics have relied upon research methodologies within their own disparate fields to shape thinking and progress in the space between humans and this technology. This compartmentalised approach to social robot design has often lead to disjunctions between the appearance, application and level of human acceptance of a social robot, as demonstrated through the survey discussed in section 2.1 of this thesis. Further, a haphazard approach to design, paired with the techno-linear progress of social robotics as a field propelled by technological innovation, has left the methodological approaches and resulting aesthetic designs largely unexamined and with limited critique.

This thesis adopts the philosophical approach of agential realism as defined by Barad (2007), which in this context provides an epistemological framework for reconfiguring the entrenched dichotomies of subject/object and human/machine. Agential realism is herein critically applied to the design of nonhuman bodies of social robots and to the existing limited and tangential discourse surrounding robot design. Barad contends that agential realism "privileges neither the material nor the cultural: the apparatus of bodily production is material-cultural"; it "entails the interrogation of boundaries and critical reflexivity"; and it "underlies the necessity of an ethics of knowing" (Barad 1996:179). In light of this framework, the thesis surveys existing social robot forms and employs a range of discursive cultural discourses to interrogate the matter and production of social robot morphologies, to foster critically reflexive and knowing approaches to the design of social robots. The thesis mines the author's education in art and particularly in sculpture as a departure point for approaching the body and representation–two areas of deep significance in the figuring of robot bodies–as well as a methodological entry point for visually analysing aesthetic trends and historical traces in the appearance of social robots, applying the findings to a conscious reworking of artistic techniques developed by the Futurists.

In examining a variety of social robots developed in the last twenty-five years, the author has identified that although these robots vary vastly in function, application and cultural context, a common trajectory of motivation for the designers has emerged; deeper interaction, collaboration, and more subtle, sustainable and meaningful human-robot relationships were cited as the driving motivation behind their work. These designers sought the "increasing acceptance and integration [of social robots] into people's lives" (McGlynn 2014), "longer and ... a much more rewarding interaction" between humans and robots (Jacobsson 2007), and "to combine human creativity, emotion, and aesthetic judgment with the algorithmic computational capabilities of computers, allowing human and artificial players to build on each other's ideas" (Weinberg 2009). It will be argued that fluid communication and meaningful interaction between humans and social robots requires an integration of both human and robotic characteristics in the movement and morphology of robots. From the beginning of research into biologically-inspired robots in the 1940s (Fong et al. 2003), the integration of human-like qualities into the morphology of robots has given them a form which mimics to some degree that of a human or animal (humanoid or zoomorphic) (Fong et al. 2003). Contemporarily, other aesthetic approaches, such as designing 'cute' robots have been made in attempts to enhance the interaction appeal of social robots. This thesis critically reviews the dominant aesthetic approaches to social robot morphologies, and posits that new creative solutions and methodologies are required for a more knowing and conscious generation, and material-cultural refiguring of, social robot morphologies. Therefore, this research addresses the question, **How can intangible human qualities be best translated and incorporated in the design of robot morphologies to enhance human-robot interaction?**

To first gain a comprehensive understanding of the 'state of the art' in social robot design, the thesis seeks to answer the associated question

a) **What aesthetic approaches and methodologies are currently used in the design of social robot morphologies, and what are their strengths and shortcomings?**
   The present research is grounded in the author's training in the discipline of sculpture, a field dedicated to form, representation and expression. In conjunction with this knowledge, observations made from the literature reveal aesthetic links between contemporary social robot designs and the artistic work of the Futurists (1900–1916). To explore these links, the author pursues the sub-question
b) **What observable aesthetic similarities do the sculptural works of the Futurist artists share with contemporary robot designs? What does the existence of these parallels**

signify?

The author examines artworks of the Futurists between 1900 and 1925 to illuminate a 100-year-old 'futuristic' aesthetic that is shown to be prevalent in contemporary social robotics, and demonstrates that the roots of this aesthetic can be located in the sculptural work of the Futurists. This examination identifies and addresses a lack of true aesthetic diversification in contemporary approaches to robot morphology design, and illuminates problematic aesthetic trends which have emerged in social robotics under conditions of limited critical engagement.

Examination of the methodology employed by the Futurists in the development of their sculptural forms demonstrates their desire to fuse human and machine characteristics in a single sculptural form, in a kindred manner to that desired by social roboticists. The author therefore seeks to answer the sub-question

c) **How was the juncture between human and machine aesthetics distilled in the years of the Italian Futurist movement, and how was it applied to embodied forms in their works?**

As an alternative to unknowingly appropriating the 'futuristic' aesthetic generated by the artists working during the Futurist period, their documented artistic experiments are described and discussed as a methodology that could be used in social robotics to generate new robotic forms (morphologies). Chapter 4 of this thesis seeks to answer the sub-question

d) **How can the methods used by the Italian Futurist artists be captured, represented and communicated to other researchers and designers from varied disciplines in social robotics?**

A primary complication that has impeded the development of interdisciplinary methodologies in social robotics is the problem of communicating tacit or discipline-specific knowledge between researchers from disparate fields. Often the complete team designing a social robot will include researchers and practitioners from computer science, mechanical engineering, industrial design, software engineering, and social sciences such as linguistics or psychology; all of which have disparate terminology, methods and design priorities, particularly in the matter of form-verses-function. To address this complication, the author discusses the use of notation and diagrams, and how these have been employed in areas such architecture, dance, electronics and even space exploration to aid multidisciplinary communication. A notion of diagrammatic notation is proposed by the author to communicate knowledge from art for use in social robotics by other researchers outside of art, and is illustrated by the accompanying practice-led material investigations (artefacts) discussed in the penultimate chapter. The author's presented methodology is not developed as a panacea, but rather to demonstrate how interdisciplinary methodologies might be developed for social robotics, and the unique capacity they have to shape the way we interact with robots. The findings are intended for social roboticists, both designers and theorists, who wish to re-examine and expand the possibilities for aesthetic design composition and affective interaction capability of robots.

The developed design methodology focuses on the affective expression of human emotions through form, and examines how 'natural cues' may be communicated while avoiding the need for complex facial articulation. Further, historical examination of, and critical reflection on, contemporary design practices in social robotics mediates the relentless techno-centric forward-march of robotics research which has seen limited critical theoretical engagement. In doing so, humans are returned to the centre of this research, which, in the author's opinion, is what true social robotics research ought to do.

1.1 Motivation

The development of 'social' nonhuman bodies is one in which researchers cannot afford to adopt a passive or uninformed role. In 1993, Judith Butler contended in *Bodies That Matter* that human bodies are "socially constructed" and performative in the sense that subjectivity, sex and boundaries are socially delineated, formed and reformed. In her text *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (2007:191), Karen Barad offers a critical reconceptualisation of Butler's discourse, asserting that it "fails to analyse how matter comes to matter", and thereby "reinstalling materiality in a passive role". In a similar vein, Barad also critiques Foucault's comments on the body in *Discipline and Punish* (1975), finding that "while he analyses the materialisation of human bodies, he seems to take nonhuman bodies as naturally given objects. That is, Foucault does not consider the processes of materialisation through which nonhuman bodies are materialised nor does he concern himself with boundary-drawing practices through which the division of human and nonhuman is constituted" (2007:204). It is argued herein that the field of social robotics and the development of robot bodies has proceeded with limited critical engagement, and resulted in problematic morphologies. Further, much of the critical theory surrounding the design of social robots has fallen prey to taking "non-human bodies as naturally given objects" where "materiality is in a passive role," and thereby failed to examine the bi-directional *intra-active* relationship between society and robots, where these nonhuman bodies are both formed by and are re-forming society. This thesis examines the aesthetics and matter of robot bodies, interrogates the origins and implications of the resultant robot morphologies, and repositions the matter and materialisation of morphologies as central to taking an active role in the construction of nonhuman corporealisations.

While the entanglement of robotics and ethics or robotics and politics appears to be explicit and second nature in the development of industrial robots or war drones, the social robots that will potentially work alongside us in offices or occupy our children's bedrooms have, to a significant degree, circumnavigated ethical, social and philosophical examination. Social robotics is a field that requires not only collaboration from many disciplines towards technical innovation, but also the attentiveness of the social sciences and arts to foster the informed, conscious and responsible shaping of this technology.

The increasing integration of robots into society requires adaptations to be made that are not simply confined to technical advances in machinery, but also extend to a deeper critical understanding of the place that robots might have in our lives. The significance of the present research lies in the current coalescence of need and opportunity in social robotics. There is a need for a greater depth of knowledge concerning form and embodied expression for those working in the design of robot morphology, and there is an opportunity for the knowledge and inquiries of art to make a significant contribution to this need, in the form of a design methodology that focuses on the affective expression of human emotion without relying on the direct translation of human features.

Art | Sculpture

The field of social robotics shares with sculpture a history of focusing morphological design around the human body and its capacity for affective expression. The human capacity to express and recognise social signals is innate, and we are evolutionarily primed to understand human-like expression. It is therefore unsurprising that the human body has been the primary source of morphological inspiration for designers of social robots aiming to foster personal connections and encourage more fluid communication between humans and robots. However, it will be argued that a number of factors suggest that the future of social robotics does not lie in a perfected replica of the human form. Sculpture and robotics share many qualities. Most notably they both "occupy a physical space as a viewing subject, and thereby invite a different sort of physiological engagement to that which governs the viewing of pictures" (Flynn 1998) and by extension, human engagement with two-dimensional technology, such as an image on a screen. It is argued herein that three dimensionality, and notably embodiment, gives sculpture and robotics both their limitations and their magnetism. In *The Body in Sculpture* (1998), Tom Flynn describes a phenomenon shared by both sculpture and robotics:

> the realistic nature of the representation and the materials employed in the tableau are important elements in the psychology of overvaluation: that which ascribes to the model the properties normally associated with the real living body. (Flynn 1998:17–18)

Similarly, this "overvaluation" on the basis of the realistic appearance of a robot's morphology can lead to cognitive dissonance during human-robot interaction. In the following chapter, "Social | Robot | Bodies – A Literature Review", the destabilisation of the dominance of the Western classical cannon in art (and with it, the tradition of realism) that occurred in sculpture during the late nineteenth century is discussed. The modernist sensibilities of deconstruction, fragmentation and urban disruption begin to permeate and "characterise the forms of three-dimensional body during the early years of the twentieth century" (Flynn 1998:140). Here, it will be argued that the wilful reduction, subtraction and abstraction of the body in sculpture led to a more complete and instantaneous comprehension of the whole. Understanding the sociopolitical conditions in which this change occurred and the way in which it impacted the making and reception of sculpture offers insights for the future of social robot morphology. This dissolution of boundaries and artistic response to the urban and industrial developments of the late nineteenth century was expressed perhaps most poignantly in the work of the Futurists.

Futurism

The work of the Futurists, and particularly the Italian Futurists, is examined for three key reasons: First, they too were faced with the challenge of expressing abstract and intangible qualities, or 'states of being', through an embodied form. Just as roboticists wish to express human qualities and emotions through a robotic form, the Futurists sought to express notions of the machine age such as speed, dynamism and other attributes through their sculptures of the human form. These concepts are examined in depth in Chapter 3: "Futurism and Future Forms".

Secondly, the work of Futurist sculptors focused particularly on blending human and machine characteristics together in a single form, which has strong parity with the intent of many social robot designers today.

Thirdly, the author demonstrates the existence an enduring aesthetic of 'futuristic design', which began with the work of the Futurists and is still highly evident in the design of contemporary social robots. The research focuses primarily on the work of the early Italian Futurists (1908–1916) due to the substantial body of documentation that accompanied their work in the form of manifestos and political texts from prominent practitioners such as Umberto Boccioni and Filippo Tommaso Marinetti, providing primary evidence of the aims and motivation of their work. As a contentious movement known for their fascist political agendas and bombastic manifestos, reference to the Futurist movement is approached within this thesis from a position of historical political awareness and sensitivity, while also acknowledging their enduring aesthetic. With these considerations in mind, the work and methodologies of the Futurists offer a unique historical perspective from which to critically approach morphological design in social robotics.

The aim of the research advanced here is to address the lack of interdisciplinary methodologies in a profoundly multidisciplinary field regarding the morphological design of social robots, and to discuss and contribute to the body of critical examination of morphological trends, as this will surely lead to more informed designs and more congruent, effective, and rewarding human-robot interactions.

1.2 Outline of the Thesis

Following this introductory chapter, **Chapter 2**: "Social | Robot | Bodies - A Literature Review" presents an introduction to the morphological design of social robots in three progressive stages. To begin, this chapter discusses the nature of 'social' robots, and the changing expectations and applications being developed for this technology. A review of contemporary state-of-the-art social robotics projects is then presented comparing the research motivation, intended applications, and the resulting morphologies. A brief history of the relationship between art and robotics provides a framework for better understanding their shared connection through embodiment.

Chapter 3: "Futurism and Future Forms" demonstrates the aesthetic link between the work of the Futurists and contemporary social robotics projects through comparative visual analysis, arguing that the extent to which Futurism has influenced social robot morphology has not been examined in adequate depth. This chapter discusses the context in which Futurism began and describes a diverse range of examples of the enduring nature of its aesthetic. The examination of work by Filippo Tommaso (FT) Marinetti, Fortunato Depero and Carlo Carrà suggests the way in which the methods of Futurism might inform a new methodological approach for designing social robot morphologies. Following critical analysis of modernist works that illustrate the 'machine' aesthetic, the author questions what remains of the 'human' aesthetic in these works, and how this might be applied to social robotics.

Chapter 4: "Communication of Tacit and Intangible Knowledge" proposes that a style of diagrammatic notation can be employed to both render abstract elements of the human aesthetic concrete and to communicate tacit knowledge from art and design to those outside the discipline in an interdisciplinary approach to the design of social robot morphologies. This chapter reviews the nature of notation and diagrams and the variety of their applications, with particular focus on the capacity to express complex or intangible concepts. A case study of the work of Oskar Schlemmer provides a precedent for the derivations of 2-D and 3-D morphologies from gestural sketches.

Chapter 5: "Practice-led Material Investigations" consolidates the findings of chapter 3 and 4, and presents a discussion of the author's material investigations developed to demonstrate the present methodology. The author discusses her use of reflective practice as a methodological approach, and positions the work contained in this chapter as critical design. The language of this chapter switches to first person, as the author employs an authentic reflective practice to analyse the development and refinement of the gestural sketches and paper-cut collages. Documentation of the resultant artefacts in situ in the *FEMUFACTURE* exhibition (Japan Foundation 2019) is provided.

Chapter 6: "Conclusions" culminates with a discussion of the outcomes of the application of the present methodology, and the way in which it might be utilised by researchers and designers. The conclusions are discussed under two subheadings, "That Matter *Matters* in Social Robot Morphology" and "Diagrammatic Design". It is concluded that nonhuman bodies ought to be treated with the same philosophical seriousness that has previously been afforded to human bodies, with the matter, design and materiality of robot bodies as a central focus. It is argued that responsive and informed technology design ought to cultivate an awareness of aesthetic influences and critically consider the political, ethical and cultural implications of these designs. The diagrammatic approach utilised by the Futurists and within the present thesis is shown to be transactional in nature, fostering cross-disciplinary communication and generative of original morphological typologies. Future work and potential research paths resulting from this thesis are discussed.

1.3 Principle Contributions

The principle contributions of the thesis and accompanying artefacts to the body of knowledge in social robotics are made in three key areas and are summarised as follows.

Original Design Methodology

- Offers a design methodology in a field with no formal methodological approaches. This methodology suggests a means for generating new aesthetic forms in social robot morphology that may foster more fluid and intuitive interactions with robots. The review of existing literature in social robotics reveals a shared desire among roboticists for their robots to express complex human emotions and intentions, and to engage in everyday intimate interactions with humans. The desire to have robots express emotions has been met primarily through mimesis of the appearance of humans and animals, which can give rise to misleading expectations of their capacity and intelligence (cognitive dissonance) and unwanted sociopolitical implications. To address this disjuncture, the author introduces a notational and diagrammatic practice drawn from the work of the Futurists to develop a methodology for approaching the design of robot morphologies that are inspired by the embodied expression of human emotions. The use of a diagrammatic approach also suggests new methods for information to be transferred and translated among people educated in disparate disciplines.

Survey and Critical Examination of Morphology Design in Social Robotics

- Provides a comprehensive survey of social robot morphology not previously detailed in the field, paired with critical examination of existing morphological trends.

Demonstration of the Link Between Futurist Aesthetics and Aesthetics in Social Robotics

- Identifies, describes and examines a prevailing aesthetic link between the seemingly unrelated fields of Futurist sculpture and social robotics not previously identified. Develops a conceptual and methodological synthesis between these fields by utilising methods drawn from the early work of the Futurists.

Publications

The following publications have contributed to the development of the research described in this thesis:

- Dunstan, B.J. & Koh, J.T.K.V. (2014) 'A cognitive model for human willingness in human-robot interaction development'. In B. Chen (ed.), *SIGGRAPH Asia 2014 Designing Tools For Crafting Interactive Artefacts*, p. 7, Association for Computing Machinery.

  In this publication, a cognitive model based on the Theory of Planned Behaviour was developed to understand what factors contribute to human willingness to collaborate with social robots. We specifically looked towards factors that influence our assessment of our own capacity and that of a robot prior to and during collaboration. Through the employment of the proposed model, visual aesthetics can be shown to greatly influence these assessments, and thus potentially be used to increase human willingness to collaborate with a social robot.

- Dunstan, B.J. & Koh, J.T.K.V. (2015) 'A cognitive model for human willingness to collaborate with robots: The emergence of cultural robotics'. In H. Samanti (ed) *Cognitive Robotics*, CRC Press, pp. 127–137.

  This book chapter expands on the findings based on the cognitive model developed and argues that the assessment of a social robot will be fast, automatic and based primarily upon an occularcentric judgement of aesthetics and that the culture of both the human participant and the designer of the robot will influence the interaction. With this in mind, the topic of Cultural Robotics is introduced for consideration in the future development of social robots.

- Koh, J.T.K.V., Dunstan, B.J. & Silvera-Tawil, D. (2015) *Cultural Robotics: Robots as Participants and Creators of Culture*. Workshop post-proceedings, LNAI 9549, Springer.

  Based on our findings of the importance of culture in design and interaction with social robots, we held a workshop as part of IEEE RO-MAN 2015 in Kobe titled "Cultural Robotics" and the proceedings were edited in to a special edition with Springer LNAI (9549). The contributing publications are divided into categories indicative of the extent to which culture has influenced the design or application of the robots involved, and explore a progression in the emersion and overlap between human and robotic generated culture.

- Fabbri, A., Dunstan, B, J. & Hausler, H. (2018) 'HRI for the construction industry: Challenging architectural fabrication towards collaborative artisanal choreographies'. *International Journal of Architectural Computing*, SAGE (Accepted 29 Aug. 2018).

  The aforementioned publications on collaboration and cultural robotics revealed that human willingness and ease in collaborative tasks with robots will be influenced, in part, by the extent to which a robot's appearance and movements are appropriate and fluid within a given context. In application to the construction industry, this paper examines prior case studies and discusses the potential benefits for a collaborative social robot to move in well-worn artesian choreographies, based on the motion-captured movements of experienced fabrication professionals.

1.4 Overview of Methodology

This dissertation employs critical theory, observation, visual analysis and practice-led experimentation to contribute an anatomisation of the aesthetics at play in the morphological design of social robots, and advances a practice-led intervention which serves not as a panacea for all social robot design, but rather as the first of what the author optimistically hopes will be a torrent of iterative and complimentary multidisciplinary methodologies contributing to the toolkit and dialogue of future roboticists. This thesis mines an eclectic amalgam of theory and practice across a range of discursive disciplines from contemporary art to technology ethics for critical perspectives through which to approach the avant-garde of futuristic design in social robotics. These forays into discursive practices do not operate in a metaphorical manner, nor is it within the scope of this thesis to consider each in great depth, but they are collectively examined in the search of "entanglements" (Barad 2007), patterns, traces and resonances that may critically perforate and disrupt the linearity of the techno-centric narrative present in social robotics, and “nature the cracks” [Barad’s words] that may house fresh material discourses and theoretical reconfigurations. The author does not position herself as a feminist scholar, but rather a student of feminist scholarship, “concerned with ensuring the presence of multiple voices in knowledge production” (Suchman 1994:22), and with a keen intention to interrogate and contest existing structures, standards and binaries existing within technology research. In conducting the literature review, a comparative survey of social robotics projects over a span of 25 years was produced, focusing on the morphology of robots and the broader motivations behind their morphological design, as reported by the authors. The research question was drawn from observations made during this review, in light of the author’s knowledge of visual art and futurist sculpture.

Visual analysis studies comparing images of sculptures produced by the Italian Futurists with the designs of contemporary social robots were conducted, with critical discussion focusing on aesthetic similarities and differences. Through examination of the artworks produced by the Italian Futurists c. 1908–1916, the author has curated a series of works to depict an observed collective working method that emerged among some of the Futurists working concurrently within that time period. This method has been distilled and discussed in application to the problems unearthed within the design of contemporary social robots as observed during the survey. The new design method is demonstrated through a collection of practice-led sketches and compositional studies, documented as visual translations of the method, and examined through reflective practice. These studies are documented, embedded and critically examined within the penultimate chapter. In positioning the art practitioner as researcher, Ann Douglas (2000) describes the role of critical practice-led research in a PhD context where “the role of practice is part of the methodology of the research and is therefore relative and heuristic. In this sense art works and projects have a partial and functional role within the final ‘argument’ …as a means of embodying knowledge more efficiently and appropriately than through text alone.” The thesis is therefore not positioned as practice-based, where inquiry is made into the author’s personal practice, but rather the author’s knowledge and background in art shapes her inquiry in social robotics, and the practice-led artefacts contained within the penultimate chapter have a partial role in illustrating elements of the argument.

The author’s practice-based compositional studies demonstrate one possible application of the proposed design methodology for the design of social robots through a case study examination of the emotional movements performed by the social robot Kip1, designed by Guy Hoffman and Oren Zuckerman (2015). The emotions of curiosity, fear and calm were specifically named by the researchers as essential for the interaction capacity of their robot. They also represent emotions that are characterised by a clear and full-bodied expression, rather than purely relying on articulation of facial features. In the methodology these emotions are drawn or 'plasticised' through a series of three sketch studies based on the style of sketches produced by Filippo Tommaso Marinetti in 1915 (see *Action*; *Bombing*; and *Propeller* in section 3.2).

These 'plasticised' emotional movements are then sketched together with the robotic hardware, in the style of a technical drawing in a method similar to that demonstrated by Fortunato Depero in his 1916 dancer and costume series. The triptych of sketches was exhibited in the *FEMUFACTURE* exhibition at the Japan Foundation, Sydney, in February 2019, and is documented and discussed in Chapter 5. The sketches are then extended in the form of three paper-cut collages in the method demonstrated by Fortunato Depero in the same series.

Reflective Practice

In addition to some more 'traditional' methodologies, perhaps the most important methodology utilised within this thesis is reflective practice, where the author reflects on the process and results of the 'making' component presented herein. The present research could aptly be described as a "creative-production doctoral project" as identified by Steven Scrivener, where artefacts are generated and are intended as a means of intervention or innovation. In his paper, "Reflection in and on Action and Practice in Creative-Production Doctoral Projects in Art and Design" (Scrivener 2000), Scrivener describes a wide range of doctoral projects in design research that are "intended to effect change". He likens these projects to technology research, sharing a range of common features.

Section 5.2 of the thesis outlines the norms, rigour and reflexivity involved in reflective practice. In discussing the role of the artefacts produced within this project, emphasis is given to the importance of their transferable application to the construction of other artefacts. The artefacts produced to accompany this thesis constitute critical design translated into materiality. Critical design is defined in section 5.3, and the artefacts are positioned as a means for proposing a "new type of reality" (Dunne 2013).

Chapter 2

Social | Robot | Bodies – A Literature Review

> In the cases where boundary crossings occur, we discover that crossing boundaries involves encountering difference, entering onto territory in which we are unfamiliar … The development of useful systems must be a boundary-crossing activity, taking place through the painstaking (and often painful) creation of situations that allow for the meeting of different partial knowledges. (Suchman 1994:25)

The present boundary-crossing multidisciplinary thesis begins in what was unfamiliar territory, territory which has now "painstaking[ly]" become familiar. The literature review comprises a summation of the findings resulting from the pursuit of understanding what defines the field of social robotics and separates it from traditional robotics and other fields of technology research, and where art and sculpture may make a meaningful contribution to knowledge. The review is organised by the intuitive questions that drove the author's research in this new territory: What is a social robot? How do they communicate? What can they do (applications)? What might they do? What do they look like? How are they designed? What is the history of understandings between art and robotics? What might the future of this pairing be? These questions are examined with reference to social robotics and human-robot interaction (HRI) projects and publications, and framed through critical theory from a range of related disciplines.

Section 2.1 surveys a diverse range of social robots, the increasingly complex and subtle applications for which they are being developed, and the social agendas that motivate these applications. Theoretical insights from Selma Šabanović, Sheila Jasanoff and David Gunkel position social robotics as a technology that is not neutral but is shaped by, and is shaping, our epistemological understanding of the world and the ways in which we choose to represent it. The author defines social robotics for the purposes of this thesis, and discusses existing interaction modalities and applications, as well as reviewing speculative theory from David Levy, Sherry Turkle, David Gunkel, and Karen Barad concerning future applications and the metaethical questions being stimulated by work in social robotics.

Section 2.2 provides a survey of existing state-of-the-art social robot morphologies, where the author presents a comparative survey of social robots from the last 25 years, comparing their morphology and user interaction methods with the motivation for design as cited by the researchers (with reference to the survey found in Appendix A). Aesthetic trends evident from this survey are discussed, with the dominant categories of humanoid and 'cute' robots discussed in greater critical depth. A discussion of the corporealisation of robotic humanoids is shaped through feminist theory from Elena Knox, Lucy Suchman and Donna Haraway, concerning the social, ethical and political problems that arise from the creation of these other-selves. The call for a move away from humanoids as a dominant design typology in robotics is discussed with reference to a number of leading social roboticists. The second emergent trend of 'cute' robots is dissected through aesthetic theory from Sianne Ngai and David Harris, who describe the aesthetic category of 'cute' as having the power to commodify, domesticate and pacify. The impacts of 'cute' are discussed through case studies of violence and aggression towards contemporary cute robots.

Section 2.3 discusses a variety of studies which have attempted to categorise and understand existing approaches to social robot morphology design. Detailed attention is given to the methodological approaches detailed by Hoffman and Ju (2014): the pragmatic approach and the visual approach. Hoffman and Ju present a third approach, the movement-centric approach, and the benefits and shortcomings of these approaches are analysed. In reviewing the increasing contributions of creative practice-based fields to design in social robotics, the author contends that the evaluation methodologies belonging to these disparate disciplines ought also to be recognised.

Section 2.4 acknowledges the longstanding relationship between art and robotics and how these fields have influenced one another, particularly over the last 60 years. The author argues that sculpture and robotics share a particularly close and compelling relationship through embodiment and the impact of phenomenology on our perception of robots and sculpture. Sculpture is positioned as both a field with a significant critical contribution to make to understanding the sociopolitical nature of non-human bodies, as well as being a departure point for the development of methodological design techniques for use in social robotics. The quality of embodiment shared by sculpture and robotics is discussed, leading to the following chapter where the author draws particularly on the sculpture of the Futurists, which spoke to the representation of the human body in a new world: one grounded in the machine age.

2.1 Social Robots and Social Agendas

In her consideration of "Robots in Society, Society in Robots" (Šabanović 2010), Selma Šabanović identified that the design of social robots had been primarily developed in a unidirectional, technologically-determinist manner, where technology is developed in a linear fashion of continual progress and society fulfils a passive role by accepting and adapting to the results of technical innovation. Due to the highly social contexts for which social robots are designed, Šabanović called for a move away from the technocentric forward-march of social robot development, and instead proposed a "bidirectional shaping" between society and robots that "paves the way for approaching design in a value-centred manner, consciously incorporating social and cultural meaning-making into design" (2010:445). Šabavonić proposed that it was not sufficient to consider the social impact of a robot in post-production user testing, but rather that "the meaning of various technological choices …should be questioned throughout the process of technology design" (Šabanović 2010:445). With this in mind, Šabanović notes that the integration of robots in broader society calls for "new methods for designing and evaluating social robots", and that these new methods ought to incorporate the study of both the social and technical aspects of the technology (2010:445).

While there is a significant body of contemporary critical theory concerning aesthetic trends in technological product design and the emergence and acceptance of social robots, the identification and analysis of aesthetic trends specifically in social robot morphology is necessary to foster a more conscious incorporation of social values and cultural meaning into these artefacts that are being designed to share social spaces with humans. In response to a critical evaluation of current social robot designs and aesthetic trends, the present research proposes a new method for designing social robots that considers, ab initio, some of the cultural values and social implications of aesthetics in social robot morphology, contributing one method to what needs to be a growing, and critically considered, toolkit for approaching social robot morphology.

Šabanović (2010:455) quotes Sheila Jasanoff (2003), stating that engaging with a framework of mutual shaping between society and social robots begins with "the recognition that technology is not the 'driver' of history", but that "the ways in which we know and represent the world are inseparable from *the ways in which we choose to live* in it" [emphasis added]. Therefore, the present research presents not only fresh ways of "knowing" the world through considering the aesthetics of social robots, but proposes a new method of representation in the design of social robots, to contribute to a field for which there is "not progress linearly from problem to definition to resolution" (Šabanović 2010:445), but which requires many multidisciplinary approaches to navigate the complex societal terrain to which this technology belongs.

This chapter will demonstrate that indeed 'the robots *are* coming', and they may soon be sharing the most intimate of spaces with us. An increased understanding of this technology and the potential it represents is essential, because the depths to which social robots may impact the "ways in which we choose to live" (Jasanoff 2005:2) are still unknown to us.

In *Heidegger and the Media* (2014), David Gunkel and Paul Taylor critically consider new technology and challenge the "myth of neutrality", arguing that although it may often be said that "it's not the technology you use, but how you choose to use it that is important" (p. 2), new technologies contribute to a "technological environment", in the same way, Gunkel and Taylor suggest, that the presence of military assault rifles in an urban setting likely play a technologically determining role in violence (Gunkel & Taylor 2014). Šabanović also identifies that robot design contributes to the construction of "technoscientific imaginaries", or "narratives about social order, human behaviour and psychology, and common norms" (2010:440). The integration of robots into human environs will impact social norms and values, and the manner of this impact may be shaped, in the first instance, by design. Although the term robot comes from the Czech word *robota*, meaning "forced labour", social robotics by definition is more than a means to a (labor) end, but through the process of design and subsequent interaction with humans, this "technology is no mere means …It is the realm of revealing, i.e., of truth" (Heidegger 1977 in Gunkel & Taylor 2014:127).

To begin with 'knowing' in the field of social robotics, the definition of a social robot and the social applications and agendas for which they are being developed are examined.

What is a Social Robot?

The definition of a social robot has been examined in depth (Breazeal 2003), (Hegel 2009), (Duffy 1999), (Bartneck 2004). The term was initially inspired by the collective behavior of insects but has progressed to an association more closely aligned with "anthropomorphic social behavior" (Breazeal 2003). Cynthia Breazeal offers further sub-classification of social robots in accordance with the complexity of the interaction supported, however for the broader purposes of this thesis, Fong et al.'s definition of "socially interactive robots" in which social interaction plays a key role (Fong et al. 2003) will be used. Fong's definition refers to specific types of social robots that are engaged directly in social interaction with humans, as distinguished from other robots that involve 'conventional' human-robot interaction such as teleoperation scenarios. Fong's "socially interactive robots" specifically require consideration of the human in the loop as an interactive partner (Fong et al. 2003). For the purposes of the present research, the term *robot* refers specifically to "the physical manifestation of a system in our physical and social space" (Duffy 2003:177), and therefore virtual characters, screen-based interfaces and artificial intelligence systems without a physical body are not discussed in detail.

This thesis also recognises social robots as belonging to a distinct field of robotics, separate from industrial robots or service robots. Although service robots like the Roomba raise interesting social situations and questions of their own (Forlizzi & DiSalvo 2006), they are not designed with human interaction as their primary function even though they are designed for social spaces. The field of social robotics or that of "sociable robots" (Breazeal 2004) is concerned with “the study of all forms of human-robot interaction within a social context” (Dunstan et al. 2015:5), and gives rise to questioning the relationship of robots to many social, ethical and moral positions, such as free choice (Bello et al. 2015), the concept of “personal space” (Walters et al. 2005), self-consciousness (Brigsjord et al. 2015), radical uncertainty (Silvera-Tawil & Garbutt 2015), and long-term social interaction between humans and robots (Bickmore & Picard 2005; Gockley et al. 2005; Shibata et al. 2011).

Many financial and institutional factors suggest that the research, development, sale and introduction of social robots into the domain of human activity will continue to expand exponentially. As reported in the Financial Times (2016), the International Data Corporation (IDC) has projected that the robotics market will be worth $135 billion US by 2019, with a surge of investment interest in cheaper, more flexible and adaptive machines for use in human environments, including hospitals, warehouses and hotels. According to the report, global investment in robotics almost doubled by between 2014 and 2015 alone, reaching $600m.

Internationally, changes can be seen in a range of educational institutions to accommodate social robotics courses and research as separate from more traditional mechatronics engineering or computer science disciplines. Inclusive is the newly founded Creative Robotics Lab at the University of New South Wales (UNSW) in Sydney, Australia, and the new UNSW course, Social Robotics: Movement Design for Human-Robot Interaction. In other parts of the world, courses are being developed at both the undergraduate and postgraduate level in social robotics as seen at the Interdisciplinary Center Herzliya Israel, The American University of Paris, and Cornell University in New York. At the University of Tokyo, the newly minted Watanabe Laboratory includes researches from the arts and social sciences all contributing to research in the field of social robotics. Globally, social robotics is being acknowledged as a field worthy of financial and educational investment and therefore demands a growing body of critical engagement.

How do Social Robots Communicate?

Social robots have been designed to communicate through verbal and non-verbal channels such as morphology, movement and gestures (Brooks et al. 2004), (Lutkebohle et al. 2010).

In anthropomorphic robots, facial features can be used to articulate emotions, either in actuated features (Lutkebohle et al. 2010) or on-screen (Gockley et al. 2005). Other avenues for the communication of robotic emotions or intentions include movement and path planning (Sharma et al. 2013), lighting patterns (Jacobsson et al. 2007), sound (Song & Yamada 2017) and proximity (Velonaki 2005). For the most part, movement is emphasized as a preferred expressive modality for social robots. For example, Hoffman and Ju (2014) promote the value of movement in robotic communication, emphasising human sensitivity to physical movement and spatiotemporal affordances.

Considering that the definition of a social robot in Fong et al. stipulates that a human counterpart must be considered in the loop, these agents will be required to communicate with humans in a way that is "natural and easily understood" (Kirby 2010:322). Rachel Kirby et al. posits that "affect, such as mood and emotion, plays a major role in human interaction", so robots that are designed to engage in interaction must be able to communicate not only a message, but an emotive one. Fong et al. (2003:11) explain that while "emotions play a significant role in human behaviour, communication and social interaction" they also "guide action, control resource usage, and shape dialogue". According to Fong et al., in an interaction, emotions are not present for emotions' sake, but they drive future action and incite further dialogue. Robots that are being designed to participate in the social sphere must therefore express emotion or 'states of being' for effective communication. However, at the time of writing, robots do not possess the sentience necessary to feel emotion in the way that we do as humans. In a social robotics context we can understand emotion as a communication tool for expressing intent (Breazeal 2000). This intent for action may be preprogrammed and therefore seem disconnected from the essence of 'emotion', but as summarised by Kirby et al., "when considered solely for interaction purposes, emotions are meaningless unless they result in some outward change in the robot, including facial, vocal, or behavioural modification" (Kirby et al. 2010:323). Therefore, for the purposes of this thesis, in reference to robots we may understand "emotions" as states of being, or the display of programmed intent for action, as a stimulus to further interaction with a human.

Researchers have worked to endow social robots with the capacity to perceive and express emotional states through a range of modalities simultaneously. Some more complex examples of these include Breazeal's Leonardo (Brooks et al. 2004), which uses joint attention and is able to mimic human facial expressions, and PARO (PARO Robots U.S., Inc.), the therapeutic robot in the form of a baby harp seal, which communicates through zoomorphic body language, responding by moving its head and legs and vocalising seal sounds to show pleasure or distress. Other interactive robots use their bodies to demonstrate emotions, including the tapping of 'feet' to indicate 'enjoyment' of music (Weinberg et al. 2009), illuminating coloured lamps to communicate internal 'emotion states' (Sugano & Ogata 1996) and retreating from light sources to communicate sadness (Maeda 2004).

The effectiveness, efficiency and longevity of robotic interaction requires interactions between robots and humans to go beyond the rudimentary display of basic emotions to something more natural, fluid and meaningful. Roboticists have therefore considered methods of affective emotional expression, where the state of being expressed by the robot has meaningful impact, or affect, on the human counterpart. Kirby et al. (2010:323) have documented a number of computational models of emotion implemented with virtual agents (Elliot 1992) and embodied conversational agents (Cassel et al. 2000) where emotional models are used to mimic human-human interaction. Kirby et al. (2010:323) have developed an affective emotional model implemented through their Roboceptionist project, where the model differentiates between emotions, moods and attitudes. The research seeks to develop long-term relationships between people and the robot and similarly to have the robot display long-term attitudes towards different visitors.

The computational expression of emotions in the cases surveyed by Kirby et al. (2010), and indeed many of the methods for emotional expression found in social robotics projects, are based on detailed mimesis of human characteristics, be that facial or bodily articulation. The pursuit of advancement in robotic articulation is appropriate for some applications, however, from the perspective of detailed realistic emulation, the expression of complex emotions is technologically challenging and expensive, and may still result in undesirable outcomes, such as cognitive dissonance or user disappointment (Silvera-Tawil 2012).

Contemporarily, some robotics projects have emerged that look beyond the direct mimesis of facial expression or complex bodily articulation to capture something closer to holistic or abstracted bodily expression of emotion. Oren Zuckerman and Guy Hoffman (2015) have developed the notion of empathy objects, or ambient robotic conversation companions that use subtle physical gestures to reflect the emotions of humans engaged in an interaction. Empathy objects are designed to help mediate human-to-human conversation. By physically expressing the emotion the robot detects in the conversation, the researchers hope the robot will "increase people's self awareness to the emotional state of others" (Zuckerman & Hoffman 2015:593). The exemplar empathy object, Kip1's gestures provide "tangible representation to digital information" (Zuckerman & Hoffman 2015:594), where the digital information is an input of conversational tone or volume (digitally translated as reflective of emotion states) and then tangibly represented through a change in robot bodily posture, be that a calm slow 'breathing' motion, a curious extension of the neck, or cowering and shivering in a retreated position. Kip1 does not have a humanoid morphology and looks more like a desk lamp, yet, as will be discussed in section 3.3, still displays aspects of embodied human emotional expression. Importantly, this project also relocates or reimagines the role of technology, where the technology no longer serves as a medium of labor or communication between two distant people or between humans and a computer, but rather serves on the periphery to support face-to-face interaction between humans (Zuckerman & Hoffman 2015:594).

In 2015, Petra Gemeinboeck and Rob Saunders presented a unique methodology for approaching the design of robot morphologies and robot communication that focuses on "the expressive qualities of movement and their potential to generate affect and empathy, rather than a robot's physical features" (Gemeinboeck & Saunders 2015:86). Gemeinboeck and Saunders hypothesise that use of the dynamic qualities of human movement can "compensate for an unfamiliar appearance in a robot's capacity to convey social agency" (2015:87). The project uses Performative Body Mapping, a technique generated by the researchers where a professional dancer inhabits soft, tactile geometric costumes and moves in different emotional ways (Figure 2.1), which can then be taught to a robot with a similar shape morphology. The project capitalises on "imitation learning to capture the socially encoded, dynamic qualities of the dancer's movements" (Gemeinboeck & Saunders 2015:88). Gemeinboeck and Saunders (2015:88) explain that this methodology fosters a much wider range of potential morphologies for social agents, and is not constrained by the need to imitate natural features. Furthermore, the use of these abstracted forms allows for the "robot's behaviour to be the predominate factor for determining a person's attitude towards the machine" without the preconceptions associated with anthropomorphic projections.

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Figure 2.1 – Tess de Quincey performing as part of the Machine Movement Lab project by Gemeinboeck & Saunders.

While not explicitly designed for use in social robotics, the EmotiveModeler (Figure 2.2), a recent project from the MIT Object-Based Media Group (Mothersill 2014) also seeks to capture and codify the tacit knowledge of those working in creative fields into a usable tool-set or computational model of emotional expression and perception. The EmotiveModeler is a CAD design tool for generating "emotive forms". The group have developed a design taxonomy to catalogue the "emotive character" embedded in objects for ease of use in the "emotive modelling" of future object designs. The taxonomy has been designed from the "intuitive perception of emotive forms", which the group assert that designers consciously have, and the lay person can subconsciously perceive: "whether or not we are experts in the design language of objects, we have an unconscious understanding of the emotional character of their forms" (Mothersill 2014).

While the work presented by Gemeinboeck and Saunders allows the movement captured by a dancer to be computationally mirrored by a specific robot prototype, a taxonomy such as the EmotiveModeler may allow roboticists to consider the forms that the expression of particular

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Figure 2.2 – EmotiveModeller project "Emotive Form Design Taxonomy for Eight Primary Emotions". http://emotivemodeler.media.mit.edu

emotions may occupy before beginning the morphology design process. Gemeinboeck & Saunders (2015:87) posit that "depending on the application, sociable robots may have very specific tasks that then define the main aspects of their appearance and behaviour". An example of this is the empathy object listening companion proposed by Zuckerman & Hoffman (2015), where the robot requires only a limited range of emotional expression (e.g. curious, fearful or calm states) to fulfil its purpose and function.

While the aim of designing an advanced humanoid robot such as ASIMO (2000) or Pepper (2004) may be to have it express the full range of human emotions, the future of social robotics may not lie in the basic expression of a wide range of emotion states, but in the simple expression of a limited range of complex emotions. In either case, the need for robots to express themselves clearly and simply becomes evident when considering the diverse range of applications for which they are being designed.

What do Social Robots Do? | Applications

In the last two decades, the field of social robotics has seen rapid growth and the development of many variants of "sociable machines" (Breazeal 2000:40). With functions ranging from museum tour guides (Thrun et al. 2000) to bartenders (Foster et al. 2013), social robots have been developed to participate in an extraordinary range of roles, including domestic helpers (Sugiura et al. 2011), musical collaborators (Weinburg et al. 2009), and household companions (Turkle 2006). Defined by Sherry Turkle as "relational artefacts", social robots no longer simply do things for us, they do things *with us* (Turkle 2006). Šabavonić contends that "social robots often present technological fixes [39] –applications of technology meant to solve social problems that are non-technical in nature– for a variety of pressing issues in contemporary society" (Šabavonić 2010:439). She contends that the aims of these projects "emphasis the exploration of technical capabilities and define social problems in terms that make them amenable to technological intervention" (Šabavonić 2010:439). While this section describes many social robot applications, to what extent these social problems are being defined in terms amenable to technological intervention ought to be critically considered.

The planned participation of robots in domestic settings can be seen in projects such as Foldy and Cooky presented by Yuma Sugiura et al., where robots participate in real-world object manipulation by folding garments (Sugiura et al. 2009) or preparing a meal (Sugiura et al. 2011). Projects such as these, where a robot works collaboratively with a human on a domestic task, have been developed commercially, such as the robotic kitchen designed by Moley (Moley Robotics 2018).

Interactive game playing is another avenue for collaborative social robots in domestic settings. This has taken form in projects such as Sony's robotic pet dog AIBO (2019), and development towards more complex forms of companion robots is being undertaken in projects such as the expressive humanoid robot Leonardo (10: 2002), (MIT Media). Research in the development of natural social gesture and language towards the use of personal robots for entertainment is being conducted by the MIT Robotic Life Group (Brooks et al. 2004).

In an educational context, social robots are being used as educational assistants and tools, including the year-long use of humanoid robots in early education centres to assist teachers

(Movellan et al. 2005). Proceeded by the successful use of the LEGO Robotic Kit (Papert 1993), the use of social robots in the education sector has grown to include use in remote education to augment online learning (Yorita 2009), as well as the use of robots to motivate at-risk students in the classroom (Cerge 2014). Robots are not only being used in STEM subjects, but also in the arts and humanities, such as the use of Aldebaran's NAO and Sony's AIBO robots by Penaloza et al. (2015:81) to teach Mesoamerican religious history to South American students, who design original morphologies and cultural costumes for the robots.

Researchers Nakauchi and Simmons assert that in order for social robots to successfully participate in domestic and urban settings, they will need to understand and comply with social norms, such as lining up at a grocery store cashier. Their "robot that stands in line" is designed to recognise and respond to social behaviours (Nakauchi & Simmons 2000). Forster et al. (2013:255) have designed a robot bartender with the aim of developing methods for estimating the engagement state of customers, contending, "it is not enough for a robot to simply achieve its task-based goals; instead, it must be able to satisfy the social goals and obligations that arise through interactions with people in real-world settings".

Social robots not only participate in social settings, but increasingly serve deeper social purposes, and attend to or facilitate social interaction. The Hug, developed by DiSalvo et al. (2003), is an exploration of robotic form to facilitate intimate communication across distance. The Hug is designed to use "expressive anthropomorphic form to impart a sense of presence" (DiSalvo 2003:403) and is designed for families that live apart to communicate with the elderly in a more tactile way. An enormously successful example of this type of social robot is PARO, the robot in the form of a baby seal, who has been shown to be effective in therapy for both the elderly and victims of natural disasters (McGlynn 2014), particularly in settings where companionship is beneficial but human or animal contact may need to be quarantined, such as in a hospital. Certain social robots have been also been found to be effective in helping people with autism recognise and respond to social cues (Scassellati 2007). Scientists from RIKEN have developed a nursing care robot, ROBEAR, which is designed to help with tasks such as lifting patients from a bed to a wheelchair, and assisting with patient mobility (Riken 2015).

Koh, Dunstan and Silvera-Tawil (2015) contend that "to different degrees all social actions are culturally driven" (p. 5). Through social engagement, social robots both participate in and produce cultural artefacts: be they intangible, such as language, values and traditions; or tangible, such as creating a meal or a piece of music. For example, one Iranian teacher has harnessed the compelling nature of robots to engage students in the cultural practice of daily prayer by teaching the robot to lead prayers in the classroom (Phys.org 2019). Laursen et al. have designed a robot that supports dessert chefs through food preparation and plating (Laursen et al. 2015). In recent years there has been the advent of autonomous robotic musical performance, such as the all-robot opera (Marynowsky et al. 2015) and a robot-only heavy metal band, Compressorhead, critically discussed by (Davies & Crosby 2015:175).

The 2015 publication *Cultural Robotics* (Koh et al. 2015) categorised the participation of social robots in human social spheres into three broad tiers, inspired by the earlier work of Samani et al. in cultural robotics (2013): robots as participants in culture; robots as creators of culture; and the advent of robotic culture. These categories help us to understand "the role that social-cultural norms, values and assumptions play in the daily practices of designing robotic technologies" (Šabanović 2010:445), as well as the degree to which the activities of robots are embedded in, or generators of, cultural practice, social norms and values. Considering the activities of robots in this manner serves as a reminder that this technology is not neutral, but generative and culturally charged. Where Koh et al. (2015) have segregated the activities of robots as either the 'participation in' or the 'creation of' culture, in the examples discussed here participation in social (and thereby cultural) practices might be understood as generative, where the robotic performance of norms is affirmative and reinforcing of those norms. In this sense, the categories of participants and creators of culture are intertwined.

Consideration of the function of robots in light of their influence on cultural production reveals a few small truths about how robots currently function in society, and how they may function in the future, which sit in some contrast to commonly held beliefs perpetuated by popular fiction and the media. While it is true that in research and industry there has been an overriding "technologically optimistic perspective on the place of robots in society" (Šabanović 2010:441) pushing technological innovation, the popular media has concurrently been flooded with articles and documentaries concerning the inevitable doom that robots will bring through disruption of the job market and the economy, and as autonomous "killer war machines" (ABC 2017; BBC 2017; CNBC 2018; The Guardian 2018). It is interesting to note that the types of robots that may replace human labor or be sent to bomb civilians are likely to be industrial or service robots with a highly mechanised appearance, yet the images of robots featured in these news articles and media are almost always of humanoid social robots. This juxtaposition has the potential to impact the public acceptance and perception of social robots when and as they enter the market en masse.

While the likelihood of a robot-saturated future is not yet clear—and the following section will elaborate on some theoretical predictions on the place of robots in the future—there are trends emerging in speculation about how robots may operate in society in the future. The robots discussed in this section often have a specific or singular function, and more often than not work collaboratively with or alongside a human counterpart. Notably, where it might be said that the robot is occupying some part of the human's job, the robot is replacing the mechanised or repetitive part of the labor, and allowing the human to return to the most creative or sensitive part of the task. For example, ROBEAR is designed to relieve the physical burden on aged care workers required to lift patients, and allows them instead to hold the patient's hand and comfort them while they are being moved. By running a randomising algorithm, the dessert chef (Laursen et al. 2015) spirals a unique chocolate pattern on each plate, and allows the chef to respond creatively to the robot's design in the dessert assembly, instead of mechanically repeating the same pattern every time themselves. This research suggests that the emergent role of social robots in society may largely be one of augmentation, or assistance, and not that of replacement.

What *Might* Social Robots Do?

There is a wide range of theoretical speculation on the role that social robots might play in society in the future, yet much of this theory does not detail specific applications, but rather what the integration of robots might come to mean for humans. Questioning the role of robots in our future prior to and during the process of designing them allows researchers to play a more conscious role in shaping this technology.

A variety of studies have examined the role of social robots as companions in the future, such as Martelaro et al. (2016), Dautenhahn et al. (2005), and Heerink et al. (2011). It has been anticipated that as companions, robots will have an impact beyond that of mere company. Hoffman and Vanunu (2013:323) found evidence that humans engage in 'social referencing' behaviours with robots in the same way that they do with humans, where a robot's perceived enjoyment of music influenced the participant's enjoyment of the music. Hoffman and Vanunu concluded that this "suggests a novel role for personal robots as contributors to, and possibly amplifiers of, people's own evaluation of external events" in the future. In a study of the pet companion robot AIBO, Kahn Jr et al. (2002) analysed comments posted online from owners of the robot. The researchers found that the comments often reflected an accreditation of agency and social standing to the robot, but seldom attributed moral standing, for example, that the robot had rights or deserved respect. Contextually, Kahn Jr et al. (2002:633) identified both positive and problematic implications of these findings:

> We are concerned because people in general, and children in particular, may fall prey to accepting robotic companionship without the moral responsibilities (and moral developmental outcomes) that real, reciprocal companionship involves. Yet we are hopeful that for some populations—such as for elderly who may no longer be capable of caring for real animals—this separation of social from moral standing may accord benefits.

For some age groups, Kahn Jr et al. anticipate that companion robots may teach or reinforce negative interpersonal behaviours, while for others, companionship without the responsibility to adequately care (as for a living creature) may have many benefits.

On a different level of interpersonal relationships, David Levy (2009) has speculated that "love and sex with robots on a grand scale [is] inevitable" (p. 22), claiming that "much of the groundwork has already be laid for the sexual-robot craze to start" (p. 288). Levy discusses our growing attachment to technologies and changes in societal attitudes towards sexuality, stating that "it is only natural that a child who grows up in a house with a robot . . . would be highly receptive, as it developed into adulthood, to the concept of friendship and love with other types of robots" (2009:104). Levy spends a significant portion of his book *Love and Sex with Robots* (2009) addressing and critiquing earlier speculations made by Sherry Turkle in *The Second Self* (1984), where she questioned the future potential for computers and robots to corrupt or replace the authenticity of social relationships. In a later address, Turkle summarised some of these concerns, asking, "If our experience with relational artefacts is based on a fundamentally deceitful interchange, can it be good for us?" (Turkle 2007). Turkle states that "the idea of 'original' is in crisis" (Turkle 2007), and believes that it is unsettling and dangerous that "for a new generation, simulation is not connoted as second best" (Turkle 2007). Levy and Turkle speculate that robots may come to replace and simulate friendships, love and sex, and may even challenge the notion and value of authenticity. It is no wonder that David Gunkel (2012) has therefore proposed the *Machine Question*: that is, will robots be counted as moral agents and worthy of ethical consideration? He asks, "Can machines be held responsible for actions that affect human beings? …What responsibility might we have to such …machines? (Gunkel 2012:2). Gunkel describes many potential philosophical approaches to machine morality, but arrives at a Kantian critical stance of "functional morality" (2012:74), which addresses the questions of machine moral agency without needing "to resolve the big metaphysical, epistemological, ontological or metaethical questions" (p. 75). Functional morality accepts that there are already, according to Anderson (2007), "ethical ramifications to what machines currently do and are projected to do in the future". Gunkel considers the effect of machine actions on humans and human actions on machines, concluding that "The machine is not just another kind of other who calls to us and requires a suitable moral response. The machine puts 'the questioning of the other' (Levinas 1969) into question and asks us to reconsider without end 'what respond means"' (Derrida 2008:8 in Gunkel 2012:216).

While Gunkel has speculated at length as to whether or not robots will ever be considered moral agents or come to have agency, Barad (2007) contests that agency is not something someone has, but something that someone does (p. 235). The enactment of agency, says Barad, is "a matter of making iterative changes to particular practices through the dynamics of intra-activity", and thereby it is "not only appropriate but important to consider agency as distributed over nonhuman as well as human forms" (2007:214). Barad discusses agency in terms of the intra-activity or "kick back" (2007:215) that robot technology will have on the world, which is shaping and being shaped through development in this field. This indicates that within the framework of Barad's agential realism, robots exhibit agency as intra-activity with their environs, including the reconfiguring of boundary articulations, through their very design and presence, before engaging in any autonomous action or moral decision making. Beyond any specific application or technological horizon that we might best anticipate from robots in the future is an increasing contestation and reworking of metaethical concepts and existent boundaries, such as what is meant by “authenticity”, “love”, “agency” and “human”.

In the following section, the author quotes Donna Haraway, who proposed that the way we design, plan and construct or ‘figure’ these entities (robots) is not just a matter of maximising functionality, but a moral, ethical and political problem (Haraway 1997:23, 284). It is clear that social robots will soon call into account larger ontological and metaethical questions. In returning to the quote that began this chapter, “the ways in which we know and represent the world are inseparable from the ways in which we choose to live in it” (Jasanoff 2004:2), the discussion now moves from “knowing” what it is social robots do and how they communicate, to considering “representation”. The following section 2.2 discusses social robot morphology; what do social robots look like? And, what trends have emerged in social robot morphology? These questions are discussed with deeper critical examination given to the emergent and potentially problematic trends of humanoids and ‘cute’ robots.

2.2 Social Robot Morphologies

Section 2.2 of the literature review seeks to illuminate the first of the research questions outlined in the introduction of chapter 1:

a. What aesthetic approaches and methodologies are currently used in the design of social robot morphologies, and what are their strengths and shortcomings?

To address this question, a review of state-of-the-art social robot morphologies was conducted. Firstly, existing surveys conducted by researchers within social robotics were examined, and the findings of these are discussed. Following this, prominent examples of social robots from the last 25 years were tabulated in a survey together with extracts from the corresponding research papers highlighting the user interaction methods and the broader research motivation for designing the robots. This information has been selected with the desire to better understand how representation, or robot morphology, is aligned with intention and motivation, or “the ways in which we choose to live” (Jasanoff 2004:2). The survey seeks to examine the degree to which alignment exists between morphology and motivation—between the appearance of the robot, and what it is designed to do. Without first-hand experience of many of these machines, it is not within the scope of the present research to analyse the success of these designs. Instead, the relationships between "motivation" and "morphology" are observed to foster a more conscious approach to the design of social robot morphology.

What do Social Robots Look Like?

In 2003, Fong et al. published one of the most extensive and influential surveys of social robots, examining the context, design methods, interaction and applications of social robots. Within that survey they classified the embodied form or *morphology* of existing social robots into four broad categories: anthropomorphic, zoomorphic, caricatured and functional. They describe *anthropomorphic* design as that where "the role of anthropomorphism is to function as a mechanism (for design, for interpreting behaviour, etc.) through which social interaction can be facilitated" (Fong et al. 2003, p. 9). Fong et al. are careful here to use the category of anthropomorphic rather than humanoid, making space for robots with "naturalistic embodiment" and those to which "human characteristics" may be attributed, without necessarily requiring a human-like body. In defining *zoomorphic*, this category was more closely aligned with mimesis, or, where the appearance of a robot imitates that of a living creature (Fong et al. 2003:10). The *caricatured* category is defined by the use of exaggerated, simplified or stereotypical features, such as may be seen in animation. Finally, a *functional* appearance is that which may be guided "purely by the operational objectives" of the robot.

As part of the Simon project, Diana & Thomaz (2011) conducted a survey of social robots and created an "aesthetic vocabulary" towards articulating and discussing various kinds of social robots within the design team and setting targets for the form of their design. The team collated familiar and archetypal robots—both actual robots and those seen in science fiction, cartoons, and toys—and organised them in to following categories: exposed wire, mecha, soft skin, human clone, spaceman/appliance, toybot, beefcake, femme fatale, and friendly doll (Diana & Thomaz 2011:287). Of these categories, the team chose to work with the "friendly doll" aesthetic.

In discussing design issues for robots as sociable partners, Cynthia Breazeal (2004) stated, "Design issues include the robot's morphology (e.g., should it be more anthropomorphic, creature-like or vehicle-like?), aesthetic appearance (e.g., should it appear organic or mechanical?), physical skillfulness, perceptual capabilities, communicative expressiveness, and its intelligence (e.g., social, emotional, or cognitive)" (p. 182). These questions demonstrate the variety of aesthetic directions available within social robotics, all of which, Breazeal argues, impact how effectively people interact with robots.

Other surveys of robot morphology have been conducted to determine user evaluation of robots based on their appearance. Astrid von der Pütten and Nicole Krämer (2012) conducted a web-based survey where participants analysed 40 different images of existing robots, before rating them on a Likert scale and categorising them with the following terms: weak, intelligent, unfamiliar, likable, uncanny, pleasant, natural, attractive, dominant, threatening, competent, familiar, submissive, harmless, strange, and eerie (von der Pütten & Krämer 2012). The origin of these adjectives is not made clear, but the authors sought to test robot likability in light of the "uncanny valley" hypothesis (Mori 1970).

Recently, research has been conducted comparing the cultural variances in preference for robotic design including Bartneck (2008) and Lee & Šabanović (2014). Different cultures (in the case of Lee & Šabanović 2014, defined by countries) varied greatly in their preference for degrees of anthropomorphism, apparent intelligence, robotic form, social role, interactivity and general attitudes towards robots, and thus, as outlined by Breazeal (2004), this impacts preferences for morphology. In the field of Human-Computer Interaction (HCI), Reeves and Nass (1996) found that people had strong responses to extremely minimal cues about a computer's 'personality'. Computer name, voice, confidence, and sequencing of actions were all interpreted as cues to the personality, culture and competence of the computer, and led to people liking and disliking, associating or disassociating with it (Reeves 1996:95). In robotics, similar preferences have been observed, and are often strongly linked to culture or geographical location, however, "the relationship between robotics and society is neither autonomous or linear. Robot design is influenced from its very inception by the cultural assumptions of designers" (Šabanović 2010:440). Factors such as religious beliefs, media exposure, pop culture, and so on, can deeply impact the degree of technology acceptance and willingness to interact with a robot within certain cultures, and will therefore shape cultural biases towards certain morphological trends.

While there are significant bodies of research examining specific typologies of social robots, such as geminoids and gynoids (Knox 2014) or appearance-constrained robots (Bethel & Murphy 2008), the reason for limited survey-style discussions of social robot morphology in general is explained by Fong et al. (2004:5) within their survey: “Differences in design methodology means that the evaluation and success criteria are almost always different for different robots. Thus, it is hard to compare socially interactive robots outside of their target environment and use”. Combined with varying definitions of what constitutes a social robot, a thorough or conclusive survey of social robot morphology is an oblique task—in short, social robots can look like almost anything given the breadth of their applications—however strong aesthetic trends are observable.

Appendix A shows a selection of 25 social robots across 25 years, and although it is acknowledged that the curatorial process was subjective within the methodological selection bounds (see definition in Appendix A introduction), trends in social morphology as well as a narrowing in aesthetic approaches is observable. Additionally, as the mechanical and computational capabilities of robots have increased over the years, designers have sought to achieve increasingly complex goals for the social and interaction capacity of their robots. The typologies of morphologies present within the survey can be described as mechanical, anthropomorphic, zoomorphic, appliance-like, and ‘soft toy’, however, the dominant aesthetic trends present are those of humanoid robots and ‘cute’ robots, totalling 10/25 and 13/25 respectively. Colour trends towards a muted pallet can also be seen, with preference for metallic silver and white (7: 1999), (13: 2005), (14: 2006), (17: 2009), (19: 2011), (22: 2014), (23: 2015), (24: 2016), (25: 2017).

Some of the earlier examples (1: 1993), (2: 1994), (12: 2004) are more mechanical or functional in appearance, and in many senses this is reflective of the expectations of the authors and designers who sought to firstly address the mechanical complexities of a robot navigating in a social environment, such as exploring architectural space or walking with a bipedal gait. The functional nature of these projects focused on navigating anthropocentric terrain is still present in contemporary social robot research, such as the work being conducted by Boston Dynamics (2019). PackBot (9: 2001) produced by iRobot is an interesting example of a mechanical-looking robot produced some years later that was not intended to be social, however by being placed in a particular social environment, humans have forged a meaningful connection with it. In an interview with NBC News, author Peter W. Singer noted, "One of the psychologically interesting things is that these systems aren't designed to promote intimacy, and yet we're seeing these bonds being built with them" (CNBC 2019). One PackBot named Scooby Doo has gained significant media coverage after it was destroyed in a blast in Afghanistan, to the devastation of the soldier operators. The bot had successfully defused 19 bombs in Iraq and Afghanistan, but was irreparably damaged in the line of duty. Following the incident, "One EOD soldier brought in a robot for repairs with tears in his eyes and asked the repair shop if it could put 'Scooby-Doo' back together. Despite being assured that he would get a new robot, the soldier remained inconsolable. He only wanted Scooby-Doo" (Ackerman 2013). Social attachment to these unintentionally social PackBots is widespread, "According to Gizmodo, EOD units have been known to assign their robots personalities and promote them to titles such as Staff Sargent, award them Purple Hearts, and even hold funerals for the destroyed devices that have assisted them on the frontline" (Daily Mail 2019).

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Figure 2.3 – The PackBot known as Scooby Doo, destroyed.

In the years following these earlier examples, the designers of the projects within the Appendix A survey soon turn their motivations towards robots navigating social interactions. Initially these are modest and reasonably elementary interactions that are unidirectional, such as a robot that can “cheer you up” (5: 1997) or “entertain people with dynamic motion performances” (8: 2000), or be kept as a family pet (7: 1999). The morphology of these robots clings quite closely to either humanoid or zoomorphic form, comprised of smooth geometric shapes finished in moulded plastics.

Looking at the robots reviewed within the survey, from approximately 2002 onwards the described motivations for social robots become increasingly complex and abstract, with roboticists looking to foster “meaningful experiences” (10: 2002), with “compelling interactive characters” (12: 2005), that can “understand …intentions, desires and affective states” (Foster et al. 2013) and “bring a unique spark of life to your home” (25: 2017). Such experiences require bidirectional communication between humans and robots, and the expression and evocation of emotional responses to result in meaningful and affective interaction. Although the surveyed robots within this period still vary greatly in appearance, they increasingly funnel into the two main categories of ‘cute’ and humanoid robots, where the category of humanoid accounts for robots of an anthropomorphic form such as those where a head and torso are in a human-like configuration. The roboticists cite a variety of reasons for these morphologies, including “to have a human friendly robotic platform” (Salichs 2006), “to provide assurance that the robot would be intelligent enough to listen and learn” (Diana & Thomaz 2011), “so that people like the robot and are interested in interacting with it over time” (Lee et al. 2012), or simply “We believe it is desirable for a robot that communicates and interacts with human to have a human-like appearance” (Sakamoto & Ishiguro 2009).

However, aside from expressing an awareness of Mashiro Mori’s “uncanny valley” (Mori 1970), roboticists rarely engage in critical reflection on the chosen morphology, presuming that a human-like form will be best suited to communicating with humans, or that a cute appearance will make the robot appear ‘naive’ and desirable. The following sections 2.2.1 and 2.2.2 examine these two emergent trends and interrogate these aesthetics in light of recent critical theory.

2.2.1 Humanoid Robots

Interrogation of research presented at the leading robotics conferences (e.g. ICRA, IROS, RoMAN, RSS, etc.) reveals that the pursuit of technical advancement has been the central concern of social robotics, while any critical examination of morphological design has been marginal or tangential in nature, and this is particularly true of humanoid robot design. Humanoid robots, that is, robots with a body shape designed to resemble a human, have been given form along a vast spectrum of realism, from that akin to a 3-dimensional stick figure to hyper-realistic geminoids that are designed to resemble a specific human, such as those famously coined by Hiroshi Ishiguro (Sakamoto & Ishiguro 2009). Observably, it has become common practice for social roboticists to justify their design decisions and position on the anthropomorphic/humanoid spectrum by briefly citing an awareness of the "uncanny valley" (Mori 1970), and perhaps briefly addressing the need to make their robots appear "interesting" or "friendly" (Scheeff et al. 2002; Mathur & Reichling 2009; Trovato et al. 2015; Blow et al. 2006). In rare cases, some of which are examined in section 2.3, the roboticists consider the exterior design of the robot and the implications of this design prior to and throughout the design process, but these cases are few and are often focused on pragmatically generating a unique form with limited examination of the socio-cultural political implications of the chosen form. In short, as summed by Elena Knox, "roboticists generally take for granted their everyday social behaviour, and do not analyse it when assigning form and function to humanoids; rather, they instinctively, pragmatically and 'uncritically reproduce and reinforce dominant stereotypes' (Robertson 2011: 288; cf. Siegel, Breazeal & Norton 2009)" (Knox 2014:61). For example, hyper-normative gender norms are often reproduced and immortalised in humanoid robots, such as the "receptionist robot" presented by Trovato et al. (2015) who state, "The robot should be perceived as female ... as different genders have an effect of prejudices towards robots too. According to Eyssel et al. [24], a male robot tends to be seen as more assertive and dominant, while a female robot tends to be seen more affable, affectionate, and friendly. In order to make it look female, pink tape was used to add colour to face and body". While Trovato et al. acknowledge existing prejudices, they knowingly further entrench and reproduce them in their robot's design.

For humanoid robots, the issues and implications of their production may extend beyond that of a lack of critical engagement, the avoidance of cognitive dissonance or reproduction of gender stereotypes. Knox provides feminist critique on the production of the most hyper-realistic of mechanical doppelgängers—androids and geminoids—saying "humanoid robotic corporealisation is largely based in the androcentric cultural imaginary of the father-scientist, a 'legacy of masculinist birthing, which is almost always better—less messy and more controlled, and …more challenging— than female birthing' (Castañeda & Suchman 2013:17). In terms of models of the human, this imaginary has tended to uncritically reproduce dogmatist tropes framed as breakthrough innovations" (Knox 2014:63). Knox, together with Hayles argue that this robotic corporealisation is not only the domain of misogyny, but that of egotism: "In one construal of the creation of androids and even everyday digital avatars, the drive to produce an heir is 'enfolded back into the self, so that the generosity of mentoring becomes indistinguishable from the narcissism of self-fixation' (Hayles 1999:171)" (Knox 2014:62). Knox astutely highlights that while there is an absence of critical engagement in social robotics concerning the production of these counterfeit selves, it can be found in abundance in science fiction: "Taking human reproduction out of the shared, collaborative domain into a mode of controlled individualism is a longstanding patriarchal fantasy (see e.g. Castañeda & Suchman 2013; Kember 1998:88; Theweleit 1987 [1977]) even as it resurfaces over and again in the horror and thriller genres as an 'unnatural', punishable act." (Knox 2014:62).

In her paper "Subject Objects" (2011) Lucy Suchman writes concerning human-machine relations and differences, and notes that through mimesis the humanoid or anthropomorphic robot "both align[s] with and diverge[s] from the model organisms of biology," and yet, unlike scientific animal models, is individuated and naturalised. She argues that these subject-objects embody what Donna Haraway (1989) describes as "a trope for figuring human non-human encounters: a form of relation that privileges vision, and looks to find in the Other a differently embodied reproduction of the Self". Suchman argues for a reconfiguration of our relationship with robots that goes beyond the instrumental or a restating of the model human (2011:137). To this end, Haraway (1997:23/284) calls for "a materialist …nonfunctionalist, nonanthropomorphic, and semiotically complex sense of the dynamic of nonhumans in knowledge-making and world-building encounters".

Suchman suggests that the design of social robotics projects ought to move away from the humanoid or those with corporeal similarity to the human form in favour of human-machine intra-actions where the connection is found through the encounter, rather than aesthetic mimesis. Suchman substantiates this approach through her examination of projects such as (Wei

2002) and (Numark 2001), where she says the encounter between the humans and machines is affective, and dynamically interconnected, even though the robot forms are "different" and "non-mirroring" (Suchman 2011:137) compared to that of the human. Suchman examines the subject/object dynamic of the humanoid robot and suggests that we must be "extracted" from our interest in the non-human to be either "reflective or contrastive" to our own properties, and instead she proposes turning our attention to "ontologies that radically—but always contingently—refigure the boundaries of where we stop, and the rest begins" (2011:138). This extraction requires the development of new boundary-drawing practices, a reconfiguring of material and matter.

Haraway (1997:23/284) says that the way that we design, plan and construct (or, 'figure') these entities in a manner that is both non-anthropomorphic and non-reductionist is not just a question of maximising functionality, but a moral, ethical and political problem, involving issues of membership, kinship and liveliness. Suchman suggests that refiguring our kinship with robots while avoiding rehashing the "model human" requires "creative elaborations of the particular dynamic capabilities that computationally animated materialities afford" (p. 137).

While historically it has been proposed (Breazeal, 2000:18) that a humanoid appearance is the most appropriate morphology to maximise anthropomorphism, and indeed the majority of social robot designs have pursued a humanoid form, there are a number of indicators that suggest there is a shift towards non-humanoid, non-zoomorphic morphologies for robots that still require social and affective capabilities to interact with humans. Indicators of these changing trends can be seen in the latest projects emerging from the world's leading robotics labs, including MIT's Cyberflora (2003) and IDC Media Innovation Lab's Robotic Companions (Zuckerman 2015), as well as known trends in technology dissemination such as ubiquitous computing (Lyytinen 2002), and changing demands on the application requirements of social robots such as the appearance-constrained robots used in search and rescue operations (Murphy 2004).

These factors suggest that there is an impending need for robots that will—for the most part—no longer look like humans but will still be able to express clearly an affective message to a human counterpart. Researchers Bethel and Murphy have conducted a thorough survey of the modalities through which non-humanoid robots currently communicate (Bethel 2008). These include body movements, orientation (Fong et al. 2003), coloured lights (Scheef 2002), voice patterns (Bartneck 2001), and tone and music (Crick 2006). However, together with Buck (1984), Bull (1987), Fast (1970), and Spiegel (1974), they strongly conclude, "body movements and posture can reveal more about the actual affective state of an individual than do facial expressions or even verbal communication" (Bethel 2008). This is conglomerated by research that suggests that "body movement and posture are a human's most primitive and basic methods of conveying affect" (Fast 1970).

In his article "Anthropomorphism and the Social Robot" (2003), Brian Duffy states that the role of anthropomorphism in social robotics "Should not be to build a synthetic human" (p. 181), but rather to aid a robotic agent to navigate the human world, and to capitalise on the "natural mechanism through which social interaction with people can be facilitated" (p. 181). He notes that mimicking human features too closely has known pitfalls, and that a balance must be struck between the capabilities of machines and the expectations of humans interacting with them (Duffy 2003:181) in order to avoid cognitive dissonance or disappointment. Duffy recommends that the human tendency to anthropomorphise should be realised in social robotics through a "set of solutions", providing the "language of interaction" rather than through the singular pursuit of engineering the perfect synthetic human.

DiSalvo (2002) is among many researchers who have stated that a robot's morphology must speak to its intended function. Bartneck argues "the size, shape, and material qualities of a social robot should match the task it is designed for to avoid false expectations … morphology sets expectations about the robot's capabilities" (Bartneck 2004:593). Fong et al. have also stated that "a robot's morphology must match its intended function" (Fong et al. 2003:9). These sentiments might be viewed as echoing the modernist architectural principle of "form follows function", however with the applications of social robots becoming so complex and abstract in nature (e.g. what shape does companionship demand?), the design criterion may better be reframed as a necessity for functional transparency, where the morphology of a robot alludes to its capacity and application. According to Fong at al. (2003:149), "The form and structure of a robot is important because it helps establish social expectations. Physical appearance biases interaction. Moreover, the relative familiarity (or strangeness) of a robot's morphology can have profound effects on its accessibility, desirability, and expressiveness". In summarising the results of Mashiro Mori's uncanny valley study, Fong et al. conclude, "consequently, caricatured representations may be more useful, or effective, than more complex 'realistic' representations" (Fong et al. 2003:9).

Designed attributes are the first point of contact for users and the source of the initial information users have about a product (Ulrich 2011), and it is with this information that a user will establish their beliefs about a robot. In light of this, it is interesting to note that Frank Hegel's (2012) research comparing varying human likeness in robots reveals that participants did not judge highly anthropomorphic robots to possess more social capability. Even moderate degree of human-likeness was not judged to have any less social capabilities. If the aesthetic is appropriate, he adds, any degree of realism or abstraction can be appealing (Hegel 2012:474). Hegel warns that robots will be judged as less socially competent if principles of good aesthetic design have not been considered in the process of development: "The aesthetic judgement of a robot relates most closely to the perception of quality of visual features. Poorly designed faces may cause negative attitudes towards artificial agents" (Hegel 2012:470).

While the call for a movement away from humanoid robots has many prominent advocates in social robotics practice and theory alike, the humanoid morphology still persists. Could this be indicative of the lack of methodologies for generating alternative morphological forms? Suchman's proposition that the design of robots ought to avoid both that which is directly reflective of or contrastive to human form promotes exploration of the morphological design space between humans and robots, in search of something that is different and non-mirroring, yet fosters what Haraway refers to as a kinship or likeness. This exploration demands new and "creative elaborations" that avoid mirroring the non-human. These elaborations may take the form of "a set of solutions" or a "language of interaction" (Duffy 2003), and are advised in the above research to be abstract, caricatured, posture-driven, and expressive. The reconfiguring of these forms requires not only creative elaborations but an ontological shift in our response/ability (Barad's term) towards the generation of nonhuman bodies and the designation of agency. Barad (2007:219) argues that "the acknowledgement of 'non-human agency' does not lessen human accountability; on the contrary, it means that accountability requires that much more attentiveness to existing power asymmetries". This attentiveness may operate as a subversion and disruption to the perpetuation of neo-colonial, androcentric or egocentric corperalisations, but this requires that "we be attentive to the intra-twining of material and discursive constraints and conditions" (Barad 2007:219). Conclusively, Barad contends that "Learning how to intra-act responsibly within and as part of the world means understanding that we are not the only active beings" (Barad 2007:218).

2.2.2 Cute Robots

The second significant trend in social robot morphology to be identified in the survey and literature review is that of *cute* robots. This trend has been identified in literature as an aesthetic shown to be preferable among certain cultures in new media and technology (Cheok 2011:223). To date, critical engagement with this trend as a dominant morphological aesthetic in social robotics is limited. Cultural theorist Sianne Ngai, in her seminal work "Our Aesthetic Categories" (2010), discusses the aesthetic categories of the zany, the cute and the interesting, and argues "for the contemporary centrality of [these] …vernacular aesthetic categories" (UChicago.edu n.d). Pertinent for use in the discussion of social robot morphologies, she examines the category of cute with the same philosophical seriousness that has previously been afforded to beauty and the sublime in literature. For reasons that may be cultural (Lee & Šabanović 2014), and also in response to the described complications that can accompany designing robots that are too hyperrealistic (Section 2.2.3), a strong observable aesthetic trend of cute has emerged in social robot morphologies. Typified by the use of large bright eyes, pastel colours, soft or shiny surface treatment, use of a high-pitched voice, and an overall small stature, cute robots can be seen in many examples, from Green, the DragonBot from the MIT Personal Robotics Group, through to industry-manufactured robots such as SoftBank's Pepper. While this significant morphological trend has been linked to cultural preferences and even the influence of science fiction and pop-cultural conditioning, further analysis of the indexical nature of this aesthetic is needed to understand its cultural function, and to encourage a more informed usage of cute morphologies in social robotics.

Ngai argues for the importance of examining these aesthetic categories, including the cute, in relation to production, circulation and consumption, as they historically "index economic processes" (2010:949), and hence aid "investigation of the historical conditions of possibility of specific forms" (Jameson 1991). Ngai (2005a) describes the capacity for the aesthetics of cute, when applied to an object or product, to commodify, domesticate and pacify, with the further potential to render an object charming, irrelevant, vulnerable and inconsequential. Ngai explicitly links the aesthetic of cute with consumption, as a "commodity-oriented" aesthetic that is romanticised and deemed somewhat irrelevant, and therefore evokes what Hannah Arendt describes as a "modern enchantment with the small things" that can have "extraordinary and infectious charm" (Arendt 1958:52). Arendt links irrelevance and charm to the private realm, and hence, the aesthetic of cute is a means of domestication; "for while the public realm may be great, it cannot be charming precisely because it is unable to harbour the irrelevant" (Arendt 1958:52). The cute is also a subjective discursive judgement, uttered as a first-person evaluation, an aesthetic predicate that "bridge[s] the abyss between fact and value without becoming too conspicuous" (Gérard Genette 1999:92). Genette reveals that even the pronouncement of the judgement of cuteness is a safe, inconsequential and "rhetorically stealthy" (Ngai 2010:955) means of evaluation.

In her expanded publication *Our Aesthetic Categories* (2012:64) Ngai describes a cute frog-shaped sponge that shares remarkable similarities with many social robot morphologies. It has "an enormous face (it is, in fact, nothing but a face), and exaggerated gaze (but interestingly no mouth)", which she says underscores the "centrality of anthropomorphism to cuteness". Ngai explains that "realist verisimilitude or even formal precision tend to work against or even nullify cuteness" (p. 64). Indeed, this is observable in social robotics, where there is certainly nothing cute about the humanoid robots Geminoid (2008) or Sophia (2016), which have both been designed in the painstaking pursuit of realism. Ngai argues that the move away from detail and realism towards cute is best sought in objects with round contours and little to no detail, which suggest a certain pliancy and responsiveness, either materially or metaphorically, where "the less formally articulated …the cuter" (2012:64). This rounded blob of detail-less mass is best accompanied by the qualities of "smallness, compactness, formal simplicity, softness and pliancy". While it isn't a functionally plausible option for many social robots to be pliable or soft, some are, including The Hug (2003), Keepon (2007) and PARO (2014). Others imply their social pliancy and compliancy through rounded contours, an exaggerated face, smallness and simplicity of form.

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Figure 2.4 – Robotics Today, *PaPeRo R500*, 2001.

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Figure 2.5 – Mayfield Robotics, *Kuri*, 2017.

Commodify

Cuteness, according to Ngai, while passive and pliable, is seductive and "capable of making surprising demands" (2012:64). Ngai quotes Barbara Johnson, who says that "the purchaser is often 'seduced into feeling that buying the product is, in fact, carrying out the wishes of the product itself'" (Johnson 2010 in Ngai 2012:64). Although most social robots are still significantly expensive and complex machines, cuteness allows robots to transcend the category of 'expensive home appliance' and be trivialised, appealing to the sentimental and consumerist tug to be purchased. Cuteness also invites interaction. In the case of a cute small object, the aesthetic invites the "subject to handle it physically" (Ngai 2012:63), and it can be said that in robotics, cuteness invites a viewer to move closer, to participate and interact with it.

Citing Lori Merish and Mary Anne Doane (2013), Ngai (2012:67) explains that consumption is conflated with identity, where "wanting to have" is "wanting to be like", and cuteness "thus produces what Mary Anne Doane describes as a 'strange constriction of the gap between consumer and commodity'", where "commodity and consumer share the same attributes" (Doane, Desire to Desire 1987:32). Daniel Harris says "advertisers have learned that consumers will 'adopt' products that create ... an aura of motherlessness, ostracism and melancholy" (1992:179).

In a symbiotic chicken-and-egg relationship, cute not only appeals to those wanting to be like the cute (2012:68), but cuteness is a mimetic aesthetic that generates more cuteness; those interacting with the cute tend to get smaller and lower to the ground, the pitch of their voice getting higher and they may even use "small sized adjectives" (2012:60); Interaction with the cute is a mimetic act, contributing not only to a robot's commercial appeal but also to its domestication.

Domesticate

Young et al. (2009:96) in their study "Toward Acceptable Domestic Robots: Applying Insights from Social Psychology", argue that "one of the most important and unique barriers to the widespread adoption of robotics is an especially complex socialisation process", and that for social robotics "the problems of technology acceptance are far more significant in a domestic environment than an industrial one". Young et al. argue that the domestic socialisation or 'absorption' of social robots in to domestic settings will be largely dependent on upon "domestic consumer perceptions of what robots are …and what exactly they are and are not capable of doing" (2009:96). The study contains guidelines for the acceptance of social robots, where the authors outline the importance of robot design methodology, and how designers may chose to leverage user tendencies to anthropomorphise robot appearances to influence the user's perception of the harmlessness or safety of the robot. Cuteness fosters the passage of the 'Other' into domestic environments and is indicative of powerlessness, and therefore the implied safety of the consumer.

Ngai (2012:60) contends that cuteness "solicits a regard of the commodity as an anthropomorphic being less powerful than the aesthetic subject, appealing specifically to us for protection and care". In this way, consumer concerns about the harmlessness and safety of the domestic social robot might be assuaged through cuteness, which Lori Merish argues "stages the assimilation of the Other …into middle-class familial and emotional structures" transforming "transgressive subjects into beloved objects" (Lori Merish in Ngai 2012:60). Interestingly, Ngai also discusses the capacity for cuteness to bridge generational gaps, where cuteness collapses traditional familial forms (2012:69) just as the cuteness of a grandchild might, and this may also have significant power in robotics to collapse generational resistance to new technologies in favour of the purchase of a social robot.

Pacify

Ngai argues that the cute is also undeniably trivial, and embodies a sense of vulnerability that can evoke a desire in us to protect (2005:950). Ngai argues that the cute, interesting and zany have a politically ambivalent nature that evokes a mixture of contradictory effects, where cuteness can evoke both empathy and aversion (2012:66), as well as tenderness and aggression (2005:951). The contradictory affective implications of cute can be seen in the treatment of a number of contemporary robots. Arguably one of the cutest robots produced is HitchBOT[1], the hitchhiking robot (Figure 2.6), who has a digital smiley face, pool-noodle arms, yellow rain boots, and is completely dependent on the goodwill of the public to hitchhike to its destination. HitchBOT successfully hitchhiked across Canada and Europe, gaining a popular online following, but later met a violent end in Philadelphia, USA, where civilians were caught on surveillance tape repeatedly kicking and eventually destroying the robot (CBC 2015).

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Figure 2.6 – *HitchBOT*, happily hitchhiking, 2014.

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Figure 2.7 – *HitchBOT*, destroyed, 2015.

In the 2008 study of Keepon, the researchers reported a variety of behaviours toward Keepon including (categorically): "Violent vs. Protective behaviour: …a boy …beat Keepon several times, and a girl stopped him, 'No! No!'. When [the boy] hit Keepon's head several times, [the girl] stopped him by saying 'It hurts! It hurts!'. [The boy] hit Keepon's head a couple of times …observing this, [the girl] approached Keepon and checked if it had been injured …stroking

[1] Further information available: http://www.hitchbot.me

it gently" (Kozima et al. 2008:9). In 2015 a man was reportedly arrested in Japan for allegedly "kicking a Pepper robot in a fit of rage" (Robotics Business Review 2015). The man admitted he was "frustrated with a store clerk". The robot reportedly now moves more slowly and has been permanently damaged. While the imbalance of power that cuteness affords robots may render them vulnerable and unthreatening to humans, it evidently has the capacity to give rise to aggressive and exploitative behaviour in the human counterparts.

In "Cuteness" (1992), Harris warns that cuteness "disempowers its objects, making them appear more ignorant and vulnerable than they really are" (p. 179) and, as summarised by Ngai, cuteness "excites the consumer's sadism or desire for mastery as much as her desire to protect and cuddle" (Ngai 2012:65). Ngai explains that the act of "'giving face' to an object", particularly an expressive face to a dumb object with no mouth is to "phantasmically make it lose face", which is categorically "an act of humiliation" (2012:91). Ngai describes the use of overly large eyes as "perversely literalizing the gaze (as described by Walter Benjamin)", enabling the robot to "empathetically return our gaze" while "other facial features—the mouth in particular—tend to be simplified to the point of barely being there" (2012:91). Ngai says that similar to the appearance of Hello Kitty, the large eyes and lack of any mouth seem to, in cuteness, "amount to denying speech", establishing and maintaining a strong power differential. This is observable in the documented design stages for the robot Simon, where in the prototyping phase the robot was modelled to include lips and a mouth, which were later removed as the team moved toward attaining their "goal of cuteness" (Diana & Thomaz 2011:293).

While the implications of mass-producing and populating our homes with robotic agents that adoringly gaze at us and never speak for themselves is already something to consider, should the advent of robotic sentience ever arrive to the degree discussed by Gunkel (2012), will this morphological subjugation be something we are called to account for? Further, considering the symbiotic and mimetic powers of cuteness, is this belittling, helplessness and subjugation something we also willingly bring upon ourselves? While social robot designers may unwittingly be designing cute robots in order to address the complex socialisation process and boost commercial appeal by pacifying, domesticating and commodifying robots, they also run the risk of engaging with the politically and socially ambivalent nature of this aesthetic category, provoking elements of both engaging and potentially problematic responses in human counterparts interacting with the robot.

In her discussion of Butler's *Bodies That Matter* (1993), Suchman (2007) likens the 'gendering' of human bodies over time through "the reiteration of norms" to technology construction (and indeed, the construction of technological bodies), "as a process of materialisation through reiterative forms", and that these forms can come to represent more or less uncontested "normative identifications of matter". Therefore it is not argued here that these normative forms of humanoid and cute robots are inherently problematic, or always situationally inappropriate. Rather, it is argued that these forms have materialised through multiple iterations and have resulted in normative and largely uncontested robotic typologies. An acknowledgement of responsibility for this technology and its agential capacity must be paired with a commitment to the critique and continual contestation of these human-like machines, for, as contended by Dumouchel and Damian, "how we live with robots, and what kinds of robots we live with, reflects our own moral character" (2017:xiv).

In the following section, the author examines existing social robot design methodologies, or perhaps more poignantly, the lack of formal methodological approaches, which the author contends is a contributing factor to the passive recycling of dominant aesthetic typologies among robot designers.

2.3 Existing Social Robot Design Methodologies

In 2003 Fong et al. stated "To date, most research in human-robot interaction has not explicitly focused on design, at least not in the traditional sense of industrial design. Although knowledge from other areas of design (including product, interaction and stylised design) can inform robot construction, much research remains to be performed" (Fong et al. 2003:9). Eight years later, Diana and Thomaz (2011) stated, "In the study of human-robot interaction, the aesthetic design of socially active machines is a relatively new endeavor, and there are few precedents on which to rely for guidance. As . . . social robots have been developed, they have varied wildly in terms of overall aesthetic creative direction". Significantly, in 2019 there are still no formal methodological approaches in social robot morphology design. In many ways, this is reflective of the highly multidisciplinary nature of the field, in which designers have turned to methodologies within their own disciplines to approach their designs. A small number of researchers have attempted retrospectively to categorise the design methodologies that are present in social robotics, and these papers have offered insightful critiques on the benefits and shortcomings of these methods. This section examines the research question,

a. What aesthetic approaches and methodologies are currently used in the design of social robot morphologies, and what are their strengths and shortcomings?

The comprehensive 2003 survey by Fong et al (p. 5). includes a short section "Design approaches", which outlines some key concepts important to the design of social robots, such as that the robot ought to adhere to social expectations. The section also outlines two ways in which "socially interactive robots are *built*" [emphasis added], that is "biologically inspired" and "functionally designed" (p. 5). However the authors shortly conclude that "it is hard to compare socially interactive robots outside of their target environment". Fong et al. (2003:5) note that "biologically inspired" approaches are based on theories drawn from disparate disciplines including "anthropology, cognitive social sciences, developmental psychology, ethology, sociology, structure of interaction and theory of mind". It can be concluded from this list that prior to 2003 the impact made by creative disciplines on the development of social robotics was not widely recognised.

Fong et al. rationalise the use of the "biologically inspired" approach "because it allows us to directly examine, test and refine those scientific theories upon which the design is based". This statement can be interpreted in two ways: that the theories themselves are being tested in a new field involving interaction with the artificial, or that the rigour of the robot design process and the degree to which the design 'succeeded' might be tested and weighed within the existing theoretical scientific methodology. The theories listed are ethology, structure of interaction, theory of mind and developmental psychology (Fong et al. 2003:6). While these theories within the "biologically inspired approach" may be frameworks for planning the computational design of a social robot, or the desired application, they do not offer any methodology for approaching the aesthetic design of the robot—the way it is "built". The "functionally designed" approach assumes that understanding how the mind works is not necessary, but can be substituted with a general description of the mechanism "by which people in everyday life understand socially intelligent creatures" (Fong et al. 2003:6). Similar to the "biologically inspired approach", this approach does not offer any insight into methods for "designing a robot that outwardly appears to be socially intelligent" (Fong et al. 2003:6). Although this preeminent survey details approaches that roboticists might take to plan the function of their robot, and it also outlines a range of existing methodologies, the authors were unable to detail any methodologies or techniques for how the morphologies of social robots were actually being designed.

In 2011, Diana and Thomaz wrote that the conscious "aesthetic design of socially active machines is a relatively new endeavour". The authors critiqued Kismet, one of the most well-known social robots from the MIT Personal Robotics Group, and identified an issue common among some of the early social robots: "[although it] had expressive body characteristics such as eyeballs, eyelids and ears, the form was not unified into a holistic design. That is, features varied from one another in aesthetic characteristics, and the overall form still gave the impression of being a metal frame to which a series of parts were affixed" (Diana & Thomaz 2011). Diana and Thomaz (2011:283) describe their process of developing the robot Simon, where they "sought to give industrial design an important role and included creative design at the very start of the project". The project is significant in its attempts to consciously consider design from the outset, but a lack of deeper critical engagement is evident in the design decisions and reporting by the team. Diana and Thomaz (2011) stated, "we wanted people to immediately perceive the robot's lack of initial knowledge, or 'innocence', while also having a desire to teach it through interaction". However, a "lack of knowledge" is ignorance, while innocence denotes a lack of corruption or guilt. This misnomer may indicate some of the authors' subconscious drives linked to the aesthetic of cute, as they later report, "Essentially, we needed to harness "cuteness", but also provide the assurance that the robot would be intelligent enough to listen and learn. Based on these needs, we selected the 'Friendly Doll' direction over the other categories" (Diana & Thomaz 2011:288). That is, the authors demonstrated an awareness that design and materiality matter, but not of why this matter matters.

In 2014, Guy Hoffman and Wendy Ju published the paper "Designing Robots with Movement in Mind", which outlined a case for "designing robots with their expressive movement in mind" (p. 91). The paper details techniques and methodological steps for movement-centric design but, importantly, the introduction to this paper also offers a categorical synthesis of existing methodological approaches to designing robots as identified by the authors. Hoffman and Ju exemplify their movement-centric approach through case studies demonstrating specific techniques and steps for generating an original expressive morphology.

Currently, the most common informal approach to the morphological design of social robots as described by Hoffman and Ju (2014:92) is the pragmatic approach, where the mechanical specifications, mechanical optimisation and physical goals for the robot are the departure point, which can initially result in "an assembly of limbs ... exposed links, actuators and cables". That is, the appearance of the robot is comprised solely of its hardware components and is 'mechanical' in nature. From here, "in some cases" say Hoffman and Ju, "a shell is designed post-hoc to cover internal parts and achieve a certain 'look' for the robot. The shape and structure of the shell is highly constrained by the existing core of the robot, and usually follows its lines and proportions closely" (Hoffman & Ju 2014:92). As a result of building a shell around an existing mechanical structure, this approach also results in commonly repeated forms which are built following the release of certain technologies, such as the remotely-operated platforms produced by iRobot and CMAssist, which resulted in the design of numerous social robots with a round base and similar locomotion speeds, physical manner and operational sounds. Hoffman and Ju explain that designers may also take a purely 'visual' approach (Hoffman & Ju 2014:92), where the designers chose how far along the humanoid spectrum they wish the appearance of the robot to be, and then sketch or model certain body parts such as arms, body and facial features to allow for the robot to exhibit expressive qualities. The visual approach is commonly employed "for expressive interaction, as well as for entertainment robots".

Using the pragmatic approach, the function and application of a robot take priority over the external appearance, which is considered at a later stage in the design process. Using the visual approach, human likeness and a mimesis of human skeletal and facial articulation is prioritised to allow the robot to communicate. In both cases however, "expressive quality of movement is developed later in the process, if at all" and this can be done though the generation and animation of a 3-D model, which is later translated in to a physical movement plan for the robot (Hoffman & Ju 2014:92). While these approaches may result in an ideal (unconstrained) mechanical optimisation, the expressive capacity of the robot may be severely limited. Hoffman and Ju contend that the "quality of [a] robot's motion is crucial", particularly in settings such as schools, homes and offices, where robots will not be observed by a trained operator, but where their physical actions will be interpreted by the lay people around them (Hoffman & Ju 2014:91). They argue that while the appearance of a robot can frame user expectations and set the context for interaction, movement "is critical to conveying more dynamic information about the robot" (p. 91) and can have a significant emotional impact (p. 92). The authors therefore propose a movement-centric design approach where expressive movement is factored in from the onset of the design, and is considered in relation to the "visual and pragmatic requirements of the robot" (p. 93). The authors contend that movement is "a powerful interaction and expression medium" and that humans readily perceive and classify emotional expression, even in abstract shapes and forms, attributing intentionality to movements (Hoffman & Ju 2014:93–94). Hoffman and Ju also note (p. 93) that the movement-centred design approach has tended to result in an atypical, morphologically-distinct robot that "displays formal simplicity and abstract geometric shapes, while exhibiting its complexity and sophistication primarily through carefully designed movement qualities".

Notwithstanding the limited attempts to broadly categorise the methodological approaches present in the robotics and HRI community, these categorical descriptions still tend to describe the intention or hierarchical priorities of the authors rather than specific steps or techniques that might be applicable to another context. The methodology outlined by Hoffman and Ju (2014) is particularly noteworthy for two reasons. Firstly, it aims to attend to the "complexity and sophistication" of interaction identified as desirable by many social roboticists (see Appendix A) without being hindered by the mechanical complexity or economic constraints of interaction approaches involving high-level mimesis such as detailed facial articulation. That is, this approach attends firstly to complexity of interaction, and mechanical optimisation is secondary. Secondly, Hoffman and Ju (2014) is noteworthy because this theoretical methodology is accompanied by specific practical design steps outlined and demonstrated by the authors, and therefore it has the potential for replication and application by other roboticists. Specific techniques are described that have been successfully employed in a number of case studies, including 3-D animation gesture studies, skeleton prototyping, the 'Wizard of Oz' experimental technique, video prototyping and interactive DoF (degrees of freedom) exploration. These techniques actively contribute to a "set of solutions", providing a "language of interaction" (Duffy 2003:181) to facilitate "creative solutions" (Suchman 2011) towards the generation of unique robot morphologies.

In identifying the challenges present in their movement-centric approach, Hoffman and Ju explain that "significant iteration is required to understand how the robot's physical motion relates to its surface appearance" (2014:93), and this is because the movement and morphology of the robot are, for the most part, treated as two separate entities within this approach, where interactive DoF configuration modelling may be use to explore movement, while freehand appearance sketches are used to iterate potential appearances for the robot, and these must be integrated in to the one system at a later time. To build on the findings of this work, Chapter 5 of this thesis develops a novel methodology where the appearance of a robot is generated together with, and inspired by, the pragmatic movement planning of the robot's hardware.

The design of social robots may begin with the desire to develop a robot for a specific social application, such as folding clothes (Sugiura et al. 2009), or for the advancement of a particular technology, such as navigational systems (Nakauchi 2000), or even to achieve a certain "feeling" or "character" for a planned interaction scenario (Diana & Thomaz 2011). However, the broader research motivation of the designers can play a strong determinant in the methodological approach (such as those cited in 12: 2005), as well as the degree to which the morphology is considered, and at what stage. These motivations are often discipline-driven and as such aesthetic design may be a low priority to many. In technology design, Suchman argues, "A problem that underlies the persistence of boundaries between design and use is the premise that technical expertise is the necessary, if not sufficient, form of knowledge for the production of new technologies" (Suchman 1994:24). In 2019 it is now evident that fields such as theatre (Hoffman 2006), animation (Ribeiro & Paiva 2012), dance (Gemeinboeck & Saunders 2015) and music (Crick et al. 2006) have significantly shaped methodological approaches to designing social robots. This is also indicative of the degree to which social robotics is becoming increasingly multidisciplinarity, and this multidisciplinarity is becoming increasingly reflected in the programs of international robotics conferences, such as the Robot Art Forum at the IEEE International Conference on Robotics and Automation (ICRA) in 2018 in Brisbane, Australia.

As Hoffman and Ju note, "People's understanding of non-verbal factors is often tacit and intuitive, and new methods for evaluating designs and eliciting guidelines are needed" (2014:92). This is certainly the case in projects such as those described by Hoffman and Ju where social roboticists have drawn heavily on creative practice-led techniques such as animation and sketch modelling (2014:94, 98, 99). Does it not then follow that the methods of evaluation and confirmation belonging to these fields also find legitimacy within social robotics? In Hoffman and Ju's description of the Shimon project, for example, they demonstrate iterative reflection-in-action, which is an evaluative methodology that has been peer-reviewed and tested within creative practice research projects, and in section 5.1 of the present thesis it will be argued that this process constitutes a rigorous evaluative practice. When highly successful and detailed methodological techniques are being appropriated from creative practice fields for use in social robotics, the author contends that the evaluative practices belonging to these creative fields ought not fall subject to what Haraway refers to as "power differentiated [scientific] communities" (Haraway 1991:187), but must also be granted legitimacy within the field of social robotics to foster true and rich multidisciplinarity.

The following section discusses the history of art in robotics and robotic art, aiming to constructively highlight the often unrecognised contributions of art to social robotics, and position art as a creative practice with a significant contribution to make to robotics. The discussion nurtures the traces and entanglements between the historical treatment of the body in sculpture and the insights that this can offer social roboticists for approaching embodiment and morphology in design.

2.4 Art in Robotics and Robotic Art

This thesis is written within the institutional context of the UNSW Creative Robotics Lab, which defines itself as "a cross-disciplinary research environment committed to examining human interactions with three-dimensional robotic agents and responsive structures within the context of experimental arts and social robotics" (CRL 2016). The term creative robotics encompasses both creative practitioners using robotic agents in their work, as well as providing a platform for creative or design-based practitioners to contribute to traditional robotics research. In the context of the research described in the present thesis, the Creative Robotics

Lab provides a cross-disciplinary space where knowledge and inquiry from the creative arts can be applied to the field of Human-Robot Interaction (HRI) and Social Robotics, and where knowledge within the field of robotics can, in turn, inform creative work.

Historically, some of the earliest examples of embodied robotic agents had creative (or non-pragmatic) applications, including the radio-controlled anthropomorphic *Robot K-456*, made by Nam June Paik and Shuya Abe in 1964. *Robot K-456* was a provocative and controversial political piece; an androgyne in terms of gender identity, the robot played a recording of John F. Kennedy's inaugural address and excreted beans. Examples of 'creative' robots developed just a few years later include *Senster* by Edward Ihnatowicz in 1970, a large-scale computer-controlled interactive system, and *Petit Mal* (Simon Penny, 1993), a robot that autonomously explored an architectural space and responded to viewers. From the 1980s through to the present time, performance artists such as Mark Pauline, Stelarc, and Christian Ristow have worked with robotics, animatronics and have augmented their own bodies to question "zones of slippage" (Stelarc 2009) between established social and political binaries. In 1997, Bill Vorn's robotic artwork developed into a complex multitude of robotic species, in the work *La Cour des Miracles* (1997). Based on the conceptual framework of a "misery of the machines" and somehow strongly inspired by Victor Hugo's *Les Misérables*, these machines were "designed to express such notions as 'pain' and 'affliction', as if they had their own difficulties in life" (Vorn 2016:365). Vorn says the objective of the work is "to conceive and realise large-scale robotic environments that aim to question, reformulate and subvert the notions of behavior, projection and empathy that generally characterise interactions between humans and machines" (Vorn 2016:365).

More recently, Mari Velonaki's *Fish-Bird, Circle B–Movement C* (2004) extended robotic autonomous performance to include two interactive robotic agents in the form of motorised wheelchairs, existing in an "impossible love story" and interacting intimately with one another via movement, proximity and printed text: "The chairs write intimate letters on slips of paper that they then drop to the floor, impersonating two characters (Fish and Bird) who fall in love but cannot be together due to 'technical difficulties"' (Velonaki & Rye 2016:381). Louis-Philippe Demers' *Blind Robot*, presented at Ars Electronica (2013), had robotic arms that would gently explore the face of a human participant, aiming to "understand the degrees of engagement—whether intellectual, emotional or physical—that are generated when a social robot intimately touches a person" (NTU 2014). Works such as *The Hosts* (2009) and *Robot Opera* (2015), by artist Wade Marynowsky have explored autonomous collective robotic performance and "audience-driven agency" (Marynowsky 2018).

In 2016, the Guggenheim Museum commissioned a robotic art work, *Can't Help Myself* by Sun Yuan and Peng Yu, which features an industrial robotic arm that works meticulously to squeegee and contain a puddle of viscous red liquid that continually seeps away. While mesmerising and satisfying to watch,

> the robot's endless, repetitive dance presents an absurd, Sisyphean view of contemporary issues surrounding migration and sovereignty ... the bloodstain-like marks that accumulate around it evoke the violence that results from surveilling and guarding border zones ... and ... the increasing use of technology to monitor our environment. (Guggenheim 2019)

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Figure 2.8 – Sun Yuan & Peng Yu, *Can't Help Myself*, 2016, Kuka industrial robot, stainless steel and rubber, cellulose ether in colored water, lighting grid with Cognex visual-recognition sensors, and polycarbonate wall with aluminum frame.

The works described represent but a small portion of a significant international lineage of artists who have adopted, hacked, reconfigured and recontextualised robotic technology, and in some cases generated original technological advances in pursuit of creative endeavours with social agendas, including political critique, cultural commentary, narration, interpersonal and relational exploration, and entertainment. Bill Vorn has defined robotic art as "an emerging discipline where scientific research, artistic creation and philosophical investigation are intimately interrelated …Moreover, these works are raising fundamental philosophical and sociological questions about the relationships between human beings and machines, between the real and the artificial, and between the living and the non-living" (Vorn 2016:365). As identified by Vorn, the relationship between art and robotics has been one that is centralised around materiality, matter-driven investigation, and contestation of the boundaries and binaries surrounding embodied technology. While art's contribution to robotics is clearly no longer "emergent", the recognition of it in mainstream robotics is. While the history of robotic art is extensive and arguably an influential prelude to contemporary social robotics, engagement with robots in this multidisciplinary manner is still reportedly, for an academic or researcher, risky:

> Robotics without utility is anathema in most robotic research labs. Robotic art, at a cursory glance, lacks the pragmatism demanded by proprietary and prosaic research, which is the norm in engineering …As we personally experienced it, ramifications for engaging in art—robotic art in this instance, could in fact be career threatening. (Herath et al. 2016)

While Hearth et al.'s experience of creative engagement with robotics may not represent the collective experience of all artists in the field, it speaks to a lingering power differentiation concerning the multidisciplinary engagement with this technology. Yet Velonaki and Rye contend, "Designing robots creatively involves not only the conceptualisation and realisation of robots that can interact with humans, but demands a focus on the experience of people as they encounter and interact with the robot" (Velonaki & Rye 2016:378). This focus on experience, say Velonaki and Rye, is innately linked to the disciplinary expertise of creative practitioners: "Embodiment and agency are concepts that have been extensively researched by creative practitioners in a variety of interactive works that link the digital with the physical, the kinetic and the responsive" (Velonaki & Rye 2016:379). Velonaki and Rye identify that the methodological approaches utilised by creative practitioners are ones that explicitly seek to achieve expressiveness, complex interaction and experiential encounters between humans and robots, and the technology required is built around this agenda, rather than technology being the driver of the interaction. Recalling the complexity of interaction that social robots are being designed for, and the need for methodological precedents that focus on achieving this complexity, a deeper examination and integration of the methods and approaches of art is needed in social robotics.

More alien than the technological adoption of robotics in art is the theoretical engagement of mainstream social robotics with art history and criticism. As artists continue to make a significant and necessary impact on the technological and interaction capacity of robots, the theory that has shaped the nature of art's impact may also increasingly shape social robotics. The following section discusses the historical treatment of the body in art and particularly sculpture, and how this knowledge may inform our understanding of some of the implications of embodiment in robotics.

2.4.1 The Body in Sculpture

According to Flynn, "The propensity of sculpture to mimic the physical characteristics of the human body, the degree to which it can …achieve a counterfeit appearance of reality, has been a constant issue throughout the history of sculpture. Furthermore, those objects which directly mimic the body—dolls, waxworks, automata, robots—have been present as sculpture's doppelgänger". Flynn contends that sculpture and robotics share a history through their iterative attempts to achieve a "counterfeit appearance of reality". They both also "occupy a physical space as a viewing subject, and thereby invite a different sort of physiological engagement to that which governs the viewing of pictures" (Flynn 1998:8), or, for that matter, media on a screen. Arguably, this physical occupation of space and the physiological responses that it elicits contribute significantly to exciting the wider sociopolitical discourses that are present in both social robotics and sculpture. In the preface to *Bodies that Matter* (2014:ix), Butler comments on her own struggle to stay 'on track' when writing about the nature of the body saying, "Not only [do] bodies tend to indicate a world beyond themselves, but this movement beyond their own boundaries, a movement of boundary itself, appeared to be quite central to what bodies 'are'". Bodies invite practices of boundary reconfiguration, and it is posited that nonhuman bodies in particular both invite and require constant reconfigurative engagement. Barad (2007:200) critiques Foucault's insights concerning disciplinary practices and the body, saying "there are crucial features of power-knowledge practices that Foucault does not articulate". She includes among these "a dynamic and agential conception of materiality that takes in to account the materialisation of all bodies (nonhuman as well as human …); and the ways in which contemporary technoscientific practices provide for much more intimate, pervasive, and profound reconfigurings of bodies, power, knowledge". Adopting an agential realist approach to examining the matter and materiality of social robots therefore requires that we examine social robot bodies (morphologies) with the same philosophical and political seriousness that has previously been afforded to human bodies. In examining sculpture and the ways in which sociopolitical environments and power relations have historically been folded into the physical manifestations of the human body in sculpture, as well as examining the treatment of sculptures as artefacts, an appreciation of the profound reconfigurings that these non-human bodies invite might be gained.

The human form has been the primary subject of sculpture since the earliest surviving examples, dating back to 30,000 BCE with the *Woman of Willendorf*. "In fact" says Sally O'Reily, "if you think about it, it seems improbable that there is any art that does not involve the body, since making art and relating to it are rooted in the material world of encounter" (O'Reilly 2009:7). While the present section of the thesis does not offer a detailed history of the body in sculpture as this topic has been given exemplary treatment elsewhere, it aims to demonstrate some of the ways in which sculpture's history with embodiment might offer critical insight to social robotics. Tom Flynn has identified that "sculpture's central concern has always been the representation of the human body" (Flynn 1998:9). The pursuit of the naturalism and perfected classical form that consumed the western tradition saw a fascinating divergence from this trend in the late nineteenth century. Initial steps towards the destabilisation of the dominant western canon can be seen in the sculpture of mixed-media artists such as Paul Gauguin (1848–1903) and Edgar Degas (1934–1917), where elements from Impressionist painting began seeping through into their sculptural forms (Flynn 1998:139). Henceforth, "artists would search …African, Far Eastern, and pre-Columbian art and to naive or folk art to express their alienation from an increasingly industrialised world" (Flynn 1998).

At the beginning of the twentieth century, the first attempts towards bold and serious reduction of the human form began with the Futurists, where a distilation and refinement of the human body into 'purified planes' and abstracted form took place, followed by the movements of Constructivism and Surrealism, where the form was done away with almost entirely, or was merely 'implied'. The sociopolitical circumstances that initiated this divergence away from classical naturalism towards abstracted form are described in depth in chapter 3, where the fragmentation of the human body in sculptural form reflected the boundary erasure that was being experienced in many aspects of early twentieth century western life. At that time, art's representation of the body responded to the rapid influx of new technology in both manufacturing and forms of locomotion. At the present time, robotics is arguably the technology most responsible for calling boundaries of the body and human identity into question. Social robotics is symbiotically drawing and redrawing, questioning and reflecting our understandings of human and nonhuman bodies. Examination of the body-link between sculpture and robotics offers insight into three key areas: The conservative nature of both sculpture as an art form and social robotics as a technology, the political nature of classicism and hyperrealism, and the violent treatment of artefacts in both sculpture and robotics.

Conservatism

> Where the histories of painting and photography have seen the successful introduction of new and often radical theories and methodologies which open up questions of race, gender and the economic realities of lived social relations, the history of sculpture has been slower to invite such approaches and as a result has been understood as an essentially conservative art form. This is all the more surprising when one considers that sculpture's central concern has always been the representation of the human body—the site upon which issues of religion, race, gender and class have been inscribed and enacted throughout history. (Flynn 1998:9)

Flynn identifies that historically, the body has been a site for addressing concerns about race, gender, politics, and metaethical questions about humanity, and yet this contestation has been slow to have an impact on the medium of sculpture, which has remained a relatively conservative art form. Might the same be said for social robotics, where other comparable technologies have exploded in diverse and ubiquitous applications, while robotics has remained relative conservative? Might this conservatism go some way towards explaining the limited methodological approaches available and the relatively narrow range of morphological typologies? Adherence to the classical humanoid form, and indeed the pursuit of hyperrealism, may also have deeper political links.

Classicism and Hyperrealism

The arrival of the Early Classical period (c.480–450 BCE) in Athens around 480 BC began a strong return to naturalism in representations of the body. Flynn (1998:34) recounts the findings of art historian Johann Joachim Winckelmann (1764), who proposed that "the great flowering of Greek art was intimately related to the Greek's sense of their own civic liberty, both as a social group free from external interference and internal tyranny and in terms of a particular consciousness engendered by their autonomous political system". Flynn (1998:34) notes that such a simple link between civic liberty and the individual artist cannot adequately account for the marked rise in "idealised naturalism" that developed so significantly in the Early Classical period, however he argues that "Scholars are agreed that the emergence of a new humanism in sculpture around 480 BC does coincide with a new Greek self-confidence". Throughout art's canon, fluctuations in the pursuit of and return to classical antiquity and natural form in sculpture have historically coincided with both nationalism and efforts to rise to the pinnacle of supremacy within art. Indeed, the inverse of this is detailed by Michael Gill in *Image of the Body* (1989:*x*), where he contends, "In the first half of the Twentieth century the split between individual freedom and state authority was accentuated. The image of the body reflected the convulsions of a violent time, as artists dismantled all the carefully wrought traditions of four hundred years". As a new medium of human corporealisation emerges in social robotics, and with it, a resurgence in the pursuit of classical hyperrealism, it is curious to note the international leader in hyperrealistic humanoid robots is reportedly Japan (Fortune 2013); ostensibly, this reportedly coincides with Japan's international strategy to reposition themselves post WWII, both politically (Tokyo Review 2018) and as international leaders in technological innovation (Forbes 2015). The political nature of both sculpture and robotics is also evident in the violent treatment of these artefacts.

Violence

Section 2.1.1 of this thesis discussed a number of case studies of cute robots being treated with unprovoked violence. Flynn describes how historically, sculptures have been seized, toppled or completely destroyed as surrogate symbolic violence: "during moments of political instability [sculptures have] often been seized by the mob which, deprived of the real body, enacted symbolic violence on its surrogate" (Flynn 1998:17). Art historian David Freedburg (1989) has noted that the destruction of effigies of individuals by their enemies or opponents "precedes from the assumption that if one is worthy of being honoured by an image one is equally liable to be dishonoured by it". Flynn (1998:17) notes that "the destruction of these effigies can be taken as an expression of how the actual body would be treated were it present". For example, in 2003 a statue of the former Iraqi leader Saddam Hussein was toppled in Firdaus Square, Baghdad by US troops symbolically marking the fall of Baghdad.

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Figure 2.9 – The toppling of Sadam Hussein's statue in Fridoos Square, Baghdad, 2003

Section 2.1.1 of this thesis links violent treatment of robots to the politically ambivalent nature of the aesthetic of cute. However, an examination of the body in sculpture reveals that this behaviour may also be linked to the wish to symbolically destroy that which the robotic non-human body is coming to symbolise, whether that be a perceived compromise to the notion of authenticity, or the media-fuelled threat to the job market.

Flynn (1998:19) notes that the disruptions to the boundaries of the body by technology continue in a symbiotic relationship to art: "As cybernetic technology continues to explore the frontiers of the 'virtual' body in a 'virtual' reality, so the parameters of representation have altered accordingly, artists now speak of their bodies as forms of 'software', as infinitely manipulable accumulations of data". This relationship between the body and art and the non-human body in social robotic morphologies is developed further in the following section.

2.4.2 Embodiment in Social Robotics

The Media Equation by Reeves and Nass (1999) tells us that people will equate computers (and other contemporary technological media) with real social actors, and that our interactions with new media are social and natural, just like real life. Nass and Moon (2000) found that individuals automatically apply social rules in their interaction with computers as if they were interacting with human beings. Nass and Moon (2000:82) explain that although their subjects understand that a computer is not a person and does not warrant human treatment, adult subjects still engage in anthropomorphic behaviour, mindlessly applying social categories such as gender and ethnicity to computers, and engaged in social behaviours such as politeness and reciprocity. This study is often cited in social robotics papers (Turkle 2007) to explain the social appeal of robots and the human capacity to anthropomorphise. Interestingly, Nass and Moon (2000:82) are careful to distinguish computers from "dolls or robots which have faces and bodies". It is curious that the authors initially seem to insinuate that technology that includes a face or body is automatically anthropomorphised (and hence excluded from relevance to the study), and within the same text decry the significance of the technology or its impact on people's thinking about other modern technology.

The field of social robots has expanded in the nineteen years since Nass and Moon's publication, and the technical performance of these robots has developed significantly. At the time of writing, social robots are still 'rare' in the sense that they are not commonly found in homes and workplaces. However, it is argued that while 'faces' and other appendages do separate robots markedly from other kinds of technologies, the inclusion of these features is not what lends robotics so strongly to anthropomorphism, but rather embodiment in a deeper sense; that is, the human phenomenological experience of the world, and how this affectively impacts our perception of other 'bodies'. Increasingly, researchers in HRI and social robotics are recognising the immense and complex role of embodiment in our interaction with robots.

Embodiment has been discussed in the theory of phenomenology through the seminal work of Maurice Merleau-Ponty (1962), building on work by Edmund Husserl (see Lectures from 1907, in Hursserl 1997) which proposed that consciousness is phenomenal, and that experiences have a certain affective feel in the body, a kinaesthetic value. As summarised by Shaun Gallagher (Gallagher 2013), "The artefacts around [us] elicit certain kinds of movements by us, and we feel them in our bodily preparations for such movements. That is, they affect our bodily attunement." Gallagher has published extensively on phenomenology and its implications for social robotics (Gallagher 2006; Gallagher 2007). He argues that "phenomenological research has direct relevance to design since the artefacts, tools, and technologies that we make affect the way that we experience our surroundings, and this is what phenomenology studies. Emphasizing the important role that embodiment plays in perception and cognition, it investigates, among other things, affective, aesthetic, and action-oriented experience as it is informed by environmental factors and by actual and potential bodily movement".

Embodiment and affect have been examined in social robotics in relation to movement and affective expression (Karg et al. 2013), perception and recognition (Kleinsmith & Bianchi-Berthouze 2013), trust and reliability (Kidd & Breazeal 2004), cooperation and personal space (Bainbridge et al. 2008), and influence and social referencing (Hoffman & Vanunu 2013). However, all of these studies fall victim to Barad's critique of Butler and Foucault's discussions of the body, where materiality takes a passive role, and these non-human bodies are treated as naturally given objects, which are then discussed in the broader sense of the impact of their presence, failing to analyse the materialisation of these bodies or how "matter comes to matter" (Barad 2007:200). In *Transforming Technology* (2002), Andrew Feenberg argues that "the most important questions to ask about modern societies is therefore what understanding is embodied in the prevailing technical arrangements" (2002:19). Freenberg acknowledges that "understanding" is "embodied" in technical arrangements, and arguably, this is done through the matter and materialisation of design. Furthermore, Freenberg urges that uncovering what understandings are embodied in modern technical arrangements are among "the most important questions to ask". The following chapter therefore examines some of the matter and materialisation evident in the bodies or morphologies of social robots, and questions what "understandings" are embedded therein.

Chapter 3

Futurism and Future Forms

The following chapter presents the Futurist movement as a departure point for critique of some contemporary trends in social robot morphology and a re-envisaging of the way roboticists might embed emotional expression in the morphological form of social robots. The author posits the sculptures of the Futurists as a genesis for the emergence of an aesthetic of refined surfaces and impersonal planes, "bespoke[n] to a new sensibility, one grounded in the machine age" (Flynn 1998:141). This aesthetic is examined as being pervasive and prevalent in today's social robot designs.

Throughout this thesis, the author refers to and draws upon both the aesthetics and making methodologies of the Futurists, with focus given to the Italian Futurists working between 1908 and 1916, including those artists such as Jacob Epstein who collaborated with, or were closely influenced by, this group. She acknowledges the potential historical and political contention of doing so, and these issues and her approach are explored within Section 3.1 of this chapter, which identifies the *deus ex machina* or, more plainly, the 'saving grace' of Italian Futurism. The author does not apologise for the Futurists, but rather acknowledges the Fascist agenda that influenced the later work of some of the key leaders of the Futurist movement, whilst also describing the contemporary relevance of their aesthetic and artistic methodologies. The author describes contemporary readings and approaches taken by theorists in referencing this movement, and their nimble negotiation of Futurism's contentious connotations.

Section 3.2 defines the concept of *plastic dynamism* as described by a leading contributor to Futurism, Umberto Boccioni. Plastic dynamism, described by Boccioni as (body + environment) or (body + speed) in a single form, suggests a method for those working in social robotics who wish to embed expression and emotion in to the body form of their robots, potentially theorised as (robot body + emotional movement). The definition of plastic dynamism is described through key non-examples addressed by Boccioni in "The Technical Manifesto of Futurist Sculpture" (1912), which in turn provides a point of insight as to why certain morphological approaches in social robotics may be less effective than others.

Importantly, section 3.2 outlines a series of works by Filippo Tommaso Marinetti and Fortunato Depero, which the author curates to demonstrate a collective development in the ability of the Futurists to convey a subject together with its movement, emotions or environment, 'plasticised' as one form: For example, (body + speed). In sequence, these works form a methodological approach that can analogously be replicated to give 'plastic' value to the embodied expression of human emotions for use in social robotics. The author details all steps of the process, as seen in the example works by Marinetti and Depero.

The work of Carlo Carrà is discussed in Section 3.2.1, as an additional example of the Futurists' 'plasticisation' of the non-material, such as the 'shape' of a sound. Carrà's work contributes another intermediate point on the continuum from representation of the physical and concrete (such as a horse stable) to the less tangible (such as a scent) towards the physical representation or 'plasticisation' of human emotion.

Section 3.3 begins with analyses of the sculptural work of selected Futurists, identifying the roots of an aesthetic that has had an enduring impression on contemporary robotics, and which has remained—until now—unexamined. In 1998 Tom Flynn first identified that Umberto Boccioni's *Unique Forms of Continuity in Space* (1913) might be "read as a not-so-distant ancestor of the cyborg" (Flynn 1998:143). Despite Flynn's insight, the implications of the extent to which Futurism has influenced social robot morphology has not been examined in depth. As seen in section 3.3, the author first considers the aesthetic qualities of sculptures by prominent Futurists Umberto Boccioni and Constantin Brancusi, followed by a visual comparison between sculptures produced between 1913 and 1916, and their contemporary robotic doppelgängers. The evident visual link between designs in social robotics and a period of sculpture that was influenced so heavily by "The machine and its … ever more ubiquitous incursions into human affairs" (Flynn 1998:141) also provokes the question (b), "What does the existence of these parallels signify?" This question is pursued herein.

In Section 3.4 the author discusses Futurist sculpture along with sculptures produced in the ten years following the end of this movement, and asks what remains aesthetically as 'human' when it is stripped back and fused with the 'machine'? Through interrogating the essence of the 'human' aesthetic, we can determine which elements the Futurists felt best communicate 'humanness', and consequently which details are perhaps unnecessary for communication in the body of a robot.

This chapter contains information and modes of inquiry which are highly discipline-specific, but are intended to be accessible in a multidisciplinary field. Section 3.5 therefore introduces the following chapter on the author's approach to cross-disciplinary communication of tacit knowledge.

3.1 The Deus Ex Machina of Italian Futurism: Context and Legacy

deus ex machina
/ˌdeɪʊs ɛks ˈmakɪnə/, /ˌdiːəs ɛks məˈʃiːnə/
noun: *an unexpected power or event saving a seemingly hopeless situation, especially as a contrived plot device in a play or novel.*[1]

As a canonised art movement, Futurism has certainly suffered a particular kind of historical relativism: It has been stretched, reduced and sensationalised. For contemporary art critics or indeed practitioners, positive reference to the work and methods of the Futurists can be extremely problematic, where sifting of the formally progressive modernist values (or 'technical innovations') of Futurism from the political ideology may be instantaneously discredited by

[1]Oxford English Dictionary.
Author's note: *Deus ex machina* is a Latin calque from the Greek term meaning 'god of the machine'. Used as a popular trope to resolve the plot of tragedies in theatre, Artistotle warned in *Poetics* (c.335 BC) against the use of this device, preferring for the resolution of a plot to arise internally. However, in *Ars Poetica* (c.19 BC, lines 191-2), Horace instructs poets that 'the god of the machine' may be employed for a difficulty "worthy of a god's unravelling".

Fascism. Indeed, this has been a recurring issue for critics historically, and in the decades following the collapse of Fascism in Italy, Futurism was largely ignored due to these associations (Benton 1983:30).

The founder and leader of the Futurist movement, Filippo Tommaso Marinetti (1876–1944), would likely be pleased with the nature of this unsavoury legacy. From the bombastic rhetoric of the manifestos to his passionate nationalism and later self-proclaimed Fascist leanings, the efforts of Marinetti and the Italian Futurists were designed to provoke outrage, generate discussion and dissent, and ultimately, mobilise supporters. Aged 23 when he published "The Foundation and Manifesto of Futurism" (1909), Marinetti was strongly influenced by the popular writing of Friedrich Nietzsche, and also the anarchist movements present in Italy at the time. Writing at the beginning of the manifesto to decry the "inherited sloth" of the bourgeoisie, Marinetti was in fact describing his own inherited apartment in Milan, and went on to publish the majority of his writing through a printing press he purchased with inherited wealth (Benton 1983:7). It was this substantial inherited wealth that allowed Marinetti to expand his ideas in such a rapid and wide-reaching manner, with a capacity that no other young poet of his generation possessed (Hultén 1986:18). While the ironic theoretical underpinnings, lack of political know-how and short-sightedness of the Futurist politics have been exhaustively criticised, these concessions have not managed to emancipate the art and innovation of the Futurist movement from its problematic political alignments.

American sociologist Anne Bowler (1991:765) has examined how art historians have dealt with the relation of Futurism to Fascism, outlining two general approaches; "The first of these, in the tradition of aesthetics ... has been to ignore the issue through implicit assumptions about the absolute separation of art and politics". The second approach, she says, "has been to displace the significance of the political dimension of Futurism by relegating it to a later, less aesthetically important phase of the movement ... [Marjorie] Perloff explicitly locates the movement's political affiliations and activities to its post-1920 phase".

Bowler and American poet and theorist Marjorie Perloff both identify that Marinetti did not embrace Fascism until the 1920s, some years after the major artworks and key manifestos of the movement were created, including all of the works examined in this thesis. However, Bowler is reductive in her assessment of what she calls an "otherwise impressive deconstructionist study" conducted by Perloff. Perloff (1986) does not dismiss the emergence of fascist values in Futurism, but rather she identifies that a separation of the aesthetics and politics of the Futurist movement endured long after the movement ended, through a multitude of disparate media.

Perloff describes modern and contemporary applications of the concerns of the Futurists as "cool Futurism": Where the enthusiasm or Fascist exuberance of the Futurist movement had cooled off, but the avant-guerre dissolution of boundaries and futurismo aesthetic endures, exemplified, she says, in work such as in the writing of literary theorist Roland Barthes, "Indeed, iron provides human communication with a new image, that of the thrust jet." (Barthes, 1964).

Perhaps the most popularly recognisable tendrils of cool futurism endure in the 'futurismo' aesthetic qualities and praise of the 'machine age' in painting, as recognised by American art collector Sidney Janis (1954:238):

> The machine and its multiplex activity, speed, force, dynamics, are salt of the American spirit, and many of our serious painters generously flavoured the character of their work with the valid pictorial ideas from the Futurist movement.

However, the more significant and perhaps more interesting legacy of Futurism is present in the experimental dissolution of boundaries and dismissal of syntax, found in many aspects of the contemporary arts, notably in performance art, poetry, sculpture, assemblage, (and most popularly) sound and noise art. Perloff identifies a myriad of modernist and postmodernist works where this is evident, and describes the interesting example of Robert Smithson's *Spiral Jetty* (1970) (Figure 3.1). Smithson, cited in Holt (1979) describes his choice of site for the work:

> It was one of the places where the water comes right up to the mainland ...while flickering light made the entire landscape appear to quake. No ideas, no concepts, no systems, no structures, no abstractions could hold themselves together in the actuality of that evidence.

Smithson chose to work in a landscape where the geographical syntax and boundaries of 'land' and 'sea' are blurred and undefined, and in such a space a work intended to challenge systems and structures could take shape.

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Figure 3.1 – Robert Smithson, *Spiral Jetty*, 1970, Great Salt Lake, Utah.

While describing the breadth of examples covered by Bowler is beyond the scope of this study, in doing so herself Bowler demonstrates not only the commanding historical reach of these Futurist concepts, but also that they have undeniably been separated from and reapplied in isolation from any Fascist political agenda.

This dissolution of boundaries, both physical and theoretical, is perhaps seen most concretely in Futurism as the blurring of the boundaries between the qualities and aesthetics of humans and machines in the sculptures of the Italian Futurists. Arguably the most recognisable of these is Boccioni's *Unique Forms of Continuity in Space* (1913). In this work, the qualities of dynamism, fluidity, and blurred movement observed in the automobile were fused with the human body. The Futurists desired that the age of speed and simultaneity be enclosed in the lines and muscles of the body, exclaiming in the "Technical Manifesto of Futurist Sculpture" (1912) (Apollonio 1973), "let us open up the figure like a window and enclose within it the environment in which it lives". In defining the term "social robot" within this thesis, the author has cited Fong et al. (2003) who describe the necessity for a robot to be able to express emotion and use natural cues to be truly regarded as socially interactive. In other words, a robot must enclose within it the environment in which it lives—that which is human, and social.

To date in social robotics, attempts to design robots that are able to express emotion has been done, for the most part, through literal translation or mimesis of human or animal body parts and facial features. The robot then 'performs' emotional responses. Similarly, in the early work of the Futurist painters, the expression of rotation, speed and movement was "to be found in the repetition of legs, arms and faces", a literal translation of an intangible element applied to the body. However, this was soon dismissed by Boccioni as "idiotic" in his "Plastic Dynamism" (1913). Instead, Boccioni described the result of his intuitive search for one single form (which produces continuity in space): "We Futurists have discovered form in movement and movement in form" (Boccioni 1913). It is this form, generated from movement—in the case of robotics, the movement of emotional expression—which can engender a new method for approaching the design of social robot morphologies.

A number of art critics have defended positive references to the Futurist movement in modern-day practice: "The nature of the Futurist impulse in politics ... should not influence the assessment of its achievements in art" (Joshua Taylor, 1961). Whilst acknowledging the many shortcomings of the Futurist movement in his exhaustive survey of art history in Europe (1880–1940), George Heard Hamilton, Professor of Art History at Yale University, concedes that "they deserve their moment in history for their concern with motion and their attempt to represent it with unconventional materials and techniques" (Hamilton 1981:291).

Contemporary Readings of Futurism: A Note on Gender

As a woman writing about a movement which has become infamously known for its "disprezzo della donna" or scorn for women (Marinetti 1909), the author will take a moment to outline some contemporary studies on Futurism, and their repositioning of the place of women in Futurism.

In 2011, Walter Adamson et al. organised a panel titled "Reconsidering Futurism" at the annual conference of the American Historical Association in Boston. The panel called for papers that "specifically questioned standard notions regarding any aspect of Futurism and sought to promote new areas of research" (Adamson 2013:390). New interpretations and historiographical literary explorations of the movement and of "Second Futurism" (1920–1944) have revealed ways in which Futurist women (the Futuriste) challenged, appropriated and shaped the Futurist message, and how the provocation and social discourse stirred by the movement ultimately advanced the agenda of women.

An elegant study by Erin Larkin (Larkin 2013) presented at the panel examines the work of writer and artist Benedetta Cappa Marinetti, wife of Fillippo Tommaso Marinetti. Larkin challenges the notion that female Futurists were victims of their self-accepting inferiority, arguing that the anti-women rhetoric of Futurism was in the first instance, misinterpreted (Larkin 2013:447), and in the second, challenged by the work of female Futurists, such as the artist known by the name of Benedetta (1897–1977), who was FT Marinetti's wife. Benedetta "exploited the issue of motherhood to reverse some Futurist notions of women" (i.e. sentimentalism and pacifism), and built on recurrent themes of "the return to instinct" and the primacy of women's role as artist, in arguing for her status as creative co-equal in the Futurist revolution (Larkin 2013:446). Larkin argues that the scorn for women within the Futurist movement is "framed within the scorn Futurists professed for the academic and the sentimental" and that the "misogynistic proclamation is an assault not on women as a biological category, but on the conservative bourgeois values [historically] associated with the [feminine], especially in literature" (2013:447).

Larkin points out that the void of scholarship concerning female Futurists has perpetuated conclusions concerning the role of women in Futurism that cannot be sustained by closer examination of the contributions of over forty Futuriste. She further argues that by questioning what had historically constituted 'the feminine', and in provoking a public forum for discussing issues of gender and society, works like the "Manifesto del Futurismo" paved the way for publications such as "L'emancipazione Della Donna" (authored by Arturo Blangino and introduced by Marinetti in 1919), which "proposed policies from women's education to universal suffrage" (Larkin 2013:449). Larking notes that the Futurists sought to stir reactions and generate discussion, not formulate rules or declare inviolable truths (Berghaus 1998:244 cited in Larkin 2013:449). Fittingly, such is the nature of the research conducted herein.

The Italian Futurists

It must be acknowledged that any critical use of historical images is subject to a certain level of subjective interpretation. Eloquently discussed in Michael Holly's *Past Looking* (1996), "the act of interpretation, of course, must always be an appropriation, a forcing of either the work or an aspect of the past to fit the needs of the interpreter" (Holly 1996:65). While Futurism saw parallel movements in Russia, Belgium, England, France and elsewhere, in focusing on the work of the Italian Futurists and those closely associated with this movement, the author is able to draw upon the wealth of literary accompaniments that were produced in Italy contemporaneously with the artworks to mitigate the potential for this subjective interpretation. However, included in this study is the work of Jacob Epstein (UK) and Henry Gaudier-Brzeska (France). Epstein is discussed by Flynn (1998:145) as another sculptor who (if only briefly) confronted "the aggressive dynamism of the machine age", although he was reluctant to be associated with the British Vorticist movement (Hultén 1986:473). Gaudier-Brzeska was influenced by Marinetti after meeting him in 1913, and associated closely with Epstein and Brancusi after meeting them in London in 1912 (Hultén 1986:484). Gaudier-Brzeska published on behalf of the Vorticists in their magazine *Blast* in 1914.

The work of Italian Futurist Filippo Marinetti is of particular interest to the present work. His sketches play a key role in informing the author's present design methodology, not only because he founded and sustained Futurism (Benton 1983:5), but his visual work is significant because he was primarily a writer, and the intention of his work can be closely traced through his prolific publications. This also lends some explanation to the use of onomatopoeia in his gestural sketches. Marinetti was said to be so active in the distributions of his correspondence that one recipient finally answered, "Just let me die in peace!" (composer Camille Saint-Saëns, cited in Hultén 1986:18). The Italian Futurists also experienced a late and rapid industrialisation which gave unique propulsion to the movement in Italy, as described by Benton (1983),

> Essentially, the path toward rapid industrial development upon which Italy had embarked in 1896 promised for the Futurists the fulfillment of Italian nationalist and irredentist goals. For the Futurists, technology is not an ethically neutral vessel into which society projects values and uses but, rather, contains its own set of values embedded within it: speed, destruction, and orgiastic upheaval or violence." (Benton 1983 cited in Bowler 1991:774)

Similarly, technology today is not an 'ethically neutral vessel'. A strong and observable aesthetic synchronicity exists between the sculptural works of the Futurists and examples of social robots produced in the last fifteen years [2]. This synchronicity and the enduring aesthetic of Futurist sculpture is explored in section 3.3.

[2]These aesthetic echoes and historical resonances of a such a politically charged movement naturally give rise to concerns regarding the potential for neo-fascist agendas in contemporary social robotics. There is no

3.2 Futurism: Plastic Dynamism

The blending of human and machine qualities, and other forms of 'simultaneity', defined by Umberto Boccioni as "the synthesis of what one remembers and what one sees" (Boccioni 1913), were explored in depth and expressed by the writers and artists of the Futurist movement, at a time when Europe was experiencing the slippage and erasure of contours across many aspects of life as new technologies and transportation emerged. This 'simultaneity' or duality of experience and form would be expressed though a multitude of media, including poetry, film, drawing, painting, and sculpture. In art, the Futurist sculptors would later express simultaneity through the concept of plastic dynamism, a term which is defined within this section.

The following section details an original systematic arrangement by the author of experimental sketches, paintings, and paper-cuts produced by various Futurist artists across a five year period in order to articulate an observed collective contemporaneous evolution and methodological approach towards the expression of plastic dynamism.

Between the years of 1900 and 1916, Europe experienced the erasure of boundaries across many aspects of life. As insightfully documented by Marjorie Perloff (Perloff 1986:9-14), the appearance of advertising posters and polychrome menus saw 'art' and 'life' blurring together in every shop window, and towering above the streets. In 1905 the Trans-Siberian Railway was completed, linking western Russia to the Pacific coast, together with the Trans-African Railway and the Trans-Andine Railway, dissolving nation boarders and impossible distances. Between 1909 and 1914, the corners of the globe were tugged tightly together as "the world witnessed the first successful expeditions to both the North and South poles", together with "the first extended airplane run (Wilbur Wright 1909), [and] the first flight across the English channel (Louis Blériot 1909)" (Perloff 1986:13), where humankind now traversed the globe somewhere between the land and the sky. One's thoughts and words could be spoken in one place and heard miles away in another with the increasing availability of the telegraph and telephone. Seated in one of the nearly 200 new cinemas that had opened in Paris by 1913, one could sit in one place, and be transported entirely to another through the advent of film (Perloff 1986).

evidence of such agendas in social robotics, however it is interesting to observe that the emergence of this field does coincide with the most significant re-emergence of ultranationalism, anti-socialist and anti-immigration policies in a number of leading Western countries since WW2; all key characteristics of neo- and post-fascism.

The increasing production of automobiles, together with the steam train saw the body and self move with speed and dynamism through space, observable as a blur: simultaneity.

The expression of these intersections and instances of simultaneity are evident in much of the work of the early Futurists, who instinctively began experimenting across a wide range of media. Italian composer and leading Futurist, Francesco Balilla Pratella, began composing revolutionary music of absolute polyphony, by "fusing harmony and counterpoint", favouring "polyrhythm" over classical metric order (Lista 1986). Free-verse poetry and a renewal of poetic theatre was advocated by Marinetti, who did away with punctuation—"the foolish pauses made by commas and periods"—which suppress "the continuity of a living style" (Perloff 1986:57). This experimental "intuitive disorder" served as a kind of "confirmation of Boccioni's ideas: breaking through the veil of objective reality" (Lista 1986:25).

Of all the slippages and states of simultaneity, none were experienced by the Futurists in such a profound way, and with such lasting phenomenological magnetism, as the blurred boundaries they felt between the human body and the qualities of the machine age. As detailed in the Futurist Manifesto; "4. We affirm that the world's magnificence has been enriched by a new beauty: the beauty of speed…a roaring car that seems to ride on grapeshot is more beautiful than the Victory of Samothrace" (Marinetti 1912). The speed, efficiency, mobilisation and dynamism of the mechanical world would be expressed not simply as something they experienced, but rather, something they were becoming, and would become, as "motion and light destroy the materiality of solid bodies" (Lista 1986:18). They sought to express "…[Their] contemporary life, intensified by the speeds made possible by steam and electricity" (Lista 1986).

This simultaneity, initially depicted by Futurist painters as stages of motion in repetitive linear sequence in works such as Giacomo Balla's Dynamism of a Dog in Motion (1912) (Figure 3.2) demonstrated quite a literal interpretation of the phenomena of the body in space, with repetition of arms and legs in a blurred reduplication of form, "scientific formalizations related to the camera eye" (Lista 1986:21): No doubt aided by increasing prevalence of the motion picture camera and the rolling film, a phenomena exemplified by Eadweard Muybridge's animal locomotion studies (Figure 3.3), developed 25 few years prior.

However, this depiction of dynamic movement was soon dismissed by Boccioni as too literal, declaring it "idiotic" (Boccioni 1913), as he proposed that dynamism ought rather to be ex-

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Figure 3.2 – Giacomo Balla, *Dynamism of a Dog in Motion*, 1912, oil on canvas.

pressed "through the intuitive search for the one single form which produces continuity in space" (Boccioni 1913). Boccioni wanted to "evoke the vital intensity of the phenomenon and its emotional and lyric dimension, not provide an optical reconstitution of motion" (Lista 1986:21). In the "Technical Manifesto of Futurist Sculpture" (1912), Boccioni urges, "Let us open up the figure like a window and enclose within it the environment in which it lives". In social robotics, we have witnessed many similar examples of literal translation, where a mechanical object has been made to look literally like a human, and performs "reconstitutions of [e]motion"[3]. For these robots, the dissonance between appearance and behaviour has proven to be objectionable, and in some cases, repulsive. Rather, social robotics calls for an approach where morphology might be drawn from the intangible qualities of human-ness (Fong et al. 2003) and emotional movement can be conveyed in a concrete way that is not a literal translation. Boccioni sought to translate the intangible qualities of the machine age into a sculpture of a human body through the concept of plastic dynamism.

[3]Just as Boccioni encouraged Futurist artists to evoke the vital intensity of emotion in their forms rather than simply reconstituting emotive movement, similarly, social roboticists ought to draw more deeply on the "vital intensity" of emotional movement, rather than just performing emotional movement.

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Figure 3.3 – Eadweard Muybridge, *Cockatoo; flying*, Plate 759, 1887, collotype print.

Plastic Dynamism

Boccioni explained the simultaneity of (body + environment), or (body + speed) as a desire to give plastic value to intangible qualities that encounter or intersect with the body. He explained:

> Sculpture should give life to objects by rendering their extensions into space palpable, systematic and plastic, because no one can deny any longer that …everything that surrounds our body (bottle, automobile, house, tree, street) intersects it …forming an arabesque of curves and straight lines. (Boccioni 1913)

In the painting Movements of Birds (1916) (Figure 3.4), Fortunato Depero depicts the sweep of the birds' neck and the flutter of its wings with the same weight and value on the canvas as the head, or the leg of the bird. Perhaps even the small points of light that appeared for a moment between the rustle of the wings have been given pure permanence as orange, green and yellow ellipses. Boccioni described this as revealing "the immanence of gesture" (Lista 1986:26), where light and movement and fluster are given concrete representation, manifested

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Figure 3.4 – Fortunato Depero, *Movements of Birds*, 1916, oil, tempera and enamel on canvas.

in the material world: Made plastic. Thus, as explained by Boccioni in "Plastic Dynamism", it is the "manifestations of the relativity …between the environment and the object which come together to form the appearance of the whole: environment + object" (Boccioni 1913). It is no longer an image of a bird in movement, it is the bird as movement, is movement = birdmovement.

> There can be a reawakening only if we make a sculpture of milieu or environment, because only in this way can plasticity be developed, by being extended into space in order to model it. By means of the sculptor's clay, the Futurist today can at last model the atmosphere which surround things. (Boccioni 1913)

Here, Boccioni revels that through this approach, the Futurists had devised a way to model the atmosphere they were surrounded by: the steam and electricity, the roaring motors, violence, the turning of gears, the "whirling world of steel, pride, fever and speed" (Lista 1986), and to fuse this with their very selves to make a new form.

In the images reproduced as Figures 3.5 to 3.8 Marinetti is attempting to draw verbs—he is trying to assign 'plastic' value to an event, rather than to a subject. In Figure 3.7, he is trying

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Figure 3.5 – Filippo Tommaso Marinetti, *Propeller*, 1915–1916, ink on letter paper.

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Figure 3.6 – Filippo Tommaso Marinetti, *Air Raid*, 1915–1916, ink on paper.

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Figure 3.7 – Filippo Tommaso Marinetti, *Bombing*, 1915–1916, ink on paper.

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Figure 3.8 – Filippo Tommaso Marinetti, *Action*, 1915–1916, ink on paper.

to draw "bombing"; not a bomb, or the place that is bombed, but the very moment and feeling and value of bombing. In these sketches he is searching for an aesthetic signification of these actions, and still slips back to linguistics and onomatopoeia, coupled with gestural strokes. In the first image, Propeller (Figure 3.5), Marinetti's ink spirals to the left with the mechanical movement of the propeller, showing directional arrows pointing to both the left and the right, articulating the optical illusion we experience of a propeller reversing at high speed. His onomatopoeic words "ran ran zaaaf" describe the propeller's start-up sound with arrows and spikes pulling away from the centre, and also the rush of air and the energy of the motor. Marinetti carefully avoids any direct symbolism of a physical propeller, but rather the sound, speed, and energy of its function signify both its presence and motion.

In these early sketches, we can see the determination of Marinetti to move away from a literal translation, and to find a value on paper for intangible qualities like "action" or the experience of an air raid (Figure 3.6). These sketches also mirror the difficulty roboticists have experienced in attempting to convey intangible human-like qualities in the design of their social robots—for example curiosity, fragility, or shame—without relying on literal communication modalities such as digital voice or simulated facial expressions, in much the same way that Marinetti falls back to language. These initial sketches, although fervent and imperfect, suggests a first step for designers to determine the shape or 'plastic value' of human-like qualities such as curiosity, or the shape of emotional movement.

The desire to make speed, rotation and energy plastic was refined in the work of Fortunate Depero, who further flattened and abstracted plastic qualities together with the human body, which was then abstracted into a new form.

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Figure 3.9 – Fortunato Depero, *Ballet Dancer*, 1917, China ink diluted on paper.

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Figure 3.10 – Fortunato Depero, *Ballet Dancer*, study of costume, 1917, tempera on canvas.

In Depero's ink sketch of the ballet dancer (Figure 3.9) the drawn lines of the legs and body are steady and considered, where the lines of emphasis, movement and twirl remain light and gestural. It is still clear which lines are those of the body, and those of dynamic movement, emphasis, or emotion, indicating states of being.

In the second image (Figure 3.10) where the sketch has been translated into tempera paint, the solid colour serves as a reductive agent, and helps to 'plasticise' the movements and rotations of the ribbon, to share equal weight with the body and head. The limited pallet contributes some depth and space to what has become an otherwise flattened image.

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Figure 3.11 – Fortunato Depero, *Costume for Mimismagia*, 1916, watercolour on paper.

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Figure 3.12 – Fortunato Depero, *Ballet Dancer for Le Chant du Rossignol*, 1916, collage of paper on paste-board.

Further, in Depero's study *Costume for Mimismagia* (Figure 3.11), the snap of her fingers and the stamp of her feet sprout violently outward, and crown her head. Plasticised in paper collage (Figure 3.12), the whip and snap of the cape fans out and joins the rotation of her skirt. The dancer has become fused with the sounds and movement of the dance, just as she may have been in the moment of performance.

In Figure 3.12 one can now read volume, axis of rotation, the location of sounds and points of emphasis. There is a certain functional transparency in this new depiction of the dancer. With a single glance, the performance is surveyed in its entirety. Similarly, Futurist poet Blaise Cendrars and painter Sonia Delaunay-Terk also conducted experiments to this effect, "[writing] in contrasting colours, in order to train the eye to read with one glance the whole of a poem, even as an orchestra conductor reads with one glance the notes placed up and down on a bar" (Perloff 1986:9).

When we consider the established necessity for the function and capacity of a social robot to correlate strongly with its appearance, the immediacy and transparency of the performance achieved within these paper-cut iterations point toward a highly valuable step within this approach, and suggests a system of notation, or diagram, similar to a script or a musical score for use in robot design. In this way, the emotion, intention, or character of the robot might be comprehended instantly, as a whole. Like a score, the physical movement capacity of the robot might be read in its morphology, limiting the potential for alarming unexpected movements. Further, sketching a robotic form together with its embodied emotional movement arcs (robot body + emotional movement) might suggest a new abstracted morphology, less human or animal-like, to avoid cognitive dissonance or disappointment in its behaviour.

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Figure 3.13 – Umberto Boccioni, *Dynamism of a Racing Horse + House*, 1915, gouache, oil, paper collage, wood, cardboard, copper, and iron, coated with tin or zinc

In the final three-dimensional stage of plastic dynamism, the image *Dynamism of a Racing Horse*

+ *House* (Figure 3.13) depicts an unfinished construction by Boccioni (Hultén 1986:139). What can be seen is a sculptural attempt to articulate “not pure form, but pure plastic rhythm, not the construction of bodies but the construction of the action of bodies …complete fusion of the environment with the object by means of the interpenetration of planes” (Anglica Zander Rudenstine cited in Hultén 1986). The speeding horse and the rhythm of its gallop intersect with the facade of the building situated further behind, and with the light that passes through it. Here, both physical and intangible qualities have been given tangible form and weight, intersecting with the horse’s body to create a new form. Boccioni’s sculpture demonstrates the potential third stage of the methodology, where a two-dimensional paper-cut collage of a new amalgamated form, such as those developed by Depero, might be translated in to a three-dimensional rendering. This sculpture is no longer of a horse, but reminds us of a horse, and suggests natural form and movement, but does not mimic any form or creature directly.

Although these examples do contain some immaterial elements such as the sound of snapping fingers or the dynamism of the racing horse, both the horse and the dancer’s costume are still relatively tangible elements when compared with some of the human elements roboticists might wish to embed within their robots, such as curiosity. The following discussion of the work of Carl Carrà develops the potential of this method further.

3.2.1 Carlo Càrra

In considering the full continuum of the potential for plasticisation of the immaterial, where form and value is given to the intangible, the work of Carlo Carrà extends this notion to the sounds, noises and smells.

Carlo Carrà was an Italian painter and a leading figure of the Futurist movement. Carrà signed the Manifesto of Futurist Painters together with Umberto Boccioni, Luigi Russolo and Giacomo Balla, and authored a text on “The Painting of Sounds, Noises and Smells” (1913). In his writing, Carrà details:

> Imagination without strings, words-in-freedom, the systematic use of onomatopoeia, anti-graceful music without rhythmic quadrature, and the art of noises—these were created by the same Futurist sensibility that has given birth to the painting of sounds, noises and

smells. It is indisputably true that (1) silence is static and sounds, noises and smells are dynamic; (2) sounds, noises and smells are nothing but different forms and intensities of vibrations; and (3) any succession of sounds, noises and smells impress on the mind an arabesque of form and colour. We must measure this intensity and perceive these arabesques. (Russolo 2012:115)

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Figure 3.14 – Carlo Carrà, *Funeral of the Anarchist Galli*, 1910–11, New York MoMA.

Carrà's most important Futurist work is *Funeral of the Anarchist Galli* (1910-11). Pontus Hultén explains that the aim of the work was not to show the workers and police on a specific occasion, but "rather to depict powers in society confronting each other in a conflict determined by destiny" (Hultén 1986:20). The red shouts of the police and the workers envelop the crowd below, and above, the green smells of the newly industrialised city pierce the sky in oblique lines and acute volumes (Russolo 2012:117). Not only do the use of line and colour depict the clashing sounds and smells of the conflict, but Carrà has employed the "rrrrrreddest rrrrrrreds that shouuuuuuut" and "greeeeeeeeeeeeens that screeeeeeeam" [sic] (Carrà 1913), using a literal contrast in colour to render contrasting political ideologies plastic, shouting from the canvas.

Carrà (1913) described the sensation of sounds, noises and smells as forming "abstract plastic wholes", or "arabesques of form and colour". Using the metaphor of being shut in a dark room with a strong smell, such as gasoline or flowers, Carrà asserts that "our plastic spirit gradually eliminates the memory sensations and constructs particular plastic wholes whose quality and weight and movement corresponds perfectly to the smells found in the room" (Russolo 2012:119). Similarly, when we hear the word 'humility' or imagine the embodied movement of curiosity, it is not a particular face or features that we might see, but rather, the author argues that an arabesque of form presents itself. An arabesque or a movement, perhaps made up of a curve in the back and extension of the neck, or a lowering of the brow and a hunching of the shoulders, which might form a line and shape in the mind. It is this shape that forms what Boccioni describes as the nucleus of what one wants to create: "One must start with the central nucleus of what one wants to create, in order to discover new forms" (Boccioni 1913).

The shapes, lines and surface finishes found in Futurist art sought to do away with the "sentimental mimicry of natural appearances" (Russolo 2012:14) and instead, replace them with the "dynamic modalities of a machine's aesthetic, which celebrated speed, power, modernity" (Flynn 1998:141). The following section introduces some of the most commonly recognisable Futurist sculptures, which finally saw the Futurists apply the notion of plastic dynamism to the human form: The machine age, as well as the Futurist political agenda for Italy embedded within the body of man.

3.3 Visual Comparisons: Twentieth Century Sculpture and Twenty-First Century Social Robots

While the field of social robotics seeks to adapt and express both human and machine qualities within the morphology of robots, the degree to which this has been achieved with critical consideration is still limited. It is common practice for those working in a discipline concerned with aesthetics or design to engage with their designs equipped with historical and theoretical knowledge of the 'canon' and other kinds of precedents. It is expected that designers will knowingly invoke the semiotics of certain time periods or movements to convey a considered message. It is argued here, however, that social roboticists in many cases have employed a 'futuristic' aesthetic for robots without knowledge of a strong aesthetic link with the original work of the Futurists, as will be demonstrated below. It is argued that blind appropriation without critical examination of aesthetic origins results in a certain stylistic anachronism, where robot morphologies from the last twenty years might easily have been designed by Futurist sculptors working in the early twentieth-century. Boccioni asserted "It is not simply by reproducing the exterior aspects of life that art becomes the expression of its time" (Boccioni 1913). Similarly, how can the social robots of the twenty-first century truly be an expression of our time when their designers are (perhaps unknowingly) reproducing exterior aspects of life (such as the sterotypical "futuristic look"). Further to this, Barad explains in her account of agential realism that it is a component of the "responsible practice of science" to account for the "full set of practices" (2007:390) that are part of the "larger material arrangement" that is being produced. Barad argues that where traditional objectivity and responsibility may take shape in conforming to the "norms of correct practice" within a confined discipline, agential realism calls for a full "accounting of constitutive practices in the fullness of their materialities, including the enactment of boundaries and exclusions, the production of phenomena in their sedimenting historiality, and the ongoing reconfiguring of the space of possibilities for future enactments" (Barad 2007:391). When examining some examples of sculptures from the Futurist period (early twentieth century), and comparing them with examples of the forms of robots produced during the last twenty years, over one hundred years later, striking aesthetic similarities and tendrils of 'sedimenting historiality' can be observed. By comparing and contrasting these forms, as well as examining the ideation and methodological underpinnings of the Futurist works, insight can be gained into the pervasive aesthetic synthesis between 'human' and 'machine' qualities, "a body born from a fusion of the organic and the technological" (Flynn 1998:143) developed by the Futurists. Barad contends that these intra-actions hold deeper implications than just the "results", or in this case, the resultant morphologies. These historical aesthetic intra-actions shape both "what will be and what will be possible—they change the very possibilities for change", and they urge us to responsibly and consciously engage with these constitutive practices.

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Figure 3.15 – Umberto Boccioni, *Unique Forms of Continuity in Space*, 1913, Tate Gallery, London.

Futurist Sculpture

Arguably the most ubiquitous work of the entire Futurist period is Boccioni's *Unique Forms of Continuity in Space* (1913). Boccioni worked prolifically in painting, sketching and collage, however he has become most well known for his sculptures, and particularly for his 1913 bronze sculpture *Unique Forms of Continuity in Space* (Figure 3.15). Although the key members of the Futurist movement were primarily poets and painters, Futurist sculpture has proven to be historically compelling and monumental to the movement. As Flynn describes, there is "an inescapable fact of the sculpted object":

> it occupies the same physical space as the viewing subject and thereby invites a different sort of visual and psychological engagement to that which governs the viewing of pictures …we cannot ignore it. It is for this reason that sculpture has been the favoured medium of political and public art, of monuments and memorials. (Flynn 1998, p. 8)

As discussed in section 2.4.2, it is this occupation of physical space and resulting physiological engagement of the viewer that links sculpture and robotics, and it is the place where Futurism and social robotics share the closest ties.

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Figure 3.16 – Constantin Brancusi, *Male Torso*, 1917, The Cleveland Museum of Art, Ohio.

Boccioni declared that "a Futurist sculptural composition will contain the marvellous ... geometric elements of modern objects. They will not be placed alongside the statue ... they will be embedded in the muscular lines of the body" (Boccioni 1913). Where Boccioni has indeed embedded a moment of speed and dynamic movement within the very lines and volume of the body shown in Figure 3.15, the reduction of both man and machine qualities found a deeper simplification some four years later in Constantin Brancusi's *Male Torso* (1917) (Figure 3.16). "Brancusi's (1876–1957) *Male Torso* betrays a lingering fidelity to natural forms ... while shifting emphasis onto the purifies planes" (Flynn 1998:141). Brancusi extends the infiltration of the machine age beyond subject matter to materiality and manufacture; the human figure is now machine-finished: extruded, welded, polished and shining. In Brancusi's work, Flynn directly links the impact of the machine age on the Futurists with the impact of the digital on the lives and productions of our own time:

> Brancusi's *Torso* ... bespoke a new sensibility, one grounded in the machine age. The machine in its increasingly diverse manifestations and its ever more ubiquitous incursions

> into human affairs was to have a profound impact on the evolution of sculpture during the first two decades of the twentieth century. Just as new developments in digital technology and cybernetics have exerted an impact in our own period. (Flynn 1998:141)

The purified planes and complex amalgamation of human and machine qualities seen in Brancusi's Male Torso would come to have a permeating effect on the aesthetics of the automata and robots of the future. It is interesting to note that in his "Technical Manifesto of Sculpture" (1912), Boccioni proposed the use of motors in a sculptural work to give it a sense of rhythmic movement (Boccioni 1913). Already, Boccioni sensed that these machine-like humans might soon become human-like machines.

Visual Comparisons

The pairs of images discussed in this section were identified and curated in the literature by the author. The robots pictured share an aesthetic resonance with sculptures located in the Futurist period and also the few years following, known as Second Futurism.

The 'futuristic' aesthetic that emerged through Italian Futurist sculpture was typified by sleek lines, simplification of surfaces, elongation, a reduction to basic organic and geometric shapes, and a neutral colour pallet (plus a range of lesser attributes). This aesthetic has evidently endured, as contemporary social robotics design appears to be caught in a 100-year loop. In identifying the origin of this loop, we may employ the Futurist movement as both the critical lens for examining social robot design aesthetics, and as the origin of a new methodological approach.

Jacob Epstein's *The Rock Drill* (1913), originally carved in plaster and mounted on a mechanical drill, was later truncated by the artist and cast in bronze, resulting in the final (1916) version featured in Figure 3.17 (a). Exhibited in the London Group show in 1915, Epstein described the work as "a machine-like robot, visored, menacing …protective". Epstein's aesthetic approach was "supported by his friendship with the philosopher and critic T. E. Hume", who predicated that the new art would be "clean, clear-cut and mechanical" (Flynn 1998:473). Flynn describes this work by Epstein as confronting "the aggressive dynamism of the machine age as a means by which to forge a new mode of expression relevant to the modern world" (Flynn 1998:145). This new mode of expression was an embodied aesthetic: part man, part machine.

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(a) Jacob Epstein, *The Rock Drill*, 1916

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(b) Oren Zuckerman and Guy Hoffman, *Kip1*, 2015

Figure 3.17 – A visual comparison of a Epstein's *Rock Drill* and Zuckerman & Hoffman's *Kip1*

Guy Hoffman's Kip1 (2015), Figure 3.17 (b), is a social robotic device designed to be a 'conversation companion', and is described by Hoffman and Zuckerman as an "empathy object" (2015). The authors describe empathy objects as "respond[ing] to human behavior using physical gestures as nonverbal expressions of their 'emotional states'. The goal [in designing such objects] is to increase people's self-awareness to the emotional state of others, leading to behavior change" (2015:593). The robot is capable of expressing a range of 'empathetic emotions' through movements of its 'neck' and 'head', and it can even shiver in fear through a vibration mechanism, or 'breathe' calmly through micromovements.

Although the two artefacts in Figure 3.17 vary greatly in application and context, they share an undeniable aesthetic link that is typified by a "clear, clean-cut and mechanical" appearance, yet something human remains. The two works share an elongated 'face' with a curved brow, which tilts with emotional intent on the end of an elongated neck. Kip1's form has a hint of shoulders, which the head extends away from or retreats toward. The shoulders of *The Rock Drill* are squared, and are arguably the most human-like part of the work. Where the lowering of the head of Epstein's *Drill* may be a warning, it also denotes fear for the young it protects within its ribcage. Kip1's 'chest' harbours its mechanical parts, and is also guarded by an exposed rib-

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(a) Henry Gaudier-Brzeska, *Dog*, 1914

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(b) SONY, *AIBO (ERS-110) Robot Dog*, 1999

Figure 3.18 – A visual comparison of Gaudier-Brzeska's *Dog* and SONY's *AIBO* robot

like element. Both works are mounted on round bases, which serve as a rotational degree of freedom for Kip1, and a suggested axis of rotation for *The Rock Drill*. Both works demonstrate a duality of emotional expression around fear/protection and curiosity/watchfulness.

Henry Gaudier-Brzeska was a French sculptor who also "toyed with anarchism" (Hultén 1986:485) and was said to have engaged in lively debates with Marinetti upon meeting him in London in 1913. It is proposed that he may have associated with François Pompon, "who since 1908 had been exhibiting animal sculptures that …were slick like pieces of machinery" (Hultén 1986:484) (Figure 3.19 b). Hultén describes Gaudier-Brzeska's interest in the "animal brutality of action" and his cultural tendency for an "opposition between rounded and sharp forms, where sharpness triumphs" (Hultén 1986:485). Gaudier-Brzeska's *Dog* (Figure 3.18 a) could be interpreted as a dachshund, but without a full set of breed-defining features; it may simply be Gaudier-Brzeska's approximation of 'dog'. Yet, of all the possible dog-like appearances, it shares remarkable aesthetic similarity to Sony's AIBO (Figure 3.18 b), designed and produced 85 years later.

Sony's AIBO [4]is a robotic 'pet' developed by the Sony Computer Science Laboratory, which first became available to consumers in 1999. Many successive models have been released, including a new model in January 2018. Sony's website provides some insight to the intended application and 'personality' of AIBO:

> Aibo is full of charm. A cute, roly-poly form, moving around with infectious energy, and an identity that's just waiting to be explored and discovered. Being with people is

[4] A stylised abbreviation for 'Artificially Intelligent Robot', and homonymous with aibō, "pal" or "partner" in Japanese

> what aibo loves best. With its irrepressible curiosity, Aibo wants to know you, explore its environment, understand the ways of the world—and, from time to time, be a little mischievous. (AIBO 2019)

Hultén describes the way "Gaudier transformed the muscular appearance of [his] models into increasingly abstract geometric forms" (Hultén 1986:485). AIBO shares this abstraction: both 'dogs' sport a conical and almost featureless snout, with only an indication of eyes, and floppy flat ears are rendered motionless at the side of the head, widening at the bottom. For both forms, the body is distinctly separate from the head, with one smooth form arching at the lower back to meet the raised hind legs. AIBO's 'forearms' are formed in two key sections, distinguished by their points of articulation. Both the snout and the chest are finished at a flat angle.

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(a) Ivo Pannaggi, *Female Bust*, 1922

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(b) PLEN Project Company, *PLEN2*, 2016

Figure 3.19 – A Comparison of Pannaggi's *Female Bust* sculpture with the PLEN Project's *PLEN2* robot.

Italian architect and painter Ivo Pannaggi worked in contact with the Roman Futurists, exhibiting with them from 1921. His work was "closely connected with the theme of machines and Futurist dynamism" and used what Hultén has described as a "abstract mechanical formula" (Hultén 1986:533). Pannaggi's *Female Bust*, although not as obviously similar to PLEN2 as the other pairs discussed, nevertheless shares a remarkable number of qualities with PLEN2 and many other social robots that have been produced. Pannaggi has divided the form in to two dominant components: the chest and the head. The head is angular and block-like, and connects directly to the torso without a discernible neck. The torso is one solid volume, block-like and perfectly smooth, located on a plinth, or in PLEN2's case, the legs. The overall small scales, protruding eyes and white finish of both the marble and the 3-D print filament further consolidate the aesthetic similarity.

The PLEN Project Company Inc. is a Japanese robotics company who have published the following description on their website:

> Our aim is to open up the relationship between humans and robot through PLEN. PLEN was named from the word plain meaning simple and plain. The name indicates a "simply shaped robot" that everyone can imagines [sic]. PLEN was designed by pursuing a simple appearance and simple functionality. (PLEN Project Company Inc. 2018)

The company can be forgiven for describing the form as a robot "that everyone can imagine", as this is the quintessential 'robot' shape found in many fictional and real-life robot depictions. Yet the described form has proven to be highly problematic for communicating emotion in an expressive manner, as much of human embodied emotion is expressed through muscular pivot points, not skeletal pivot points. Human expression is often shown through the cradling or expansion of the centre of the chest, or extension and retraction of the neck, yet many social robot morphologies include a single solid chest piece and no discernible neck. Deeper discussion of this concept is furthered in section 6.3 Future Work.

Boccioni (1913) cautioned that by simply "reproducing exterior aspects of life", sculpture would never come to be a true expression of its time. The author posits that the demonstrated mimesis of this 100 year old 'futuristic' aesthetic may be preventing contemporary social robots from becoming a true and unique aesthetic expression of their time. Furthermore, this largely unexamined notion of the 'typical robot body' may be impeding roboticists from achieving the fidelity in emotional expression that they desire.

The 'Manufactured' Machine Aesthetic

In the sculptures discussed in section 3.3, it is apparent that the qualities that came to represent the 'machine' aesthetic were akin to those resulting from early mass manufacturing technology, which flourished in the post Industrial Revolution era. The broad smooth surfaces in basic geometric shapes that appear to meet at a seamed line or fold (seen clearly in the conical snout of Gaudier-Brzeska's *Dog*) closely mimic the finish of products produced by new mass-manufacturing technologies that emerged in the late 1880s, including parts stamped or extruded from steel, and the blow-moulding and injection-moulding of new materials such as polystyrene and polyvinyl chloride (PVC) (Roser 2017:11). Often multiple pieces of a product would need to be stamped or moulded and then joined through gluing, welding or heat sealing. The new streamlined surfaces and polished finishes that appeared on automobiles and household appliances came to symbolise the intangible qualities of the machine age—speed, efficiency, predictability, repetition, reliability and strength—as these were the qualities of their manufacture.

It is interesting to observe the traces of manufacturing methods and their associated qualities in industrial-era machines lingering in the morphology of contemporary social robots, even when the technology has long been superseded. In the examples of Kip1 and PLEN, both works are 3-D printed, so there is no need for seams or simplified geometry, yet the designs speak to shapes that might easily be stamped or moulded. It might be argued that these prototypes mimic the qualities of mass-manufactured technologies to make them viable for mass-manufacture later on, but in the case of PLEN, the DIY robot's open source files are designed to 3-D printed, and the components might therefore have had any imaginable shape (see Figure 3.20).

In the introduction of this thesis, the following question was posed:

b) What observable aesthetic similarities do the sculptural works of the Futurist artists share with contemporary robot designs? What does the existence of these parallels signify?

A number of technical, material and morphological aesthetic similarities between the sculptural works of the Futurists (and associated artists) and contemporary social robots have been outlined here. The existence of these parallels signifies a long historical influence of the aesthetic priorities of the Futurists and the manufacturing methodologies present in 1900–1916.

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Figure 3.20 – The printing of a component of PLEN2, 2016, by the PLEN Project Company.

It also signifies that the Futurist's image of the 'future' has indeed come to pass, and social robotics has not yet fully broken free from the aesthetic constraints of these projections.

While these two periods share commonalities in what has been identified as 'the machine aesthetic', something of the human remains in both the Futurist sculptures and many social robot designs. When the machine aesthetic has been overlaid, what is it that remains of the natural human form? What is the human aesthetic? The following section 3.3.1 examines this question.

3.3.1 The Human Aesthetic

This section interrogates the juncture of human and machine aesthetics that was achieved by the Futurist artists in their artefacts, and which is presently pursued in design by social roboticists. The author questions what elements of the Futurist designs represented "humanness", and how examining the boundaries of the human/robot binary may lead to more human-centred design.

Suchman (2007) argues that feminist research "contributes a critical orientation on the politics of difference" and is concerned with the refiguring of boundaries and constructed binaries. Suchman refers to Barad in saying "Barad argues that we need a simultaneous account of the relations of humans and nonhumans and of their asymmetries and differences … remembering that boundaries between humans and machines are not naturally given but constructed, in particular historical ways and with particular social and material consequences" (Suchman

2007). What has constituted the 'human' within these historical and contemporary artefacts is examined in the following.

For the Futurists, the machine aesthetic was closely linked with the material and dynamic qualities of manufacture, yet as described by Flynn in referring to Brancusi's work, "a lingering fidelity to natural forms" remained (Flynn 1998:141). In social robotics, the 'machine' element of the morphology is clear—it is the hardware needed to execute the function and movement demands of the robot—but what of the human element? Fong et al. (2002) state, "When designing a robot's form …if peer interaction is important, the robot must project an amount of 'human-ness' so that the user will feel comfortable in socially engaging the robot. At the same time, however, a robot's design needs to reflect an amount of 'robot-ness' (Fong et al. 2003:9)". Section 2.2.1 of this thesis indicates that a robot morphology that is too close to human likeness can result in a range of sociopolitical and technology acceptance issues. To avoid the complications of mimesis and yet still foster affective interaction and fluid communication in HRI, understanding what constituted the remnants of the human aesthetic for modernist artists such as the Futurists may suggest what elements ought to speak to the 'human' in contemporary social robots.

Tom Flynn employs the poetics of Walter Benjamin in conveying how the cataclysmic effect of the First World War worked to "undermine the stability of human affairs, [and] was mirrored in representations of the body" (Flynn 1998:140). Benjamin writes, "in a field of force of destructive torrents and explosions was the tiny, fragile, human body" (Benjamin 1963). The resultant fragmentation and disruption to the human psyche meant that the body in art was liberated from the overtly recognisable and body fragmentation became a valid subject in its own right. Freed from all external subject matter, it "became …related merely to the here and now; in short, pure abstract form" (Flynn 1998:140). For the modernists, the truncated human form in its many—often abstracted—sculptural representations was totemic of the fragmentation, fragility and boundary erasure experienced socially and culturally in the early twentieth century. The form of the human body was no longer whole, nor was it contextually appropriately representative of the 'human' condition in modernist art. Similarly, whole bodies are not often seen in robotics; we may often see only a head, or a truncated torso and head.

So what element of 'human' ought to stand for us in robotics? In an attempt to differentiate humans from machines, Donald Norman (1993) describes “what people are good at”:

> Language and art, music and poetry. Creativity. Invention. Changing, varying the manner of doing a task. Adapting to changing circumstances. Inventing new tools. Thinking of the problem in the first place. Seeing. Moving. Hearing, touching, smelling, feeling. Every one of these is hard for a machine. Enjoying life. Perceiving the world. Exploiting taste (food), smell (flowers), feelings (amusement parks), body motions (sports). Aesthetics. Emotions such as joy and love and hope and excitement. And humour and wonder. (Norman 1993:223)

Norman concludes, “Humans are emotional, machines are logical” (1993:223). From this it might be said that is not our aesthetic likeness that is the most human element, but rather our perception, creativity and abstract reasoning, and the expression of emotion and intent. With the exception of hyper-realistic robots like Geminoid (16: 2008), roboticists are often not trying to make social robots look precisely like humans, even when they have lips, eyes and detailed articulation. Rather, robots are given human-like limbs and features to allow them to move like humans; to move in the lines and arcs that convey emotional intent. Whether by the lifting of a brow or bobbing of the head with excitement, the human element is in emotional and intentional movement rather than purely functional movement, something which in comparison is quintessentially ‘robotic’. In the case of Kip1, although its morphology is similar to that of a desk lamp, it is designed to mirror emotional movement, retreating with fear or extending forward with curiosity.

The purpose of the machine has been, until recently, to do. We can now conceive of a machine with a purpose to be, and to be like us. In discussing simulation verses authenticity, Sherry Turkle (2017) commented, “Relationships with robots bring us back to Darwin and his dangerous idea: the challenge to human uniqueness”. Does it therefore pose a risk to human uniqueness to simulate the most human things, such as emotions, in our designs? Norman (1993) argues that designing systems that are sensitive and responsive to human needs and are appropriate for the ways in which humans naturally operate is the core of human-centred design. Norman further contends, “one of the principles of human-centred design is that the visible, surface representations should conform to the forms that people find comfortable”. He adds, “let the machines use numbers internally, but present the human operators with information in the format most appropriate to their needs and the task they must perform.”

Now that robots and machines are becoming more technically capable, it can be concluded that the most distinctive of human-like qualities are relational: emotions, empathy, creativity, abstract reasoning, agility and intimacy. In the age of mechanical mimesis, some of our most 'human' qualities are not necessarily our appearance, nor elements of our intellect, but our emotional capacity. If the expression of emotion will be that which comes to define social robots as truly social, then as expounded by Kirby et al., this emotion must result in some outward movement or expression by the robot (Kirby et al. 2010:323). The author argues therefore, that the postures and lines of movement resulting from emotional expression and intent ought to inform the 'human' element of contemporary social robot morphology design where "[human designers] should take extra steps to do the translations from the machine centred form internally to the human-centred form at the surface" (Norman 1993:226).

Cross-Disciplinary Communication of Tacit Knowledge: An Approach

Chapter 3 has discussed both explicit knowledge from art history, and tacit knowledge and techniques employed by artists in their efforts to convey the intangible. For this knowledge to be used in collaboration with researchers from other disciplines, or for those outside of art to apply this thinking to their designs, the author argues that this knowledge must be distilled or codified into a communication format that is cross-disciplinary and is not restricted to the methods used in any single discipline, and which can be translated and applied. In the introduction to this thesis, the question was asked

d) How can the methods used by the Italian Futurist artists be captured, represented and communicated to other researchers and designers in social robotics?

In the following chapter the author will discuss the definition of tacit knowledge, and how systems of notation and diagrams have been used in a variety of disciplines to communicate ideas between practitioners, to give representation to tacit knowledge, and to "render abstract ideas concrete" (Allen 2000). Following this, it is posited that particular works of Futurist art can be classified as diagrammatic, and through this classification can form sequential steps in a methodology that may allow roboticists to apply knowledge from art to the design of social robots.

Chapter 4

Tacit and Intangible Knowledge Communication

With the benefits of collaboration within a multidisciplinary field such a social robotics comes issues of knowledge transfer and translation among researchers, problematised in part by difficulties in the elicitation and codification of tacit knowledge. Quoting Haraway, Suchman asserts that "our own work requires 'the ability to translate knowledge among very different—and power differentiated—communities"' (Haraway 1991). Suchman argues that "problems of standardisation" are particularly present in technology production and research, and there have been numerous searches for the development of "universal languages" for translation across devices, and consequently, disciplines. Haraway has argued that this "scientifically legitimised professional discourse" (Suchman 1994:35) and the "search for translation, convertibility, mobility of meaning and universality" is invariably "reductionism …when one language (guess whose) [sic] must be enforced as the standard for all the translations and conversations" (Haraway 1991:187). With this in mind, this chapter presents the use of diagrams as a means for making methods and tacit knowledge from fine art available for broader interpretation and application in the field of social robotics in a mode which is widely used in creative disciplines such as dance, music, theatre and art for authentic communication. It is argued that, while reductive in appearance, diagrams are generative in nature.

The method for generating new robot morphologies presented in this thesis is a means for thinking and for communicating between practitioners to consciously incorporate the purpose, movement and emotional capacity of the robot into its morphology. Understanding how tacit knowledge and intuition might be codified and expressed throughout the design process towards generating new morphologies is therefore essential, particularly if the place of designers and artists is to become more deeply integrated within a multidisciplinary team, rather than tangential or touristic in nature.

In the latter half of the chapter the author classifies a series of artworks by the Futurists as diagrammatic, and collates these works into a series of methodological steps that were used by some of the Futurists for developing new forms, and may be applied to social robotics. This method of plasticising both intangible and tangible elements allowed the Futurists to develop the morphology of collages and sculptures with qualities of both human-ness and machine-ness. It is argued that the present sequential method might be appropriated to develop robots that combine qualities of robotic hardware with the movement generated by emotional expression. In defining this method as diagrammatic in nature, the author argues that this definition allows for authentic interpretation and communication with those outside of the field of art. In exploring the nature and definition of the diagrammatic and the notational, the author demonstrates the fluidity and convergence that can exist between the two, and where borrowing from the properties of both may have advantages for particular kinds of knowledge transfer.

Section 4.1 of this chapter establishes the problem of knowledge communication and translation between disciplines, and particularly that of tacit knowledge. The author defines tacit knowledge, and outlines the necessity for knowledge from sculpture to be elucidated and codified such that it might be made use of by those outside of the field for designing social robots. The examination of research by John H. Bradley et al. (2004) and Elzbieta T. Kazmierczak (2001) establishes diagrams as a medium for approaching tacit knowledge transfer, semantic understanding, structural relations, and conveying reality not necessarily as we see it, but as we understand it.

Section 4.2 begins by examining the nature of diagrams and notational systems, and the variety of their applications from science to contemporary art in representing complex and intangible concepts to those within and without of the discipline of origin. By examining these examples, the diversity and plasticity of the use of notation and diagrams is revealed. Examples of the use of notation in artworks by Australian artist Marco Fusinato are used to advance the assertion that slippage can occur between the boundaries of 'notation' and 'diagram' to form 'diagrammatic notation'. Fusinato's work also demonstrates the way that a diagram of a full performance, or diagrammatically connecting many possible moves and outcomes, can generate new shapes and forms. The subcategories of autographic and allographic arts are discussed, and the author examines how these categories aid us in understanding the role of diagrammatic notation in the transfer and translation of information.

Section 4.3 provides a case study of the work of Oskar Schlemmer and his techniques for tracing the bodily movements of dancers in order to translate 2-D diagrammatic shapes into 3-D wearable costumes. Schlemmer's work displays a synergy between the diagrammatic, the notational and the pictorial, and demonstrates how 2-D diagrams can be translated in to 3-D forms. This work provides a case study precedent for the methodological approach proposed in Chapter 5.

Section 4.4 analyses the diagrammatic techniques employed by two Italian Futurists to articulate intangible qualities as a model for how diagrams may allow us to translate embodied emotional human movements into shapes to form new robot morphologies. Firstly, the work of Filippo Marinetti is examined for his attempts to draw verbs such as 'action', 'bombing' or the experience of an air raid with particular attention given to his use of line and direction to show emphasis. Following this, the work for Fortunato Depero is considered, where the lines of emphasis from movement are drawn alongside the body and eventually fused with it to create a new morphology. Extending on the study of these works from Section 3.2, the diagrammatic and notational qualities of these works are highlighted and formally elucidated as a methodological approach, in preparation for the author's application of this approach to social robotics in Chapter 5.

By presenting the working methods of the Futurists as a diagrammatic approach to distilling and transferring information, the author offers it as multidisciplinary tool that may be utilised by those outside of the field of art for design in social robotics.

4.1 Tacit Knowledge

Tacit knowledge, or that knowledge which is understood or implied without being stated and "governs the use of explicit knowledge" (McGraw & Harbison-Briggs 1991) can often be mistaken for intuition, or natural ability (Bradley, Paul, Seeman 2006:77), or in the case of the creative practitioner, just being 'art-y'. The seemingly abstracted, naturally inherent or unobtainable quality of tacit knowledge has undoubtedly contributed to the limited attempts to capture, codify or convey tacit processes. In a multidisciplinary field such as social robotics however, creative practitioners may come to face the complication that was outlined by Star and Griesemer (1989:389) in their work on 'Institutional Ecology'; that of interessement, or "the translation of the concerns of non-scientists into those of the scientist". Star and Griesemer note that "consensus is not necessary for cooperation nor for the successful conduct of work (p. 388)", although they emphasise the importance of researchers maintaining integrity of information in the presence of diversity, and formulating a mutual modus operandi between actors from different scientific worlds (1989:388-389): "These actors …must translate, negotiate, debate, triangulate and simplify in order to work together". Star and Grisemer identify that a simplification and translation of creative concerns (or indeed concerns belonging to any field) must take place to aid best-practice collaboration.

The limited codification or representation of tacit knowledge has perpetuated its non-knowledge status, where it is "confronted with the suspicion that it aims to designate something as knowledge which strictly speaking may not be a type if knowledge at all because it lacks the necessary epistemic quality of discursive availability" (Loenhoff 2015:23).

However, Bradley et al. (2006:78) place a high value on tacit knowledge, and argue that "explicit knowledge without the concomitant of tacit knowledge is incomplete and will result in a suboptimal solution when used in a problem solving task." While the present thesis outlines some explicit knowledge from art history and theory which may usefully be considered during the process of social robot design, without offering an approach to accessing and applying the tacit knowledge contained herein, the contribution of sculpture to social robotics would remain siloed, and not truly multidisciplinary or complete. As Bradley et al. stress, "an individual's knowledge cannot be useful to others unless it is expressed in such a manner as to be interpretable (2005:78)".

In "Analysing the Structure of Expert Knowledge" (2006:77), Bradley et al. propose that innovative methods and techniques are necessary for the "elicitation, codification, storage and distribution" of tacit knowledge, as this has proven to be a challenging task. Bradley et al. describe tacit knowledge as problem-solving action knowledge about how information should be structured or processed (Bradley et al. 2006:78). They describe one possible approach for capturing tacit knowledge, by recreating a cognitive map of, for example, objects and relationships used by experts to convey the content and organisation used to solve a particular problem.

The development of a cognitive map to describe relationships and processes requires a semiotic approach to information design. Aesthetics philosopher Elzbieta T. Kazmierczak proposes that "the rules for constructing images at the early stages of form development are identical with the rules of designing diagrams" (Kazmierczak 2001:76). Kasmierczak is interested in the early education stages of visual literacy, but while examining the drawing stages of childhood, she argues that "early representation forms are diagrammatic models of reality, by virtue of focusing on structural characteristics and structural relations of an object, instead of immediate likeness" (2001:179). It could be argued that as a multidisciplinary field, social robot morphology design is in its infancy, and may benefit from focusing on representing structural relations through a diagrammatic approach, rather than attempting to represent immediate visual (human) qualities through a pictorial approach. In breaking from the Aristotelian tradition of art as imitation (mimesis), Kazmierczak (2001:177) argues that diagrams are "most suitable for visualisations of conceptual knowledge", and that "images are the most effective tools for modelling reality as we see it, while diagrams are the most effective tools for modelling reality as we understand it".

It is established that tacit knowledge is valuable, and there is value in codifying it and making it available for use when working in a multidisciplinary field. Further, a diagrammatic approach to elucidating this information allows for some semantic dimension, rather than restricting consideration to syntactical or mimetic praxis. The following section examines the nature of the diagrammatic and the notational, and how diagrams have been employed in a number of other fields to translate and transfer information to those within and without a particular discipline. Further, the slippage that can occur between the diagrammatic and the notational opens up space for degrees of interpretation and authenticity, and the pliability of this terminology is examined herein.

4.2 Notation and Diagrams: Mapping the Intangible

Examining the nature of notation and diagrams reveals two potential key uses in social robotics; firstly, they allow designers to capture and distill the essence of how the body expresses the intangible (e.g. emotions), and render the shape of these on paper. These lines and shapes may suggest the basis of a new morphological form, where the robot's body incorporates its expressive capacity, rather than being separate from it. Secondly, adopting notational properties within these diagrams will potentially allow researchers from outside of art to interpret, borrow from, or apply this information to develop social robot morphologies.

American architect and theorist Stan Allen argues that the need for notational language in a discipline such as architecture is present because of the "need for participation of many hands" in construction (Allen 2000:48).This is also the case in a multidisciplinary field such as social robotics, where computer scientists may need to work closely with mechatronics engineers, sociologists, artists and designers. Nelson Goodman confirms that a project or discipline's amenability to notation is present when the work in question is either ephemeral, or not producible by one person (1968:121). Explaining the contemporary need for systems of notation, Allen (2000:56) describes a problem in architecture of the "contemporary city", of needing to represent concepts present in a "radically discontinuous and incoherent" city, from the "language of its inhabitants to the space of the street". As new realities of the contemporary urban city transpire, it "follows that new tools are required" (Allen 2000:56). So too in social robotics, as new technologies and complex or subtle social applications emerge, new tools of transfer and translation are required. New tools of transfer allow information to be passed from one practitioner or researcher to another within a collaborative group, and tools of translation allow for information to pass from one discipline to another, and allow for that information to be decoded, interpreted and applied in a context removed from that of the author of the information.

Allen argues that in architecture, the diagrammatic can depict that which is beyond the limitations of a drawing, giving representation to the experience of a space itself, the shifting of shadows, reflections, changes in atmosphere, unconscious elements, or the intricacies of peripheral vision (Allen 2000:42–43). Although reductive in appearance, notation and the diagrammatic allow for the transference of information that is beyond the pictorial. Considering this capacity, the use of diagrams may allow artists to capture and convey sensibilities for materials, emotional expression, and knowledge from their practice that may be beyond a drawing, and express these sensibilities to other researchers.

In the chapter "Notations and Diagrams – Mapping the Intangible" from *Practice: Architecture, Technique and Representation* (2000), Allen compares the nature of diagrams and notation, and examines these through examples of not only architectural drawings and musical scores, but also cloud formation diagrams, mathematics, dance choreography, stop-frame photography, and instructions for the Apollo 11 moon landing. Allen distinguishes notation as a class separate from the general category of diagram, where notation belongs intrinsically to time, whereas diagrams speak to space and organisation. Notation is reductive and abstract, instrumental, and not an end in itself. Allen (2000:45) notes that the dry and dispassionate nature of notation makes no attempt at "approaching reality through resemblance", but rather through interpretation, the emotional and evocative elements conveyed through notation will come to bear on the real and concrete in an unpredictable mixture. For example, a performance of a musical score may comply with the constitutive properties demanded by the notation, yet each performance may differ in music features such as tempo, phrasing and expressiveness (Goodman 1968:117). The most distinguishing feature of notation is that its composition and interpretation depend on a specific interpretive community, shared conventions and an understood system of semiotics, such as musical scores, codes or scripts. A diagram, however, is for the transfer of information between those who do not necessarily share any common system of symbols.

Diagrams are "highly schematic and graphically reductive … syntactic and not semantic … they suggest a working model of the whole" (Allen 2000:50). Importantly, Allen (2000:50) argues that the key difference between notation and a diagram is that while notation belongs to time, or may be a description of time-based phenomena, "reading a diagram is almost instantaneous;

there is an immediate apprehension of the relation between the parts". While this is true of many diagrams, some diagrams are complex and may take hours to interpret. They are not usually, however, representational of a time-based system, such as music.

Allen quotes the renowned mathematical physicist James Clerk Maxwell (Maxwell 1910), who describes the relational and transactional nature of diagrams as open to multiple interpretations. In diagrams, the signs and symbols used to depict qualities such as approach, emphasis, force and resistance, density, hierarchy, direction, flow, distribution, pause and crescendo vary between each example of a diagram, and yet are perceptible and transferrable to any recipient, with no dependence on a shared system of semiotics.

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Figure 4.1 – The Golden Record sent aboard NASA's *Voyager 2* mission, 1977.

There can be little dispute as to the ease with which a diagram may be interpreted, or the vast comprehensibility of diagrams when we consider some of their applications. Figure 4.1 and Figure 4.2 show the diagrams inscribed on the cover of the Golden Record stowed aboard the NASA *Voyager 2* spacecraft in 1977. The record contains sounds and images displaying the diversity of life on earth, for potential discovery by others in the distant future. The inscribed diagrams depict the galactic origin of the spacecraft and instructions on how the record should be played, intended to be interpreted by an extraterrestrial recipient, who could have no possible knowledge of the systems of semiotics established on earth.

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Figure 4.2 – Explanation of the diagrams on NASA's Golden Record, *Voyager 2* mission, 1977.

A similar style of diagram was sent aboard the Pioneer 10 and 11 spacecraft (Figure 4.3) four years earlier, depicting the origin of the launch and the size of the inhabitants of Earth relative to a diagram of the spacecraft. The diagram received critical speculation concerning the race of the humans depicted, the lack of detail on the female genitalia, and feminist concerns with the dominant role afforded to the man in issuing the greeting wave. Additionally, Ernst Gombrich criticised the diagram in his article "The Visual Image" in *Scientific American* (1972) for the use of the 'arrow' symbol to denote the travel trajectory of the spacecraft. Gombrich asserted that the arrow is a clear reference to hunter-gatherer societies, and may be meaningless to a recipient of a different cultural heritage. Here, the use of the arrow breaks away from the nature of the diagrammatic and draws upon the notational quality of a shared knowledge of symbols which, for Gombrich, detracts from the interpretative potential of the diagram.

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Figure 4.3 – The Pioneer Plaque, sent aboard the *Pioneer 10* spacecraft, 1973, gold-anodized aluminum.

This brief example highlights a scenario where strict adherence to the definition of the diagrammatic with no interference from the notational is essential for opening up the capacity for translation of information to those outside of the field (or in this case, the galaxy). However, the following discussion of artworks by Marco Fusinato (b. 1964) and Oskar Schlemmer (1888–1943) demonstrates slippage between the diagrammatic and the notational as a method for enhancing and layering meaning and bolstering interpretative potential.

Referencing Nelson Goodman's *Languages of Art* (1976), Allen distinguishes broadly between two types of art forms: those that are *allographic*, such as music and dance, that are "capable of being reproduced at a distance from the author by means of notation"; and *autographic* arts, such as painting or sculpture, which "depend for their authenticity on direct contact with the author" (Allen 2000:45). Goodman approaches these definitions in relation to authenticity on reproduction: all correct performances of allographic works are equally genuine instances of the work, whereas for autographic, even the most exact duplication does not count as genuine (Goodman 1968:113).

While the philosophical discussion of authenticity in creative reproduction is beyond the scope of the present work, the categories of allographic and autographic may be more simply defined: allographic arts involve an author of notation and the interpreted articulation of the noted (for example, a choreographer and a dancer, a composer and a musician, an architect and a builder). In counterpoint, autographic arts are typically planned and executed by the one person or party: for example, the artist sketches and then paints a painting. Naturally, exceptions to these rules exist, for example, where a team may build an artwork on behalf of an artist. In such examples, the execution of the work still relies solely on the intention of the author, with no interpretation on behalf of the workers. However, the arts are not clearly divided into these two categories, and there is the potential for slippage between them. According to Goodman (1968), the autographic art may win emancipation from its author (towards the allographic) through notation.

Given the previous definitions, many art practices such as sculpture could be categorized as autographic, which places limitations upon their methods as a means for transferring knowledge to social robotics. Firstly, any reconfiguration or reproduction of sculptural work may be viewed as a violation of authorship, and secondly, sculpture depends on direct contact with the author (sculptor) for production. This separation of art's methods from the methods of other disciplines means that the contribution of artists to social robotics often remains touristic in nature, and can happen only through direct collaboration with the artist, rather than through the genuine integration or reapplication of artistic knowledge to robotics. Through the following examination of the use of notation and diagrams in contemporary art, it can be seen, however, that there is more of an overlap between the nature of notation and diagrams than Allen allows, and that autographic arts may borrow the qualities of the allographic through the use of diagrams.

Allen argues that "to work with notations and diagrams therefore implies giving up ideas of depth, authorship and intent, betting instead on immediacy and presence" (Allen 2000:49). The sacrifice of "authorship" is what lends diagrams so well to tacit knowledge communication, and arguably, the addition of "presence" generated through the depiction of intangible qualities contributes additional depth.

The generative nature of both the notational and the diagrammatic is outlined by philosopher Gilles Deleuze and psychiatrist Fèlix Guattari (1987), who state, "the diagrammatic or abstract machine does not function to represent, even something real, but rather constructs a real that is yet to come, a new type of reality." The series of works titled Mass Black Implosion by contemporary artist Marco Fusinato depict a selection of musical scores, where a line is ruled from every note on the score to a central point on the page, as "a proposition for a new composition, in which every note is played at once, as a moment of consolidation and singular impact" (Fusinato 2014:60).

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Figure 4.4 – Marco Fusinato, *Mass Black Implosion (Mikrokosmos: Clashing Sounds, Béla Bartók)*, 2012.

Simultaneously, the work appears as both a dramatic implosion to a singular point and an instantaneous explosion in the manner of nuclear fission, where a neutron strikes the nucleus of a plutonium isotope, splitting the nucleus into fragments and releasing an enormous amount of energy, in a self-sustaining process that can cause an atomic explosion. Figure 4.4 depicts Fusinato's appropriation of a score by Béla Bartók. When observing this work, the eye of the viewer oscillates along the single-point perspective implosion lines, tracing the collapse and expansion of the score. Here, Fusinato has arguably collapsed a notational system (to be read over a period of time) into a diagram (comprehended instantaneously), where the viewer now apprehends the work as a whole. The diagrammatic lines disrupt the careful notation and blur the symbols, whilst layering intangible notions of energy, direction and singularity on top of Bartók's score.

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Figure 4.5 – Marco Fusinato, *Mass Black Implosion (Free music No. 1, Percy Grainger)*, 2009. Ink on archival facsimile of score.

In Figure 4.5, the 'implosion' is even more visually generative. The notation has merged past the diagrammatic and begins to return to the pictorial. *Something else* in addition to the musical score and the diagram lines has been created. The conical undulation of the waves that flow and overlap generate a layered and delicately cinched fabric, with its own slow rhythm that disrupts the immediacy of the implosion. In this work, Fusinato has connected selected points on the score and this has generated new physical shapes and forms. Similarly, a roboticist might draw and connect lines and arcs of movement necessary for a robot's function, in order to generate new shapes and forms from which a morphology might be drawn. Examples of this diagrammatic method are presented in Chapter 5.

In different ways, the works in Figure 4.4 and Figure 4.5 demonstrate the potential fluidity between the notational and the diagrammatic, where the allographic returns to the autographic, where one may fold into the other, and where the collapse or combination of the two may generate the pictorial; what Deleuze and Guattari (1987) refer to as “a new type of real”. This freedom and fidelity in translation is evident in the diagrammatic sketches and 3-D compositions of Oskar Schlemmer, who draws on the generative potential of diagrams and notation to construct unique 3-D forms, as discussed in the following section.

4.3 A Case Study of Generative Diagramming: Oskar Schlemmer

The work of Oskar Schlemmer exists in the intermediary realm between the geometric and the organic, between theatre, art and architecture, between 2-D and 3-D, and in the realm of *homo–variations*, somewhere between human and machine-like variants. Schlemmer’s compositions negotiate time, space and form and draw directly on the diagrammatic, offering a compelling precedent for the present methodological approach to social robot morphology design. This section discusses the work of Oscar Schlemmer as an artist who has combined the human body with the lines and shapes made by its movement to produce costumes that may be worn by dancers to allow them to become a new morphology. This approach, developed in the 1920s and 1930s, provides a methodological stepping stone towards the author’s method presented herein.

Oskar Schlemmer (1888–1943) was a German painter, sculptor, designer, choreographer, and leading practitioner at the Staatliches Bauhaus, with his main creative period falling between 1920–1932. Although at first glance much of his work may appear ‘abstract’, Schlemmer aspired to something closer to “a synthesis—form and content in creative fusion” (Beye 1972:5). In an effort to revel the “deeply hidden”, Schlemmer’s work pursued “the representation of man. Man of course, not in his limited time-restricted individual appearance, but as the incarnation of an idea” (Beye 1972:8). Although Schlemmer’s work fell within the Constructivist period, in describing Schlemmer's intentions the words of art historian Peter Beye closely mimic those of Boccioni concerning the pursuits of the Futurist sculptors: "Let us open up the figure like a window and enclose within it the environment in which it lives" (Boccioni 1913). For the Futurists, enclosing the environment within the representation of man meant incorporating the qualities and finishes of the machine age, whereas for Schlemmer, his figures incorporate "interpretations of the space [in] which, standing or walking, sitting or laying, they articulate their meaningful functions" (Beye 1972:9). It is in the synthesis of the body together with its spatial articulation that Schlemmer's work speaks to the work herein, where the author seeks a synthesis between a robot's hardware and its emotional expression ("meaningful functions") in a single form.

Schlemmer produced a large number of drawings and diagrams throughout his lifetime which formed the preliminary basis—explicitly and at other times tangentially—of 3-D works, such as sculptures or costumes. Beye notes that when studying as a scholar under Adolf Hoelzel, Schlemmer rejected the obligatory pictorial conceptions of the Impressionists, and instead, "founded a compositional theory based on the regulating laws of plane and colour, independent of pictorial representation" (Beye 1972:8). This shift away from the pictorial naturally lends itself to the diagrammatic, qualities of which are evident in Schlemmer's sculptures as well as his drawings. The reductive and syntactic nature of a diagrammatic approach saw Schlemmer concentrate his efforts on the organisation and stereometry of the "organic and geometrical worlds, fusing them together [in] … a formal synthesis" (Beye 1972:8).

Interestingly, however, much of Schlemmer's writings about both his sculptures and his diagrams make reference to the notational qualities of time and established semiotics. In a text from January 1924, Schlemmer wrote, "Sculpture is three-dimensional … It cannot be absorbed immediately … [like a two-dimensional picture] … but rather through a sequence of changing points and angles … Walking round the figure and the sum total of impressions leads to an understanding of the sculpture" (von Maur 1972:34). Schlemmer suggests that sculpture must be read over time as the viewer walks around it, like a musical score, and cannot be comprehended instantaneously, as a diagram might be. Schlemmer also placed importance of capturing the "essence" of man and a sense of movement in a medium that is otherwise static, as "represent(ing) movement caught in a fleeting moment" (Beye 1972:38). This representational quality is of great potential value to social robotics, as a field where technology acceptance and the likability of robots is governed so closely by the capacity to predict what the robot might be capable of, and to have close congruence between its appearance and capacity. This notion is currently referred to in the literature as 'legibility'. An ability to capture and represent a robot's expressive range of motion within its morphology might go some way towards addressing both of these concerns.

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Figure 4.6 – Oskar Schlemmer, *Diagram for Gesture Dance*, 1921

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Figure 4.7 – Oskar Schlemmer, *Wire Figure*, c. 1922.

Figure 4.6 shows Schlemmer's *Diagram for Gesture Dance*. An observable similarity can be seen between it and the Wire Figure costume in Figure 4.7, where the pirouettes and spirals of movement and extension captured in the diagram have now become fused with the dancer through a wire-frame costume, creating a new kind of human morphology. Schlemmer spoke explicitly about the spatially plastic nature of his costumes, where "the more the apparently violated body fuses with the costume, the more it attains new forms". This terminology mirrors that of the Futurists, who spoke of plastic value in sculpture, where "sculpture should give life to objects by rendering their extensions into space palpable, systematic and *plastic*" (Boccioni 1913) [emphasis added].

Schlemmer's work occurred ten to fifteen years after the work of the Futurists that comprise the focus of this thesis. His practice demonstrates a flow and organisation of stages from diagrammatic sketches of movement, to illustrations of shapes fused together with the human body, through to full 3-D resolutions of those shapes into costumes that allow the human dancers to become a synthesis of form and content (body + movement), revealing something hidden about the fullness of human capacity and movement. The stages of Schlemmer's design methodology find their origins in the collective work of the Futurists across the practices of a number of artists and spanning a number of years. The emergence of this methodology is examined further in the following section.

4.4 Futurist Diagrams

In many examples of contemporary social robots, the expression of human qualities and emotions is separate from their form or morphology; that is, the robot is given a body of sorts, which then performs human-ness. However, by diagrammatically sketching the performance of these intangible qualities alongside the body, such as the bow of humility, or the extension of curiosity, the diagrams might then be mined to generate new morphologies, just as Schlemmer synthesised the pirouettes and limb extensions of dancers together with their body forms to produce a new kind of body, represented through costume.

It is understandable why this has not been explored in robotics thus far; giving diagrammatic aesthetic signification to intangible qualities such as humility or curiosity is not necessarily intuitive or easy. How does one draw curiosity? What are the lines and arabesques of humility? In examining Marinetti's early sketches such as *Action* (1915) and *Bombing* (1915) (Figure 4.8 and Figure 4.9), it is clear that they might be classified as a kind of notational diagram as per Allen, where, "a consideration of drawing as notation directs attention toward all of the intangible properties of the real that cannot be set down in graphic form" (Allen 2000:43). In the following examples, Marinetti is trying to sketch and communicate all that is intangible about the dynamism and immediacy of 'action', or the confusion and devastation of 'bombing', as separate to the bombs, or to those who take action. Where Depero attributed and attached the qualities of the dance to the body of the dancer, Marinetti has removed all aircraft and bombs and people from the scene, and is just giving weight and stroke to the verbs.

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Figure 4.8 – Filippo Tommaso Marinetti, *Bombing*, 1915–1916, ink on letter paper.

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Figure 4.9 – Filippo Tommaso Marinetti, *Action*, 1915–1916, ink on letter paper.

This raw diagrammatic interpretation of verbs forms the first stage of the methodology that is drawn from the Futurist movement. When we plan for a robot to indicate that it is curious, what are we asking it to do? It must demonstrate the internal state of curiosity with its body and, to do so, must move in a certain way: an extension of the neck and chest, a widening of the eyes, perhaps it might cock his head to one side in order to listen with its good ear? Each of these movements form lines and stereometric boundaries in the air. These shapes could be indicative of the locomotive and emotional affordances of the robot, just as the compressed bellows of an accordion indicate its functionality and capacity for movement, or the epidermal plates (known as *scutes*) on the back of an armadillo indicate its mode of defence and flexibility in movement.

In the images shown in figures 4.10 and 4.11, Depero has given diagrammatic indication of the whip of the dancer's cape, the snap of her fingers and the stamp of her feet. The sketch of the dancer's cape in figure 4.10 is no longer simply pictorial, but diagrammatically shows extension, direction, speed and emphasis. The energy and movement of the entire performance is condensed into a moment, as is the nature of the diagrammatic, yet it makes notational reference to a performance over time, which plays out as the eye of the viewer lingers, and is drawn along the diagrammatic lines. The sketch, which by Allen's definition ought to be considered

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Figure 4.10 – Fortunato Depero, *Costume for Mimismagia*, 1916, watercolour on paper.

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Figure 4.11 – Fortunato Depero, *Ballet Dancer for Le Chant du Rossignol*, 1916, collage of paper on paste-board.

autographic, soon functions as something akin to allographic when in the second image (Figure 4.11), the key notes of woman, dancer, twirl and snap are still played, yet have been given new emphasis, and new hierarchy through interpretation, and the Futurists' concepts of 'plastic' value. The dancer, and the performance have been flattened and reduced even further, and are now much closer to a diagram. The movement, emphasis and energy have become the dancer, and through the diagrammatic, she is fused together with these intangible qualities, producing "a new type of real".

In the same way, the movement of emotional expression planned for a robot's application might be sketched alongside the necessary hardware to form the basis of shapes that could be flattened or 'plasticised' to form its morphology. While Depero never converted images such as these into three dimensional sculptures or costumes, they "suggest a working model of the whole" (Allen 2000:50).

This chapter began by outlining the difficulties experienced by practitioners in communicating tacit knowledge to those from disparate disciplines. It was shown that notation and diagrams have been utilised in many fields as a reductive and schematic approach to communicate that which is beyond the pictorial and, perhaps at times, outside of language The use of notation and diagrams in the work of modern and contemporary artists was examined for their generative capacity for both interpretation and three-dimensional resolution.

In the case of a creative practitioner from fine art, communicating not only explicit knowledge from the history of art but also conveying tacit techniques and processes that might be utilised by others is essential in order that art's contribution to social robotics is not touristic or novel in nature, but able to be deeply integrated and applied where appropriate. This approach does not represent the only or best way of working, but rather demonstrates how tacit processes might be codified, and contributes to the elicitation of tacit knowledge from art for use in social robotics.

In the following chapter, the author outlines three studies where she has applied this work flow, or methodological approach, to arrive at images that suggest original robot morphologies. In the same way that a diagram is syntactic and not semantic, the resulting diagrammatic paper-cut images are only schematically suggestive of potential interpretations or morphologies, and have therefore not been resolved into three-dimensional robotic forms, nor are they resolvable into one unique or 'correct' robotic form, but many.

Chapter 5

Practice-Led Material Investigations

Agential realism, according to Karen Barad (2007:115), encompasses "the distribution of agency over human, non-human, and cyborgian forms". In linking agency with morphology, she argues that agency is concerned with the "possibilities and accountability entailed in reconfiguring material-discursive apparatuses of bodily production". Barad (2007:218) asserts that "There are different possibilities for reworking the material-discursive apparatuses of bodily production, including (but not limited to) acts of subversion, resistance, opposition and revolution". She discusses (p. 200) the "apparatuses of bodily production" as technologies used in medical practices and observation that produce phenomena and account for the materialisation of politics and knowledge about bodies, and extends this idea to "contemporary technoscientific practices [that] provide for …profound reconfigurings of bodies, power, knowledge". According to Barad, the distribution of agency to cyborgian or non-human bodies can be a subversive act. By acknowledging the agential impact that non-human bodies have on the world and accounting for this through conscious design reconfigurings, fresh methodological approaches to morphology have the potential to serve as resistance and disruption to the technocentric development of these non-human forms.

In Suchman's 2009 critique of more traditional frames of design practice that centre around the development of a novel invention to serve a single use, Suchman contends that these generative, resistant reconfigurings in design can contribute to a larger collective practice, which "shift[s] the frame of design practice and its objects from the figure of the heroic designer and associated next new thing, to ongoing, collective practices of sociomaterial configuration, and reconfiguration in use" (Suchman 2009). In this manner, Chapter 5 of the present thesis outlines a collection of techniques formulating a practice-led design methodology inspired by the work of the Futurists and intended as a critical design reconfiguring and generative theory in contribution to a larger collective practice concerning the design of social robot bodies.

In his book, *The Reflective Practitioner: How Professionals Think in Action* (1983), Donald Schön has argued that professionals often depend on a "knowing-in-action", operating with a kind of tacit knowledge. As the professional carries out her actions, this knowledge (or understandings implicit in her actions) surfaces, and is criticised and restructured, thus informing further actions. Schön calls this process "reflection-in-action"; it is characterised by the iterative reframing of a problem through stages of appreciation, action, and reappreciation. Similarly, in the contemporary creative-production research methodology of reflective practice, Stephen Scrivener quotes Schön in arguing that the researcher is seeking affirmation of her hypothesis rather than confirmation, and "only hypotheses that can immediately translate into action are of interest" (Schön 1983). Each stage of evaluation in reflective practice is grounded in the practitioner's tacit accumulated knowledge to determine whether changes made are liked or disliked. Scrivener believes this process is the problem-solving process carried out by the creative-practice researcher, which he summarises as *reflective practice*. Chapter 5 details the methodological stages of reflective practice carried out by the author as a means of seeking affirmation of the proposed design methodology hypothesised within this thesis. The tacit knowledge Schön refers to is given diagrammatic form to "suggest a working model of the whole" and a "relation between the parts" (Allen 2000:50), while the process of reflection-in-action provides a method of evaluation of design outcomes.

Throughout this chapter, for the purposes of illustrating the present methodology, the morphology and emotion state applications of Hoffman and Zuckerman's (2015) Kip1 robot is used, with the express permission from the authors. A robot "body" was needed to act as the "hardware" or material component, to be sketched together with lines of emotional movement. Kip1 was selected for a number of reasons. Firstly, this robot has clearly defined "emotion states" that are necessary for its application, but each of these states are complex embodied emotions such as 'curious', rather than simple emotions that could be expressed with facial articulation such as ‘happy’. Secondly, Kip1 has planned movement patterns that can be sketched together with the arcs and lines of the necessary emotion states. Thirdly, the form of this robot is not humanoid nor zoomorphic, and therefore assists in exemplifying how emotional movement planning might be incorporated into any existing form, and how existing robot bodies could be refigured in the future.

The remainder of this chapter is written in the first-person, detailing my practice-led artistic investigations, and the way in which they shape stages of action and reappreciation. Whilst I agree with Sherry Gorelick that, “the appearance of objectivity is a persuasive move”, feminist scholar Gesa Kirsch suggests (1994:382) that, “for feminists, the question of when to use the authorial I, when to situate oneself in the text … is not simply a matter of appropriateness; it becomes an ethical choice.” In the interest of authenticity, the authorial I is therefore adopted in detailing the artefacts and reflexive actions that I developed for the purposes of this thesis.

Section 5.1 discusses the methodology of reflective practice employed to develop and examine the social robot design methodology that is demonstrated in this chapter. Encompassing this methodological approach, the thesis is positioned as a “creative-production doctoral project” as defined by Steven Scrivener (2000). Within a creative-production doctoral project, reflective practice allows the author to evaluate each stage of the methodology presented in-action, and this method is used throughout each stage of the present design methodology.

Section 5.2 outlines the methodology of *critical design* as defined by design practitioners Anthony Dunne and Fiona Raby in their book *Speculative Everything: Design, Fiction, and Social Dreaming* (2013). The approach of critical design frames the practice-based material investigations as contributing “another dimension” to existing practices in social robotics, and “generating discussion” concerning existing methodological practices.

Section 5.3 “Gestural Sketches” presents the first stage of the present methodology, where I have sketched the shape of the human body’s expression of three emotions: calm, curious and frightened. The raw iterations of these sketches are in the style of Marinetti, examined in Chapter 3, and are conducted through a number of iterations, shaped by reflective practice.

Section 5.4 “Plastic Verbs + Robotic Form” illustrates the second stage of the methodology, where the shapes and arcs of emotional expression have been sketched alongside the existing robotic hardware and 'body' of Hoffman & Zucherman's Kip1 (2016), just as Fortunato Depero sketched the twirls and whips of the dancer alongside her body in *Costume for Mimismagia* (1916).

Section 5.5 "Generated Morphologies" presents the final stage of the methodology, where the emotional expression intended for the robot's application has been made plastic. Lines of movement have been sketched together with the drawings of hardware to form new abstracted 2-D morphologies, with "functional transparency" that could be interpreted diagrammatically in 3-D in any number of ways to form unique new robot morphologies.

Section 5.6 "Exhibition Documentation" documents my contribution to the *FEMUFACTURE* exhibition, where the triptych of sketches was exhibited in Sydney in 2019 as part of a group exhibition showcasing a hybrid space between traditional making techniques and contemporary digital technologies.

5.1 Reflective Practice

Steven Scrivener describes a creative-production doctoral project as one where generated artefacts are intended as a means of intervention or innovation. In likening such projects to technology research projects, he enumerates a range of common features including

> [Seventh] that the knowledge embodied in the artefact can be described separate from it (thus offering the potential for reuse). [Eighth], that knowledge embodied in the artefact is applicable to other contexts, and, [ninth], transferable to the construction of other artefacts. [Tenth], that the beyond-the-single-case application and transferable knowledge embodied in the artefact is more important than the artefact [author's emphasis], which is merely a demonstration of its existence. (Scrivener 2000:1)

Scrivener posits that creative-production within a doctoral thesis may vary greatly from traditional art practice and that the production of artefacts may be closer to a traditional research method such as a user study or an experiment. While the objects themselves are unique, they are not designed for a single-case and do not offer the *only* solution to a problem. Rather, they demonstrate transferable knowledge, or one possible solution to a known problem. In such cases Scrivener believes that these projects must demonstrate the existence of a problem, show that a solution to the problem will result in a new or improved artefact, demonstrate the usefulness of the solution, and they must demonstrate the applicability and transferability of the solution. Scrivener concedes that for creative-production projects, there are no agreed-upon methods for the process of problem definition and solution, and the practitioner is not obliged to describe their problem-solving or problem-setting process. Rather, a persuasive case for the worthiness of the problem must be provided, and the rationality of steps taken to solve it, and their execution, must be demonstrated. Scrivener asserts that in his experience this underlying problem-solving process is most closely aligned with Schön's (1983) theory of reflective practice.

Given the objectivity, control and distance required to ensure rigour in a typical research experiment, Scrivener questions how the rigour of the on-the-spot-experimentation of reflective practice is evaluated. Schön argues that the researcher must impose her own order in the form of an overarching theory, and maintain constant elements of "an appreciative system and a stance of reflection-in-practice" (1983). This is where the accumulated experience of the practitioner comes to bare on the problem. According to Scrivener, the researcher must be "open to a situation's talk-back" without falling into transaction with the situation. This sensitive cyclic process of 'listening' and responding demands a certain reflexivity on the part of the researcher.

Scrivener quotes Tindall in explaining that reflexivity is "possibly the most distinctive feature of qualitative research … it is an attempt to make explicit the process by which the material and analysis are produced" (Tindall 1994:149). "In essence" says Scrivener, "it is an on-going and disciplined self-reflection on which the research topic and process, together with the experience of doing the research, are critically evaluated." In Schön's view, the practitioner's repertoire for effectively reflecting on their practice is made up of "examples, images, understandings and actions", and this is also what comprises their original contribution; examples, images, understandings and "strategies for action" that may then be used by other practitioners "to extend their own repertoires".

The work contained in sections 5.3–5.6 is comprised of "examples, [and] images" of the author's present methodological approach to social robot morphology design. They are offered not as the best or sole approach, but rather to generate "examples, images" and "understandings".

Coupled with self-reflection throughout each stage of action, the present work aims to develop "strategies for action" to extend the repertoire of multidisciplinary approaches for practitioners engaged in social robot morphology design.

5.2 Critical Design

Throughout this thesis the terms art and design are used interchangeably, and although the author makes close reference to art history, theory and its methods, the artefacts produced within this thesis constitute design artefacts. While these terms undoubtedly ordinarily represent two distinct fields, they appropriate qualities from one another in the practice of *critical design*. Critical design is a term coined by contemporary design practitioners Anthony Dunne and Fiona Raby in their book *Speculative Everything: Design, Fiction, and Social Dreaming*, who use the phrase to describe a mode of design where "B was not intended to replace A, but to simply add another dimension, something to compare it to and to facilitate discussion" (Dunne & Raby 2013:vi). Dunne and Raby state, "It grew out of our concerns for the uncritical drive behind technological progress ... critical design uses speculative design proposals to challenge narrow assumptions ... and givens about the role that products play in everyday life" (2013:34).

As one aim of this thesis is to address critically the current state-of-the-art in social robot morphology design, the use of critical design allows for the creation of artefacts to add a new dimensions and generate discussion in the field. Dunne and Raby (2013:43) explain the role that art plays in critical design: "Critical design might borrow heavily from art's methods and approaches but that is it. We expect art to be shocking and extreme. Critical design needs to be closer to the everyday; that's where its power to disturb lies." As such, critical design employs art's methods, but does not lead to works of art for art's sake. Rather, in using these methods, works of 'design' are produced, which are intended to effect change: "If it is labelled as art then it is easier to deal with but if it remains design, it is more disturbing; it suggests that the everyday life as we know it could be different, that things could change" (Dunne & Raby 2013:43).

Dunne and Raby emphasise that critical design cannot remain purely theoretical; artefacts must be produced in order for critical thought to be translated into materiality: "critical designs need to be made physical. Their (the objects) physical presence can locate them in our world whereas their meaning, embodied values, hopes and fears belong somewhere else (in the yet-to-exist)" (2013:43-44). It is through the making of objects that designers can hope to foster a new type of reality, or bring new possibilities and ways of working into focus. Hence, while this thesis may have remained theoretical, artefacts were produced and exhibited in order to "locate them in our world".

Importantly, Dunne and Raby closely link the practice of critical design with technology development: "conceptual design should have … a certain social usefulness, specifically, to question, critique and challenge the way technology enters our lives" (Dunne & Raby, 2013:34). It is here that critical design most closely aligns with the motivation of this thesis—to question, disrupt and improve the way in which robots are steadily entering the human social sphere, towards more fluid, intuitive and conscious human-robot interaction.

5.3 Gestural Sketches

According to Barad (2007:244), "The ubiquitous pronouncements proclaiming that experience of the material world is 'mediated' have offered precious little guidance about how to proceed". As highlighted by Barad, it is one thing to declare that the material world is "mediated", or in the case of social robotics, that the materiality of robots is structured and influenced by historical precedents, perpetuated typologies and subconscious bias, but it is another to offer guidance on how to proceed in light of this knowledge. The following sections 5.3–5.5 therefore detail methods drawn from the work of the Futurists as potential points of guidance for use in the design of social robot morphologies.

The search for 'entanglements' among art history, sculpture, aesthetics and social robotics revealed aesthetic resonances between the work of the Futurists and contemporary social robotics, as examined in chapter 3. While many design approaches in social robotics employ the latest digital software and rapid prototyping technologies, in a commitment to 're/configuring' existent aesthetics, I returned to Futurism, to examine how it is that the Futurists arrived at the sculptural forms that so recognisably and successfully integrated elements of human-ness and machine-ness. The path to materialising these forms was not a straight one, nor achieved by a sole artist.

Surrounded and inspired by new technology and forms of locomotion, the Futurist artists employed a multitude of media and methods to capture the intangible energy and dynamic movement of the new age. After dismissing attempts at "optical reconstitution of motion" (Lista 1986:21) from artists such as Muybridge and Balla as "idiotic" (Boccioni 1913) (examined in section 3.2), the Futurists sought to capture the vital intensity of phenomena, and its emotional and lyric dimensions in a single form (Boccioni 1913). For artists such as Umberto Boccioni, Giacomo Balla, Luigi Russolo, Ottone Rosai and Carlo Carrà, this search took the form of paintings featuring bright colours, a multiplicity of geometric forms, hasty and painterly brush strokes, and pictorial references to elements of urban life, such as crowds, trains, bicycles and buildings. Filippo Tommaso Marinetti did not strictly identify as an artist, but he too engaged in this pursuit to capture and 'make plastic' the intensity and dynamism that he found so compelling, but in an alternate medium. Not only did Marinetti develop unique and noteworthy methods, but by examining the work of a 'non-artist', a method with a greater universal applicability for practitioners outside of fine art might be determined.

Between 1912 and 1914, Marinetti produced numerous ink sketches and collages in his *Words-in-Freedom* series (see Figures 5.1 and 5.2) that comprised of pictorial drawings, written words, gestural sketches and collages of images cut from newspapers. In the following years (1914–1915), these sketches were refined, featuring less collage, images and words. The later examples produced in 1915–1916 such as those examined in section 3.4 and 4.3, including *Action*, *Bombing*, *Air Raid* and *Propeller*, are refined down to almost purely directional and gestural lines of energy and emphasis, with limited typography. What could be the reasoning behind this reductive iterative process? Compelled by his discontent with the antiquated artistic establishment, Marinetti sought to establish a "wholly new art, beginning from scratch" (Rye 1972). Jane Rye concludes that "it must be admitted that they failed" and that "in the process they developed theories which were original and undoubtedly influential, but these theories far outstripped their practice, and their works are for the most part naïve and superficial translations of ideas which are essentially literary" (1972:23-25). Attempts to translate literary concepts into art, to plasticise the intangible, and to have this result in theories that were "undoubtedly influential"

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Figure 5.1 – Filippo Tommaso Marinetti, *Words-In-Freedom (Premier Record)*, 1914, China Ink on Paper.

is arguably far from failure. This contribution constitutes what Suchman refers to as generative theorising (Suchman 2009), and while they may not have contributed “wholly new art”, they demonstrably contributed to a larger collective practice.

Marinetti’s iterative transition away from pictorial and linguistic bounds towards the gestural sought to capture the intangible in a wholly new manner; to “render atmosphere” (Boccioni et al. 1910). In works such as *Air Raid* (1915–1916), with a few simple gestural and diagrammatic lines, Marinetti captures the wailing sound of the air raid siren, the peppering lines of gunfire from above and the chaos of action and movement on the ground. Sound, energy, repetition and uncertainty are all captured within these lines.

When we consider the application of this technique to social robotics, the affective and com-

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Figure 5.2 – Filippo Tommaso Marinetti, *Air Raid*, 1915–1916, ink on paper.

plex nature of human emotional expression entails more than just words or crude movement, it includes atmosphere. Nuanced emotional expression includes emphasis, energy and intangible physiological qualities, as argued by Fong et al.: "Much of emotion is physiological and depends on embodiment" (2003:11). Pursuant of my own desire to move away from prominent robotic morphologies, and to resist reductively reconstituting human emotion in robotic form, I sought a new method for rendering or plasticising the intangible elements of emotional expression. The following practice-based material investigations are therefore an appropriation of Marinetti's *Words-in-Freedom* series. The sketches are diagrammatic attempts to draw what was described by Carrà as the "arabesques of form" (Russolo 2012:, p. 119) that come to mind when picturing the embodied expression of emotions such as "calm", "curious " and "fearful".

I began with "fearful" (Figure 5.3), as it seemed the most approachable of the three, due to the often full-bodied expression of this emotion. The generated arcs and arabesques of "fearful" resulted in two main categories, that of the body retreating in on itself (and shaking/shivering) and that of the body retreating from present danger. The lines show confusion, mounting panic, retreating or growing smaller, changes in direction, and the seeking of shelter. I struggled to depict the emotion of "fearful" without sketching a retreating motion. Many of the

Figure 5.3 – Gesture Sketch Example, *Fearful*, 2019.

lines were curved, and this seemed to indicate both the 'seeking' of a shelter, as well as curves that may be found in the fearful body, such as the concave curvature of the neck, chest and arms.

The sketching of "curious" (Figure 5.4) resulted in a similar dichotomy, where lines of both the body's movement within itself and movement in relation to a stimulus resulted. The arcs showed lines of meandering and then 'zeroing in', and this could pertain to the curious attention of the mind, the gaze, or the physical body itself. The lines show a sudden change in direction, such as the sharp turning of the head, and an upward extension such as that made by the chin or neck to listen more closely, or see over a fence. The lines detail the possibility of a slowly developing or emerging curiosity, such as might be experienced when reading a book, and a sudden curiosity, such as that caused by an unfamiliar sound. The body's curious movements therefore seem to be both slow and rising extensions towards the object of interest, and also sudden whips or a keen gesture of piqued interest.

The arc and lines of a "calm" state (Figure 5.5) centred around deliberate, slow and repeated lines, and reclining or softening shapes that found stillness. Even when the lines were sharp or straight, repeated slowly and deliberately, they denoted control and consistency, like a resting

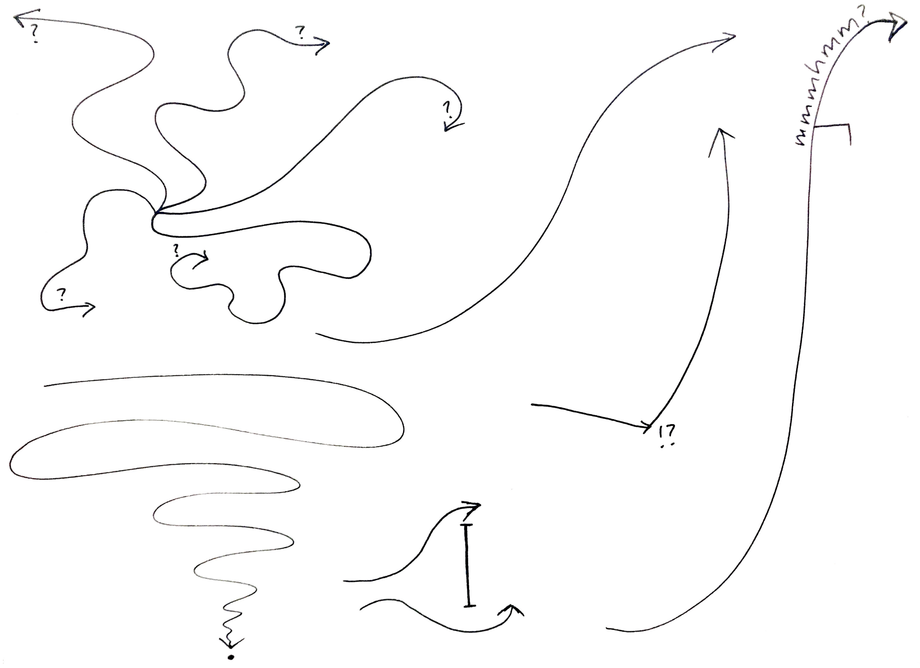

Figure 5.4 – Gesture Sketch Example, *Curious*, 2019.

heartbeat. The long meandering lines were indicative of taking one's time, of not being in a hurry. The rounded organic forms softened and spread out on the page like a body reclining, relaxing, letting go. There was an openness and unguarded shape to the lines of calm.

Although in this context I sketched emotion states, this stage in the present methodology could also be used to capture or communicate a range of intangible qualities or states-of-being desirable for a robot's function, be it emphasis, energy, or indescribably elements of "personality". It can be used to explore or communicate anything pertaining to the morphology that is beyond words or numbers.

My primary observation of the first step in this methodology is that it was challenging. Attempting to sketch emotion states, or states of being, or atmospheres, or energies without those states being connected to an object or body is complex. It is clear why Marinetti struggled and slipped back to the pictorial or to onomatopoeia in his work, and it is understandable why roboticists have looked to familiar forms for generating emotional expression in robots. Of the work of the Futurists, Hultén remarks "the first time something is expressed, the expression may be crude, and immature, but the new later appears in its purest and most impressive form" (Hultén 1986:13). These initial attempts at gestural sketches are crude and raw, as were

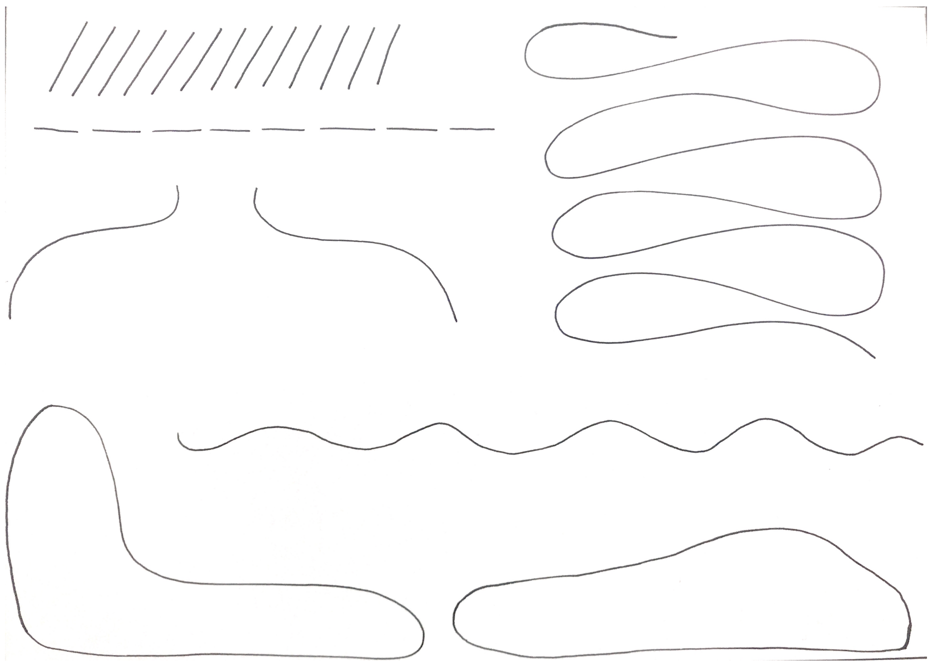

Figure 5.5 – Gesture Sketch Example, *Calm*, 2019.

Marinetti's. They do however, offer a potential diagrammatic tool for emotional movement path planning, or lines of expression that, sketched together with the hardware of the robot, can suggest new forms. In the following section 5.4, I combine these sketches of emotional expression and lines of body movement together with the physical body of the robot, "(environment + object)" (Boccioni 1913), in the manner of that done by Fortunato Depero in 1916.

5.4 Plastic Verbs + Robotic Form

The second stage of the present methodology addresses a particular difficulty in social robot morphology design as outlined by Hoffman and Ju, where "significant iteration is required to understand how the robot's physical motion relates to its surface appearance" (2014:93). The Futurists, too, were challenged by the "manifestations of the relativity . . . between the environment and the object which come together to form the appearance of the whole: *environment + object*" (Boccioni 1913). For the Futurists, this equation was inspired by the desire to create sculptures of the human form that would blend the body with intersections of other objects and atmospheres: "Sculpture, therefore, must make objects live by showing their extensions in space as perceptible, systematic, and plastic. No one still believes that one object finishes off where another begins or that there is anything that surrounds us …which doesn't cut into and sectionalise us with its arabesques of curves and straight lines" (Boccioni 1913). For roboticists, blending the necessary hardware, physical motion and external morphological appearance in a robot's design presents a significant, and arguably parallel, challenge.

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Figure 5.6 – Fortunato Depero, *Ballet Dancer*, 1917, China ink diluted on paper.

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Figure 5.7 – Fortunato Depero, *Ballet Dancer*, study of costume, 1916, tempera on canvas.

As discussed in section 3.2, in the figures 5.6 and 5.7 Depero's sketches can be seen as building upon Marinetti's diagrammatic gesture drawings, by combining lines of emphasis, movement, energy and sound with the body of the dancer. In doing so, he "brings to life" the shoes, capes, and ribbons of the dancers by "rendering their extensions into space" (Boccioni 1913). This stage also transforms the drawing of the dancer from a pictorial sketch into a diagrammatic drawing, and thus begins to suggest new forms and allows for new interpretations. In a similar manner, the planned paths of movement, rotation, emphasis and embodied emotional expression of a robot might be sketched alongside its hardware.

The first time I attempted this process, I sketched a "highly schematic and graphically reductive" (Allen 2000:50) version of Kip1's "hardware" or body, together with the robot's movement extensions into space. In figure 5.8, I have sketched Kip1's movement from its "curious" ver-

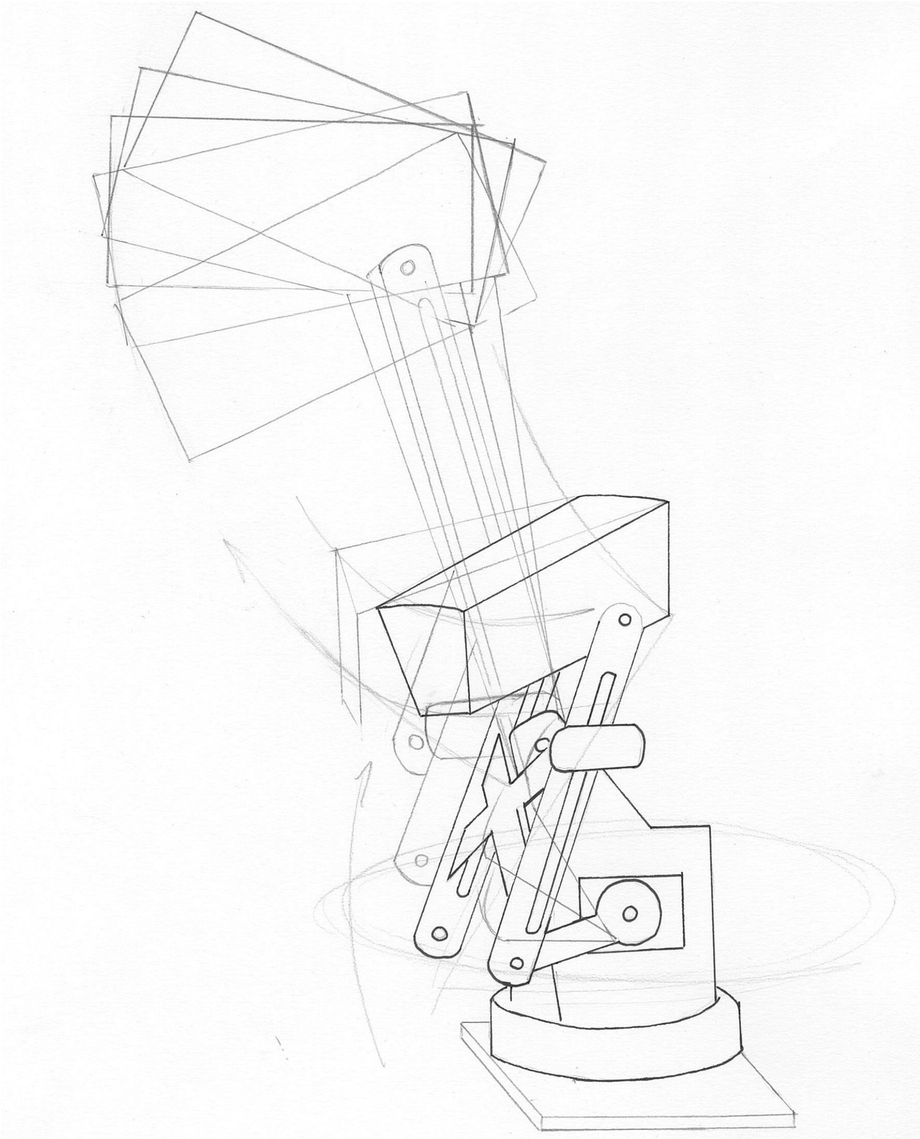

Figure 5.8 – Gesture + Robot Form Example, *Calm*, 2019.

tical extension, where the folding arms are extended and the head lifts, back down to a calm resting position. This first drawing, however, is not truly diagrammatic in nature, as it is semantic and not syntactic, and leaves very little room for interpretation. The two sketches seen in figures 5.9 and 5.10 include additional lines of energy, emphasis and direction, and arcs of optical blur, where, for example in figure 5.9, the open front of the head extends upwards in one long arc, just as it might appear optically to a viewer in the moment of movement. In figure 5.10, after I observed the "fearful" shudder that Kip1 performs, I sketched the emphasis

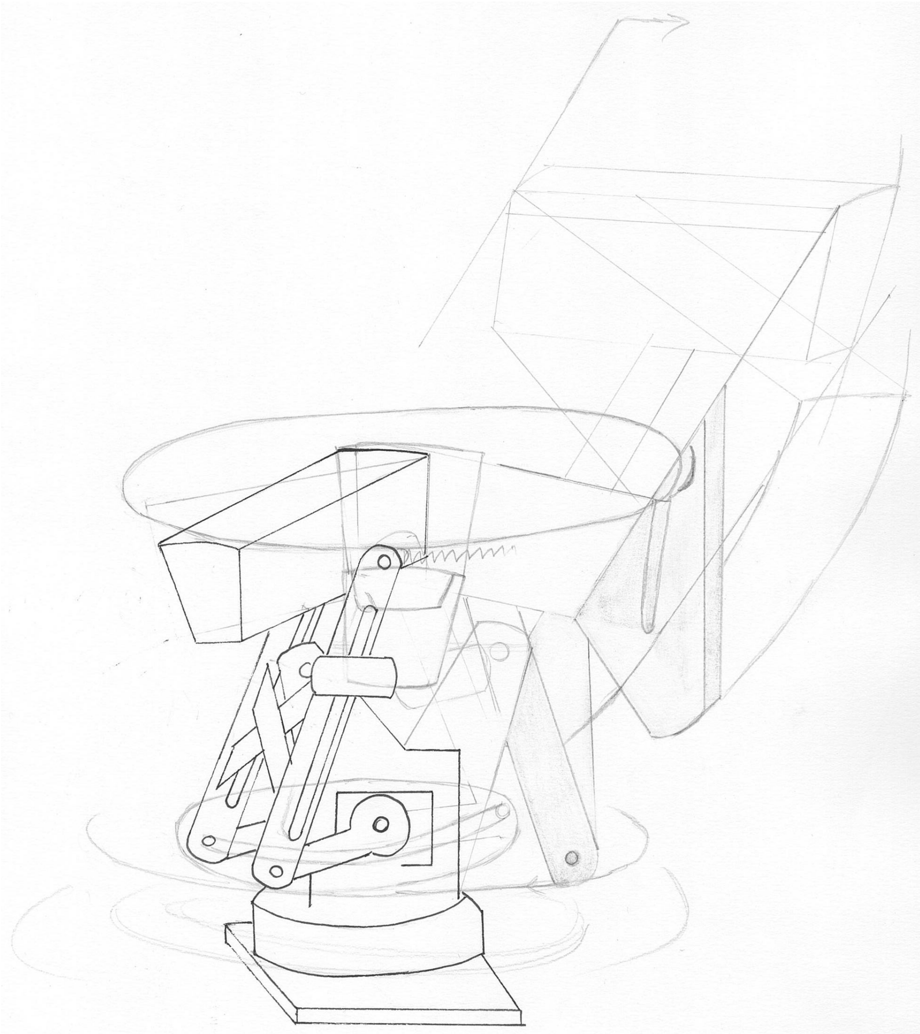

Figure 5.9 – Gesture + Robot Form Example, *Curious*, 2019.

of that movement, and moved my pencil in a similar quick and shuddering manner, to capture the energy of the movement. In this way, the diagrammatic drawing of the fearful "shivering" captures the movement—which can go on for some seconds—into an instantaneous moment, where the energy and movement is plasticised on the paper.

In figure 5.9 the vertical arrows and arabesques of curiosity sketched in the gestural sketch stage can be seen layered over the top of the movement lines. Kip1 has also been sketched in multiple positions (facing front, left and right), as though scanning or curiously pursuing different paths, as was explored in elements of the gesture sketch. In figure 5.10 the large circular arc of fearful retreat that was generated in the gesture sketch of "frightened" (Figure

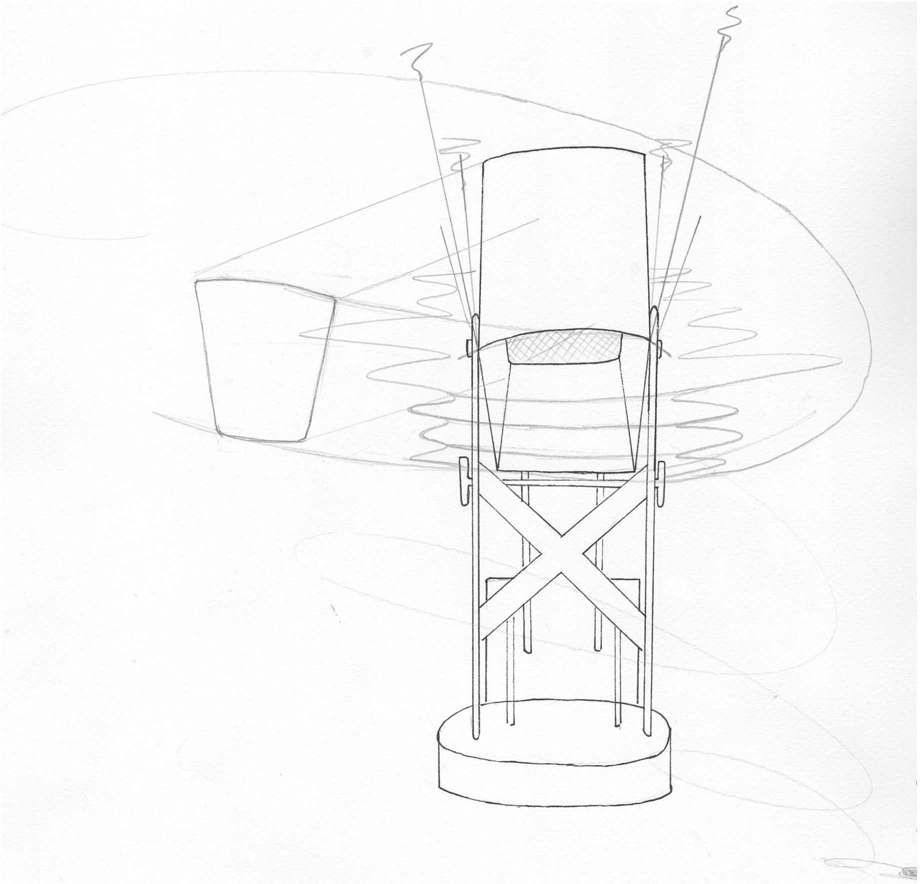

Figure 5.10 – Gesture + Robot Form Example, *Fearful*, 2019.

5.3) sweeps around and meets up with what could be a line of rotation of Kip1's movement in figure 5.10.

Reflecting on these three images[1], figures 5.9 and 5.10 are more successful as diagrams because they are more likely to be relational and transactional in nature, open to multiple interpretations (Maxwell 1910). I discovered that it is not enough to only sketch the lines of direction and movement. The qualities of the diagrammatic—that is, generative, transactional and open to interpretation—only come to fruition when the first step (demonstrated by Marinetti) of mapping intangible elements over the top is included. The present methodology necessitates that this stage results in transactional images, to aid the communication of tacit knowledge

[1]Initially, I had viewed this stage of the development as an intermediary working phase towards the finalised paper-cut collages, which I had planned as the major work to be displayed in the *FEMUFACTURE* exhibition. As the diagrams developed, it became clear to me that this stage best illustrated the central concern of my thesis. Section 5.6 therefore features a triptych of images I exhibited, drawn from the work I conducted at this stage of the methodology.

and intangible qualities among practitioners from disparate disciplines. The following section 5.5 also demonstrates the necessity for the images to be generative and open to interpretation, so that they might suggest new morphological forms and possibilities.

5.5 Generated Morphologies

The final stage of the present methodology is one of iterative re/configuration, of 'figuring' or drawing-out of potential morphologies from the multiplicity of forms that present themselves in the layers created by the first two stages. This stage is where the generative nature and interpretative capacity of diagrams really comes to bare. In this stage I examine how the body or hardware of a social robot might be considered concurrently with movement planning and aesthetic appearance. I will introduce two new images to illustrate this further.

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(a)

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(b)

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(c)

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(d)

Figure 5.11 – A visual comparison of Fortunato Depero, *Costume for Mimismagia* sketches, 1916, water colour on paper.

Figure 5.11 (a)–(d) were all developed in the same year (1916) by Fortunato Depero, in what was clearly an exploratory and iterative process. Figure 5.11 (a) is the original diagrammatic sketch of the dancer and her motions, sounds and energy. Figure 5.11 (b) and (c) show two vastly different images that represent reinterpretations of the original image, where Depero has given various weight, form and plastic value to the different parts of both the dancer and the diagrammatic elements. In the final render (d), Depero has favoured the conical legs and circular rotation of the skirt found in (b), but he has combined these with the colour pallet and three dimensional 'fans' which have been explored in (c). Neither figure 5.11 (b), (c), or (d) represent a 'correct' or proper interpretation of the diagram in (a). Rather, they demonstrate the generative capacity of the diagrammatic elements in (a). In images (b) and (c) Depero has applied watercolour paint in a limited colour pallet to begin to demarcate shapes and give three-dimensionality to the image. The watercolour plasticises the elements in order to give them equal weighting; for example, the sprouting sounds of the snap of the dancer's fingers are now of equal value to the legs or arms, where in image (a), they were still distinctly diagrammatic. The watercolour also adds three-dimensionality by 'pulling forward' some elements and receding others. This step could be of particular interest to roboticists who intend to translate these images into three-dimensional morphologies.

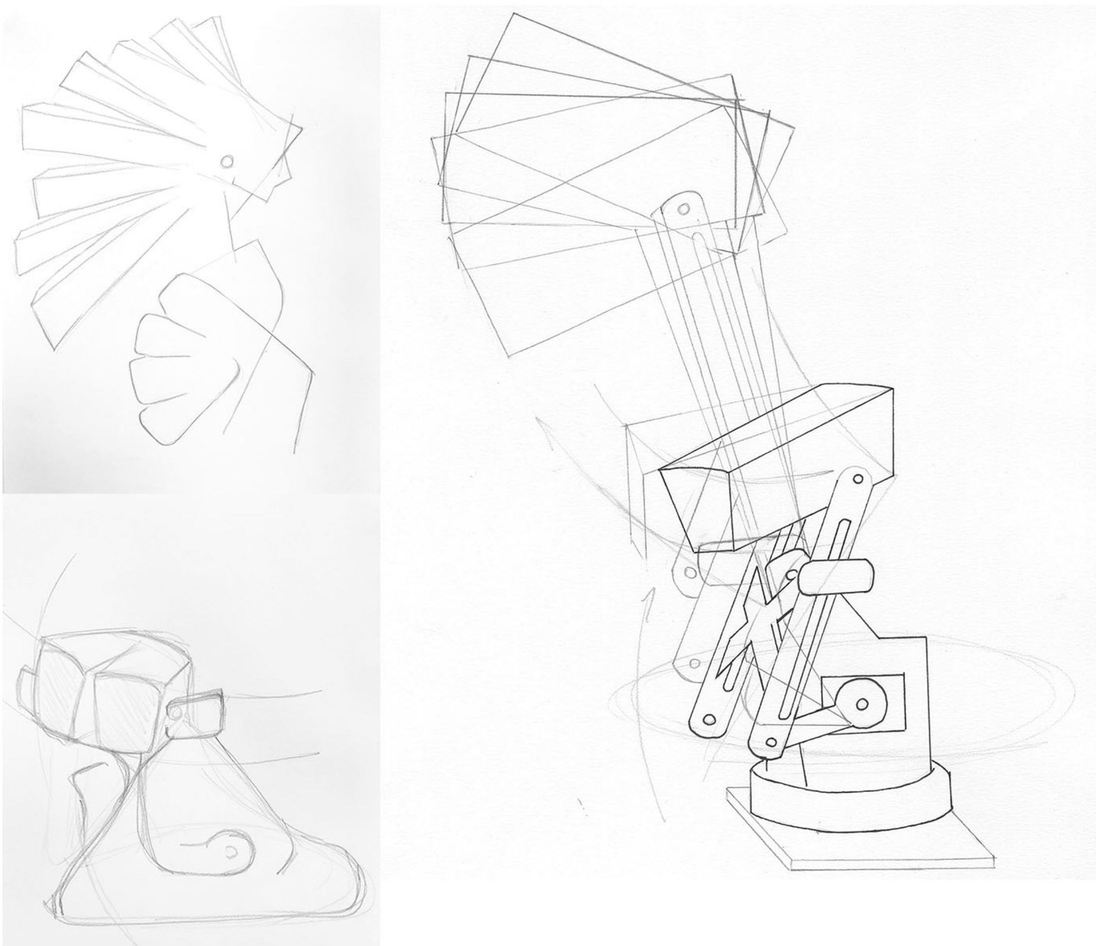

Figure 5.12 – Generated Morphologies Example 1, 2019.

Notably, the resulting images in Figure 5.11 (b)–(d) have arguably departed from a humanoid-like form resulting in a slightly unfamiliar morphology, but they are still suggestive the anthropomorphic. Turkle proposed that an unfamiliar morphology may actually promote anthropomorphisation. In *The Second Self* (1984), Turkle argues that the computer is anthropomorphised because it is not like any other thing, it is irreducible, but its abilities are analogous to that of a person (Turkle 1984). A significant body of research in social robotics, as discussed in chapter 2, has argued that a humanoid form will be the most effective for interaction with humans, yet Turkle suggests that a form or interaction which is irreducible to a known form, but reminds us of the known, can promote anthropomorphism.

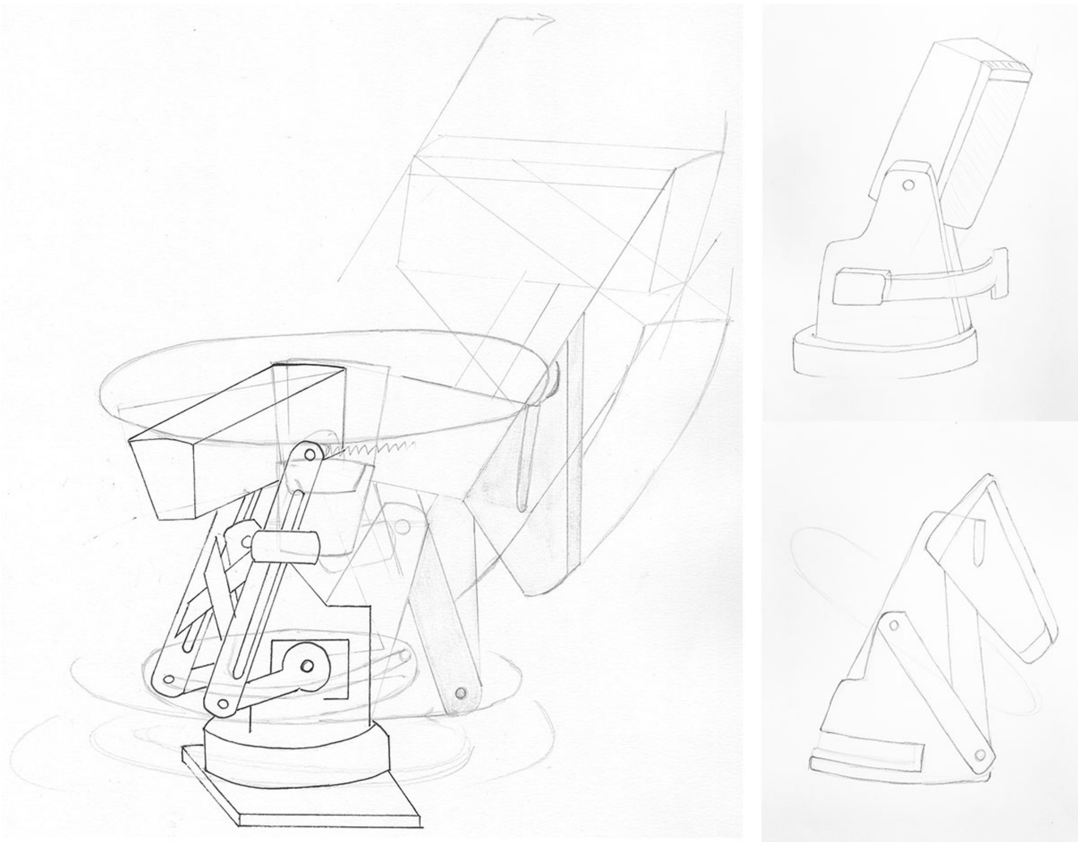

Figure 5.13 – Generated Morphologies Example 2, 2019.

In figures 5.12 to 5.14, I have examined the diagrammatic images I produced in the second stage of the methodology and attempted to distil or extract various morphological forms in the manner demonstrated by Depero. I examined various elements of interest in the diagrams, and then redrew them on separate sheets of paper, connecting lines of movement, emphasis and

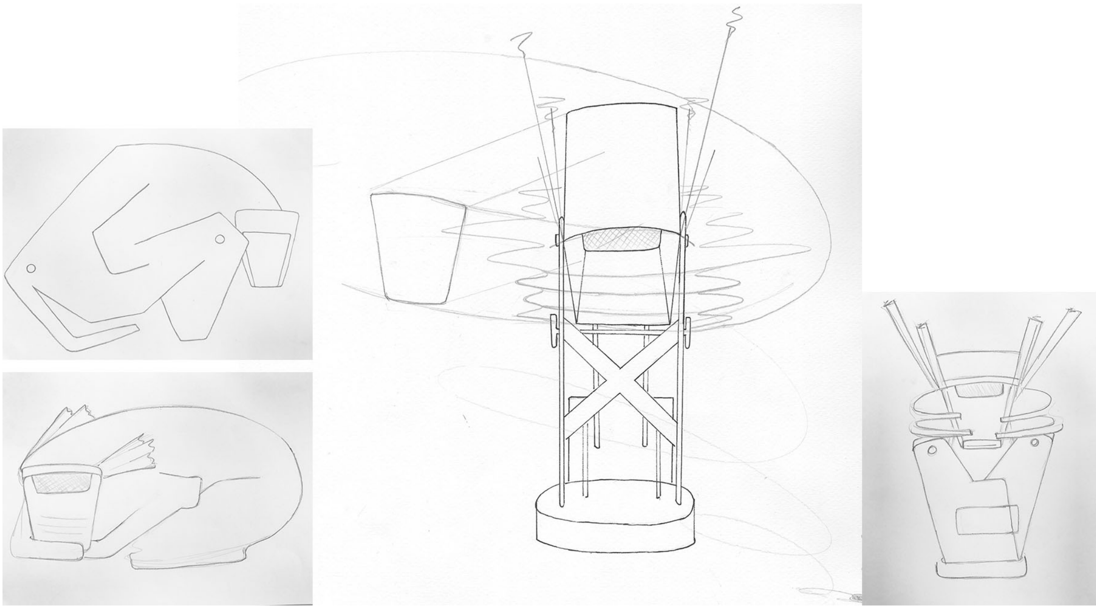

Figure 5.14 – Generated Morphologies Example 3, 2019.

emotional expression to lines of the existing hardware of the robot. Some iterations naturally took anthropomorphic shapes, but always remained suitably unfamiliar.

The reductive and 'plasticising' power of the watercolour stage was reiterated to me early on in my experimentation. In figure 5.9, I initially made the error of beginning the colour process on top of the original diagram—this was unhelpful as it instantly began to reduce the diagram's interpretive capacity. It was important to begin each new interpretive sketch as a separate image before adding colour. The colour stage could be done with any medium. Translating the new morphological sketches to a paper-cut or more refined watercolour images was helpful for understanding how different elements of the morphology might relate to one another in three-dimensional space, by receding some elements and advancing others. I do, however, recommend delaying this stage, just as Depero did, to generate as many potential morphologies as possible before resolving one further, just as is recommended in any brainstorming exercise. Additionally, as was exemplified by Depero, different elements emerging from separate sketches may be of interest to the roboticist, and could be combined in a new image. Where elements of a social robot's hardware may have fixed parameters, such as a base, arm or remotely operated platform, these elements can simply be repeatedly incorporated, with variation given to the surrounding morphology.

It is important to note that Futurist art achieved the blending of human and machine, tangible and intangible in a static form, expressing some intangible 'states of being' in an unchanging way. Social roboticists such as Breazeal (2004) have experimented with expressing emotions that can vary through a change in robot facial features (eyebrows, eyes, mouth, etc.) that are moved. Many contemporary robots must have multi-body forms with articulated joints for functional reasons. This methodology could therefore be used to not only broadly design the overall morphology, but additionally, it could be used a) to statically shape the various links in the articulated machine; b) to adjust the locations of the articulated axes to give different kinematics (by shaping the movement capability), as long as the adjustments are compatible with function; c) to shape and add non-functional elements; and d) to shape and add elements that can be moved expressly for the purpose of expressing emotion or some other intangible quality.

In a similar manner to Hoffman and Ju (2014:93–94), this design approach has tended to result in atypical, morphologically-distinct designs comprised of "formal simplicity and abstract geometric shapes". However, the present methodology need not be used only for generating new morphologies, but could be used to refigure an existing design, or one element of an existing morphology. These techniques aim to contribute to a "set of solutions", providing a "language of interaction" (Duffy 2003:181) to facilitate "creative solutions" (Suchman 2011). While the adoption of new techniques is experimental and challenging, Norman concludes, "It will take extra effort to design systems that compliment human processing needs. It will not always be easy, but it can be done" (1993:227).

Chapter 6

Conclusions

The work presented here has critically investigated social robot morphologies and design methodologies, aiming to contribute a new methodological approach drawn from, and using, art practices. This chapter provides a summary of the principle findings and suggestions for future research paths. The summary is divided into two sections: That matter matters in social robot morphology, and the approach of diagrammatic design in social robotics.

That Matter *Matters* in Social Robot Morphology

Examination of Barad's philosophical approach (2007) of agential realism has been shown to suggest that nonhuman bodies, such as those belonging to social robots, ought to be treated with the same philosophical seriousness that has previously been afforded to human bodies. It has been argued that this is because social robots and their design are involved in agential transaction with the world, both shaping and being shaped by it. These technological nonhuman bodies must therefore not be treated as "given" objects, but the materiality and matter that make up these bodies must carefully be considered, as they contribute to the dialogue of boundary drawing practices between binaries such as human and machine, real and artificial—they reconfigure the world in their becoming (Barad 2007:394). Furthermore, it has been argued that it is a responsibility of those developing these non-human bodies to consider their designs critically and consciously, because, as argued by Barad (1998:102), "we are responsible for the world in which we live not because it is an arbitrary construction of our choosing, but because it is sedimented out of particular practices that we have a role in shaping".

Through the survey of social robot morphologies from the last 25 years, it has been demonstrated that roboticists are seeking to design robots for increasingly complex and nuanced social interactions. These interaction scenarios were shown to be taking place in an increasingly wide range of social situations that require the expression of complex emotions through a variety of robotic communication modalities. It was concluded from the survey that two prominent typological trends had emerged: humanoid robots and cute robots. It was argued that these typologies had often been chosen and reiterated with limited theoretical reasoning or critical engagement expressed by the designers. These aesthetic trends were discussed in light of critical theory, and shown to be linked to undesirable sociopolitical implications or, in some applications, problematic user expectations and behaviours.

A review of existing methodological approaches to social robot design revealed a lack of formal design approaches and techniques, and this was argued to be a key contributor to the perpetuation of prominent and problematic morphologies. The lack of formal methodological approaches was attributed to the relative newness of the field, the involvement of many practitioners from disparate fields and the complexity of conveying tacit knowledge among such a team. Art was discussed as a field that has long studied embodiment and interaction and has had a relatively long engagement with robotic technology. Art and particularly sculpture are discussed as sharing surprising commonalities and priorities with social robotics, namely those concerning embodiment and interaction. It is demonstrated that art has employed a range of practice-led methods to design robots that promote affective interaction and robotic emotional expression. Art is therefore positioned as a field with valuable knowledge to contribute both to the theoretical critique and methodological approaches of social robot morphology design.

Diagrammatic Design

The approach followed in this thesis was to examine the collective work of Futurist artists to better understand the methods that contributed to the successful integration of human and machine aesthetics in their sculptural work. The Futurists have had a lasting historical impact in a wide variety of fields, but particularly in those concerned with 'simultaneity', or the blurring of existing syntactical boundaries to create something new. The Futurists were demonstrated to have achieved this simultaneity to varying degrees in a wide range of media, but it was argued that it was achieved most successfully in their sculptures. Through visual analysis comparisons, the aesthetic achieved in these sculptures was shown to share a large degree of similarity with some contemporary social robot designs, and it was therefore argued that understanding the methods behind this aesthetic, instead of simply repeating the resultant aesthetic, is critical for responsible and conscious design in the future.

Through an examination of contemporaneous Futurist artist's practices, various methods of expressing intangible qualities and combining these with an existing form were discussed. These methods were considered for their potential to contribute to the field of social robotics in morphology design, where it was shown that a nuanced blending of human and machine aesthetics was both expressly desired and recommended by those working in the field.

Through a discussion and dissection of the nature of diagrams and notation across a range of applications, the diagrammatic was shown to be both reductive and generative; reductive in its capacity to capture, codify and convey intangible qualities, and generative in its capacity to be open to interpretation, and understood by anyone.

It was concluded and demonstrated that using a diagrammatic approach in the planning stages of morphology design allows for the aesthetics, movement and hardware of a robot to be considered concurrently. This diagrammatic methodology is shown to be transactional in nature, allowing for easier communication of tacit knowledge among researchers from disparate fields. The methodology is also shown to be generative, where the layering of intangible qualities and movement lines over the hardware of the robot suggest multiple possible new morphologies.

The present methodology and techniques are not a panacea for social robot morphology design nor relevant to all social robot applications. Rather, this thesis critically highlights the need for more multidisciplinary methods and technical approaches to be detailed and made approachable for use in social robot design. The contribution of this method suggests that techniques might be drawn from disparate fields if they are framed in a transactional nature and positioned as relevant to the field. For those working in the design of social robots, critically and consciously approaching morphology is conclusively an act of ethical responsibility and resistance.

6.1 Future Work

The work presented in this thesis suggests several paths for future research.

- Expansion of the critical discussion of prevalent morphological typologies in social robotics including humanoid and cute robots would contribute to a more informed use of these morphologies in various applications. A detailed evaluation of where these morphologies are most effective and relevant would be beneficial.
- Only one art movement was considered in depth within the present thesis, and while compelling reasons for the relevance of Futurism to social robotics were given, other art movements could reveal alternative and useful methods for the generation of expressive forms.
- The concept of 'muscular' pivot points used for emotional expression in the human body (discussed briefly in section 3.3) ought to be expanded to understand how this might usefully applied to the linkages and morphological design of social robots in replacement of strictly using 'skeletal' pivot points.
- The present diagrammatic methodology suggests a method of process-driven design, where a known process might reveal an unknown outcome. Similarly, the soft robots presented at the *FEMUFACTURE* exhibition were generated by material-driven design, where the nature of the materiality prompted further and unexpected experimentation, resulting in new morphologies. Further research in material driven design and its capacity to generate unusual and expressive morphologies is needed.

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Appendix A

Twenty-Five Robots in Twenty-Five Years

Of the hundreds of social robots reviewed throughout the literature review process, Appendix A contains a survey of a selection of social robots developed over the last 25 years across a variety of institutions, companies, countries and contexts. The criteria for the selection of the exemplars was that the robot had been identified by the designer/artist/roboticists as serving a social purpose including interaction, performance, or integration with human environs, and had a significant impact on the field as measured by multiple peer-reviewed citations, international exhibitions, and similar. It is acknowledged that some of the early examples were not explicitly identified as 'social robots', but are nonetheless indicative of a move towards the integration of robots within social contexts and a move away from more traditional manufacturing or service robotics. Within those bounds, the author sought the widest available variety, to understand the development of robot morphology on an international scale. Key identifying information and an image showing the morphology of the robot has been included, as this is the focus of the research. Within this table (Appendix A), the morphology and user interaction methods are identified, along with the 'motivation' or larger intended research purpose—beyond the application—as described by the author, artist, designer or roboticist.

Table A.1 – A Visual Survey of Twenty-Five Years of Social Robots.

Index	Information	Morphology	User Interaction (UI) Methods	Motivation
1: 1993	*Petit Mal* (Penny n.d.)	This figure has been removed due to copyright restrictions	"…a physical appearance which had a 'laboratory prototype' aesthetic which visually coded the work in a very specific way. An attempt to defuse or confuse that particular reading, while avoiding anthropomorphic/zoomorphic readings has been made by the addition of coverings of domestic printed vinyl tablecloth on some of the parts."	"The goal of petit mal is to produce a robotic artwork which is truly autonomous; which is nimble and has 'charm'; that senses and explores architectural space, and that pursues and reacts to people; that gives impression of intelligence and has behaviour which is neither anthropomorphic nor zoomorphic, but which is unique to its physical and electronic nature."
2: 1994	*Spring Turkey* (Lee and Šabanović 2014)	This figure has been removed due to copyright restrictions	"All of Spring Turkey's motors are located in its upper body, with power being transmitted to the joints via cable drives. Series Elastic Actuation is employed at each degree of freedom, allowing for accurate application of torques and a high degree of shock tolerance."	"This robot was developed as an experimental platform for implementing: Force control actuation techniques, particularly Series Elastic Actuation, motion description and control techniques, particularly Virtual Model Control and Various walking algorithms."
3: 1995	*Honda P2* (Hirai et al. 1998)	This figure has been removed due to copyright restrictions	"In order to move in such an environment, which is made for humans, Honda believes that a robot with legs and arms, and which can walk like a human, is the most practical and suitable configuration." "In the head of the robot, there are four video cameras. Two are used for vision processing, and can pan and tilt independently."	"The desired goal was to develop a robot able to coexist and collaborate with humans, and to perform tasks that humans cannot. In other words, to create a mobile robot which brings additional value to human society."

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Table A.1 – continued from previous page

Index	**Information**	**Morphology**	**User Interaction (UI) Methods**	**Motivation**
4: 1996	*RoboTuna*[1] (Barrett et al. 1996)	This figure has been removed due to copyright restrictions	"A flexible hydrodynamic body propelled by an oscillating tail foil."	"An increased interest in the use of Autonomous Undersea Vehicles for oceanographic, military and commercial missions."
5: 1997	*PaPeRo R100* (RoboticsToday 2011)	This figure has been removed due to copyright restrictions	"It can greet you by name and has 300 pre-installed phrases to express. R100 is Wi-Fi enabled and can read your email. It also has 100 pre-installed phrases for commands."	"R100 is a fun entertainment robot developed by NEC. This cute robot has bright colors and will cheer you up if you feel down." "Papero R500 (2001) is a social robot designed to keep people company."
6: 1998	*Kismet* (Breazeal and Scassellati 1999)	This figure has been removed due to copyright restrictions	"Kismet has fifteen degrees of freedom in facial features, including eyebrows, ears, eyelids, lips and a mouth. The platform has four degrees of freedom in the vision system; each eye has independent axis of rotation (pan), the eyes share a joint horizontal axis of rotation (tilt) and one degree of freedom neck (pan)."	"If a robot is to interact socially with a human, the robot must convey intentionality, that is, the robot must make the human believe it has beliefs, desires and intentions. To evoke these kinds of beliefs, the robot must display human-like social cues and exploit our natural human tendencies to respond socially to these cues."

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[1] Although zoomorphic, *RoboTuna* is not a social robot in the contemporary sense.

Table A.1 – continued from previous page

Index	Information	Morphology	User Interaction (UI) Methods	Motivation
7: 1999	*Sony AIBO* (SONY 2019)	This figure has been removed due to copyright restrictions	“This sleek, small robot resembling a puppy can be purchased by consumers and “trained" through interaction with its owners. It is kept in the manner of a family pet.”	“The word AIBO comes from Artificial Intelligence roBOt and is also the Japanese word for ‘Companion’ or ‘Friend’. They were first introduced in 1999 and were the first consumer robot of its kind to be offered to the public.”
8: 2000	*SDR 3X* (Kuroki 2003)	This figure has been removed due to copyright restrictions	“A small humanoid type robot about 50cm tall with 24 DOF in total” “Another technology is the Whole Body Coordinated Dynamic Motion Control method. It realizes the stable biped walking and stable whole-body dynamic motion performances.”	“[SDR-3X] enables the Motion Entertainment, i.e. entertaining people with its controlled dynamic motion performances.”
9: 2001	*iRobot PackBot* (EndeavorRobotics 2019)	This figure has been removed due to copyright restrictions	“Quickly configured based on mission needs, PackBot easily climbs stairs and navigates narrow passages with sure-footed efficiency, relaying real-time video, audio and sensor data while the operator stays at a safer, standoff distance.”	“Modular, adaptable and expandable, the Endeavor Robotics PackBot can perform bomb disposal, surveillance and reconnaissance, CBRN detection and HazMat handling operations”

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Index	Information	Morphology	User Interaction (UI) Methods	Motivation
10: 2002	*Leonardo* (MIT Personal Robotics Group 2015)	This figure has been removed due to copyright restrictions	“Leonardo is a 65 degree of freedom (DoF) fully embodied humanoid robot that stands approximately 2.5 feet tall. It has large ears and eyes, with open arms for face-to-face interaction with a ’player’. It incorporates speech recognition and parsing, vision and attention inputs, cognition and behavior, and motor control.”	“Ultimately, we hope to not only create robots that entertain us, but robots that know how to entertain us.”
11: 2003	*The Hug* (DiSalvo et al. 2003)	This figure has been removed due to copyright restrictions	“The soft anthropomorphic pillow-like form is used in pairs by two separate parties. The robot glows when use is initiated and incorporates warmth, vibrations and voice recordings to facilitate communication during a ’hug’.”	“A desire to contribute design knowledge to the challenge of ascertaining what forms and qualities of form in robotic products will be most effective in creating meaningful experiences.”
12: 2004	*Kondo KHR-1* (Kim and Oh 2004)	This figure has been removed due to copyright restrictions	“The KHR-1’s total weight, including batteries, computer, controllers and amplifiers, is 48 kg and its height is about 120cm. The KHR-1 has 21 DOF. Each leg has 6 DOF and it can imitate human walking motion in the sagittal and the frontal plane.”	“A goal of our research is to realize a complete on-line motion control of the biped walking robot based on a sensory feedback control.” “Mobility is very important in the sense that future service robot should help and cooperate with humans in all environments.”

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Table A.1 – continued from previous page

Index	**Information**	**Morphology**	**User Interaction (UI) Methods**	**Motivation**
13: 2005	*Quasi* (Interbots n.d.)	This figure has been removed due to copyright restrictions	"Quasi is a child-sized humanoid robot that incorporates cameras, speakers, LCD monitors, and an RFID reader, and hobby servo motors that are mounted beneath the robot. It responds to user input from face-to-face interaction."	"Our primary goal at Interbots is to create compelling interactive characters who enable memorable experiences with their guests. We see robotics as a path for (…) an evolution of imagination and human expression."
14: 2006	*Maggie* (Salichs et al. 2006)	This figure has been removed due to copyright restrictions	"Maggie has an artistic design of a 1.35 meters tall girl-like doll. [The] base is motorized…equipped with 12 infrared optical sensors and 12 ultrasound sensors …The upper part of the robot incorporates the interaction modalities. On top of the platform, an anthropomorphic robot head with an attractive, well-groomed appearance has been added."	"To develop a social robot, many considerations need to be taken in to account. The required key features can be summarised in the following points: Multimodality, Personality, Additivity, Autonomy, Learning ability, Cooperativeness, Reactivity, Proactiveness, Attractiveness, Expressiveness, Mobility"
15: 2007	*Keepon* (Kozima et al. 2008)	This figure has been removed due to copyright restrictions	"We decided to use the robot's bodily movement to express emotions such as pleasure (by rocking…from side to side) excitement (by bobbing up and down) and fear (by vibrating). In the final design we made a neck/waist line …This line provides a clear distinction between the head and the belly, giving slightly anthropomorphic …impression to children."	"Keepon is a small creature-like robot designed for simple, natural, nonverbal interaction with children."

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Table A.1 – continued from previous page

Index	Information	Morphology	User Interaction (UI) Methods	Motivation
16: 2008	*Geminoid* (Sakamoto and Ishiguro 2009)	This figure has been removed due to copyright restrictions	"Its face has 13 DOF, which gives it natural facial expressions." "When we prepared its motions to be natural, we tried to make them as similar as possible to the original man's motions." "Geminoid HI-1 has 50 actuators."	"The human-like physical properties of such robots will be used for natural human-robot interaction. We believe it is desirable for a robot that communicates and interacts with human to have a human-like appearance. That is to say, in the case of a person who is injured …he/she will want the care of a human or human-like robot. No one wants to receive the care of an industrial robot like a product being repaired in a factory."
17: 2009	*Shimon* (Weinberg et al. 2009)	This figure has been removed due to copyright restrictions	"The robot combines music perception, interaction, and improvisation with the capacity to produce melodic and harmonic acoustic responses through choreographic gestures. We developed an anticipatory action framework, and a gesture-based behavior system, allowing the robot to play improvised Jazz with humans in synchrony, fluently, and without delay. In addition, we built an expressive non-humanoid head for musical social communication."	"Shimon is an autonomous marimba-playing robot designed to create interactions with human players that lead to novel musical outcomes."

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Index	Information	Morphology	User Interaction (UI) Methods	Motivation
18: 2010	*BINA48* (Lifenaut n.d.)	This figure has been removed due to copyright restrictions	“BINA48 was created using video interview transcripts, laser scanning life mask technology, face recognition, artificial intelligence and voice recognition technologies.”	“Bina48 is designed to be a social robot that can interact based on information, memories, values, and beliefs collected about an actual person.”
19: 2011	*Simon* (Diana and Thomaz 2011a)	This figure has been removed due to copyright restrictions	“Simon is an upper-torso humanoid-like robot platform under development in the Socially Intelligent Machines Lab at Georgia Tech.”	“The research goals around this robot are the study of socially guided robot learning, and human-robot interaction (HRI). Its primary purpose is to interact with humans in a way that is intuitive and natural.” “The scenario of interest for the Simon platform is service robotics–robots intended to work alongside human users to assist them in a wide array of generalized physical and cognitive tasks.”

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Index	Information	Morphology	User Interaction (UI) Methods	Motivation
20: 2012	*SnackBot* (Lee et al. 2009)	This figure has been removed due to copyright restrictions	"The Snackbot robot is a four-and-a-half-foot tall, semi-autonomous semi-humanoid robot." "To interact with the Snackbot, people eventually will engage in natural dialogue with the dialogue system. Visual feedback will occur through an LED mouth, which will indicate when the robot is "talking." Sound will be used as an additional informational cue."	"Snackbot, a robot that will deliver snacks in our university buildings. The robot is intended to provide a useful, continuing service and to serve as a research platform for long-term Human-Robot Interaction." "A major goal is to create mobile robots that interact with people over a period of time, performing a service." "The third goal was to develop interaction designs that would help to evoke social behavior."
21: 2013	*Robot Bartender* (Foster et al. 2013)	This figure has been removed due to copyright restrictions	"The hardware for the robot bartender consists of two manipulator arms with grippers, mounted to resemble human arms. Sitting on the main robot torso is an animatronic talking head capable of producing facial expressions, rigid head motion, and lip-synchronised synthesised speech."	"A robot agent existing in the physical world must be able to understand the social states, the intentions, desires and affective states of the human users it interacts with in order to respond appropriately."
22: 2014	*Paro* (PARO Robots U.S. 2014)	This figure has been removed due to copyright restrictions	"Paro has five kinds of sensors: tactile, light, audition, temperature, and posture sensors, with which it can perceive people and its environment. Paro is handed to a patient by a carer and can be stroked, petted and spoken to. Paro responds to its name and can learn and adapt its behaviour."	"Reduce patient stress, stimulates interaction between patients and caregivers, improving their relaxation and motivation, improves the socialization."

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Table A.1 – continued from previous page

Index	Information	Morphology	User Interaction (UI) Methods	Motivation
23: 2015	*Pepper* (SoftBank Robotics n.d.)	This figure has been removed due to copyright restrictions	"20 degrees of freedom for natural and expressive movements. Touch sensors, LEDs and microphones for multimodal interactions. Perception modules to recognize and interact with the person talking to him. Infrared sensors, bumpers, an inertial unit, 2D and 3D cameras, and sonars for omnidirectional and autonomous navigation."	"Pepper is the world's first social humanoid robot able to recognize faces and basic human emotions. Pepper was optimized for human interaction and is able to engage with people through conversation and his touch screen. His curvy design ensures danger-free use and a high level of acceptance by users."
24: 2016	*Kip1* (Zuckerman and Hoffman 2015)	This figure has been removed due to copyright restrictions	"Empathy Objects respond to human behavior using physical gestures as nonverbal expressions of their 'emotional states'." "Kip1 tracks the conversation state, and maintains an internal emotional model of its reaction to the conversation. This internal state is then reflected using physical gestures."	"The goal is to increase people's self-awareness to the emotional state of others, leading to behavior change." "When people interact, they are often unaware …of the effect their behavior has on others. To address this issue, we propose the notion of Empathy Objects: Interactive robotic devices that reflect aspects of the human-human interaction around them, in real-time, through subtle physical gestures."
25: 2017	*Kuri* (Gadget Flow 2018)	This figure has been removed due to copyright restrictions	"Using her 1080p HD camera, Kuri detects faces to record quick, 5-second videos of your day so you never miss a moment again. Plus, Kuri effortlessly moves around your home using mapping sensors and a quiet drivetrain."	"The vision that began Mayfield Robotics was to make robots that are joyful, useful, and inspiring" "Complete with a delightful personality, Kuri brings a unique spark of life to your home." *Kuri has since ceased manufacture and pre-orders will no longer be shipped to customers.

Appendix B

Exhibition Documentation

Exhibiting the artefacts produced as part of the present thesis in a group exhibition provided opportunities for contextualising the work among my contemporaries, peer review through discussion, and professional contribution to the visual art community. In addition to the publication of my research in the social robotics literature, this exhibition and the accompanying catalogue comprised a multidisciplinary output from the present research.

The contributing artists and designers included academics from the University of New South Wales who utilise their art practice for research in other disciplines, including Industrial Design and Textiles, and three designers from Japan. In a similar nature to the present research, these artists and designers develop research in the nexus of emerging technology and analogue fabrication techniques. The exhibition of my work alongside that of these practitioners provided context and commentary on this approach. Additionally, the exhibition provided opportunities for reflection on my practice in conversation with the viewers of the exhibition, and this contributed to my reflections on the present methodological process.

The work I presented in this exhibition included a triptych of diagrammatic drawings in the manner of those presented in section 5.4 and some soft-robot sculptures that were generated concurrently with this research and are discussed in section 6.2 as a path for future research.

B.1 Exhibition Details

FEMUFACTURE. Tricia Flanagan (curator). The Japan Foundation, Sydney, 2019.
See https://jpf.org.au/events/femufacture/

E-catalogue available: https://jpf.org.au/jpf/jpfmedia/Femufacture-e-catalogue-2019.pdf

B.2 Curator's Text

The following paragraph is an abstract from the exhibition proposal composed in conjunction with the contributing artists:

> This exhibition will bring together Australian and Japanese artists who work in the hybrid space between traditional crafting techniques and contemporary digital fabrication technologies. The works exhibit a blend of digital and analogue making techniques, with attention given to the hand of the maker and the mark of the digital. The cross-cultural blend of artists and designers brings critical interdisciplinary and intercultural perspectives on the future of manufacturing and crafting and the role of digital manufacture in contemporary art, fashion, design and architecture. This exhibition explores new modes of making evolving from deep-seeded traditional and culturally-embedded technical skills across different media, paper cut, weaving, wearables, indigo dying, silver-smithing, mashed together with techno crafting and electronics, generative coding, rapid prototyping technologies, 3-D printing, CNC machining and robotics. In this way visitors experience the future of design, defining new possibilities understandings and expectations.

Room-Sheet Text

Still, Life (2019) and *Future Forms* (2019) are two variant media approaches to the artist's work in critically rethinking the morphologies of robotic agents that may soon share social spaces with us. By returning to analogue pneumatics and gestural diagramming of movement, the artist reaches for something abstractly emotive and affective to position these agents as complimentary to human life, rather than competitive.

Wall Text

Future Forms (2019) Ink and lead on card

Still, Life (2019) Silicone Eco-Flex rubber compound, fabric, rubber adhesive Formed from laser-cut Perspex moulds

B.2.1 Images

The images included in this section show photographs taken at the FEMUFACTURE exhibition on the opening night, 8 February 2019. Figures B.1 to B.3 are photographs of the *Future Forms* (2019) triptych, and figures B.4 to B.6 are photographs of the soft robot sculptures titled *Still, Life* (2019). All photographs are by Scott Brown.

Figure B.1 – Exhibition *Future Forms*.

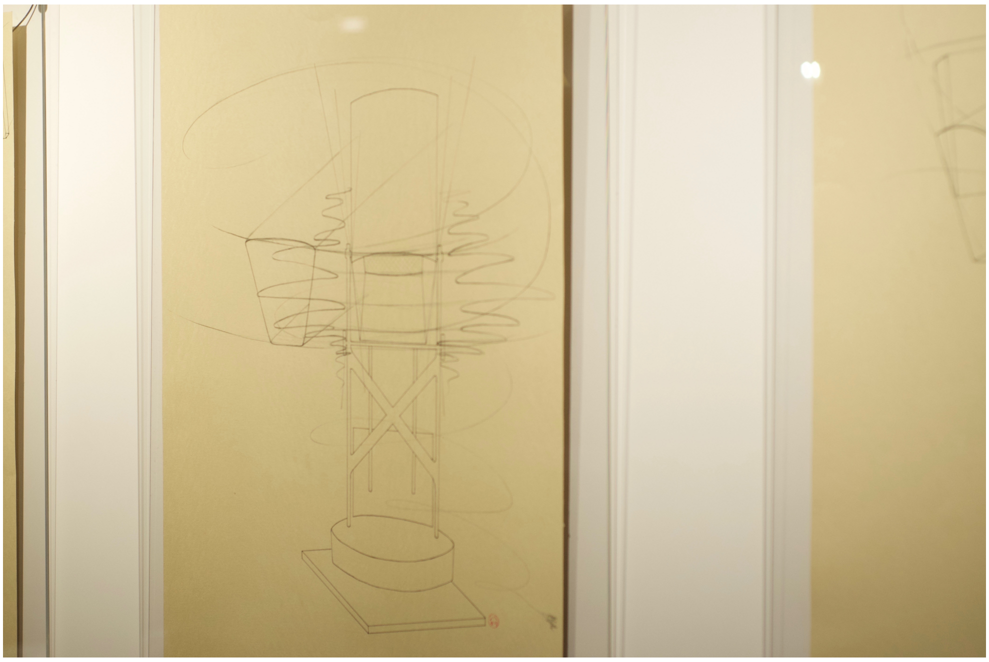

Figure B.2 – Exhibition *Future Forms* detail.

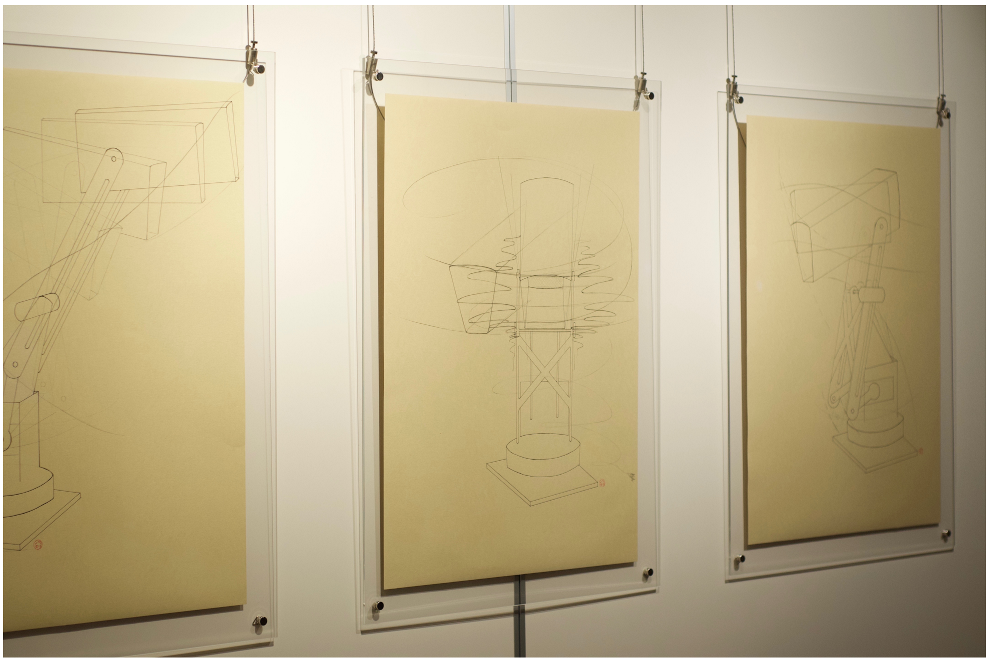

Figure B.3 – Exhibition *Future Forms*.

Figure B.4 – Exhibition *Still, Life*.

Figure B.5 – Exhibition *Still, Life* detail.

Figure B.6 – Exhibition *Still, Life* detail.