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Issue 28 Introduction

FCJ-203 Creative Robotics: Rethinking Human Machine Configurations

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'I like your dress. You must be a fashionista.' 'Really? Thanks', I reply, looking into the enormous, cartoony eyes of a child-sized robot with soft, explicitly feminine contours and a perky, human voice. This isn't a subject of conversation I expected at a male-dominated robotics conference, and initiated by a robot of all things. 'I also like your shoes', the robot "girl" continues. 'I can't wear shoes because I don't have feet.' Pepper, as the robot is called, looks down, dramatically swinging both arms to point me to "her" lack of feet. Then, the robot girl gently tilts its head and starts talking about animals. I begin to wonder if it can actually understand any of my compliant replies and seek the attention of a nearby engineer, huddling behind a computer screen. I learn that Pepper currently only understands Japanese. Hah.

My first fake dialogue with Pepper, theatrically supplemented with soft shiny curves, head-tilting, gesticulating and an innocent, flirtatious cheekiness, left me with a bitter taste. It only took some unexpected, serendipitous attention, disguising of a random recording or, more likely, a hidden engineer's lucky choice, for me to readily suspend my disbelief and to think that Pepper *chose* to converse with me about fashion, in English. This is the more disturbing as I usually consider myself sceptical of, if not offended by, marketing campaigns that promise us a soon-to-arrive future with companions, maids, and carers – smart, friendly, gendered, and mechanical. Marketed as an "emotional" robot, 'Pepper the robot wants to be your friend. It can listen to you, can tell when you're feeling down, dance, and follow you around – all on its own' (Del Prado, 2015). How impressive must this mechanical charade be for a completely unsuspecting customer, trained by countless movies and, increasingly, news stories, to suspend their disbelief and embrace robotic friends?

While today's robotic "friends" are not nearly as smart or friendly as they are in the movies, both research and marketing strategies tap into the very same pool of desires and emotions to make robots likable. To make robots apparently social. The most common strategies for "socialising" robots follow a simple recipe: human or human-like appearance, human etiquette, (a hint of) gender, and human stereotypes. Pepper excels in all of these, which explains why it is so popular (so far only sold in Japan, any batch sells out in minutes (Del Prado, 2015)). But let's not forget that, in addition to their design and programming, robots thrive in a well-established social ecology of human-machine configurations. The current figure of the "social robot", particularly its commercial manifestations, is deliberately located in a conservative, rose-tinted, Disney-like version of this ecology, where robots are the friends or servants of a privileged few, and gender roles and divisions of labour are not only unquestioned but reaffirmed.

The Creative Robotics issue wants to wrestle with the figure of the robot as a historically and culturally constructed sociomaterial assemblage and with how it enacts a number of political, social and aesthetic questions. Aligning itself with the emerging practice of Creative Robotics, the issue deliberately positions itself at the uneasy nexus from which these assemblages emerge, while subscribing to a fundamentally experimental, embodied and performative approach. Creative Robotics is a transdisciplinary practice that builds on the history of robotic and cybernetic art to explore human–robot configurations from a critical, socio-cultural perspective. It brings together concepts and methods from experimental arts and engineering, performance and the social sciences, and it often materially experiments with what Lucy Suchman has succinctly described as 'material-discursive practices through which boundaries and associated entities are made' (2011: 121). Rather than being concerned with the constrained context of currently envisioned human-machine configurations, the issue aims to unhinge, open up and expand these visions by exploring 'a more differentiated set of starting points for the robot' (Castañeda and Suchman, 2014: 340).

Probing and re-imagining our human-machine configurations is a very timely, if not urgent, matter. The United States, Europe and Asia are investing heavily in the area of Social Robotics; by 2013 Google alone has acquired eight leading robotics companies (Markoff, 2013), and a study by the Japanese *Ministry of Economy, Trade and Industry* forecasted that service and personal robots, directly interacting with humans, will account for 50 per cent of all robot sales by 2035 (Lechevalier et al., 2014). Needless to say, there's a lot at stake as we herald the integration of robots into our society and everyday lives, particularly as vulnerable groups such as patients, children, and the elderly are at the forefront of social experiments with robotic assistants or companions. Robots that mimic humans or pets, often in cute, caricatured ways, deliberately blur the difference between organic and mechanical bodies, as well as human and machine cognition, to elicit human investment based on superficial, and often fake, social cues. Suchman has argued that 'the figure of the humanoid robot sits provocatively on the boundary of subjects and objects, threatening its breakdown at the same time that it reiterates its founding identities and differences' (2011: 133). As if we were looking for a robotic counterpart, we seem to prefer to look into a mirror: a mirror that reflects a human- or pet-likeness, but which is predictable, programmable and replaceable.

Considered as an electro-mechanical artefact from an engineering point of view, the robot has to be implanted with the "social", like an alien, material Other, embellished with etiquette. But isn't a robot always already a social phenomenon, even before it is designed to appear social, or programmed to behave as if it were social? Inseparably entangled with, and dependent on, human labour and care (see Suchman, 2011) and, to no small degree, human affect, the robot certainly spawns from complex sociomaterial practices. Culture, and its countless, sometimes age-old, fictions, are also significant constituents in the manufacture of the robot. Indeed, for Chris Csikszentmihalyi, robotics in the twenty-first century is 'part of a dense stew of research, design, pop culture, commodity production, and fetishism' (2006: 125). Furthermore, the "social robot" is, to use Donna Haraway's term, a 'boundary project ... a site of production' (1991: 201). It's not only the product of a history of practices, but actively recodes the meaning of "social".

Feminist perspectives, such as Suchman’s critical research in STS (2009) and Karen Barad’s concept of 'agential realism' (2003), allow us to refigure the robot, or, more precisely, to re*con*figure the figure of the robot. Here, the robot is no longer seen as a separate agent but is reconceptualised as an embodiment of particular practices, enacted within a particular human–machine configuration (which itself is always entangled in a much wider network of sociomaterial relations). This reconfiguration not only changes our viewpoint but, importantly, shifts the ground upon which many dominant assumptions in robotics and human–robot interaction are built. Looked at through a feminist lens, we can thus begin to unhinge these assumptions, together with their Cartesian-haunted politics. An experimental art practice informed by this diffractive lens, then, provides a productive and affective, material-discursive platform upon which to develop and materially "play out" a Posthumanist perspective that shifts our focus from representation to performativity. My own Creative Robotics practice challenges our humanist assumptions and anthropomorphic desires by engaging audiences in provocative encounters with strange, nonhuman machinic performers or human–nonhuman ecologies. As an artist, I also have firsthand experience with every audience member bringing with them their own vivid expectations of what a robot is, concocted from Csikszentmihalyi’s 'dense stew'. Looking at human–machine configurations as complex sociomaterial assemblages allows us to understand not only the robot’s agency as enacted in the dynamic in-between (see Barad, 2003), but also its social dimension. That is, more than embodying our history of practices 'as specific material configurations' (Barad, 2003: 814), robots also become specific social entities as we negotiate these material configurations. In my own creative research practice, notions of embodiment and movement (and their connection-making, worlding potential) become core constituents in these negotiations – similarly to an unfolding seam, along which negotiations can take place and affect is produced. Importantly, I believe that this "becoming of agency" promises to be the more transformative the more we embrace the differences (relative to humans) of machinic embodiment, movement and, consequently, cognition. Rather than investing in robots to make them more human, we need to investigate the ecology of relations by which a robot becomes an affective assemblage. That is, we need to investigate how sociomaterial relations and dynamics are produced and activated and, furthermore, how alternative, posthumanist notions of intelligence are spawned from these (always material) interdependencies.

The articles gathered in this issue inquire into a wide range of robotic material practices, from "too-feminised" gynoids to maverick machines to Martian machinic life. It could be argued that each article develops its own boundary project or boundary-making practice to rethink human–machine configurations. In Suchman’s words, '[d]oing this work requires slowing down the rhetorics of humanlike machines, and attending closely to material practices' (2011: 134). As editors, we were thus most interested in material practices of creative, critical investigation, and in critical, creative investigations of material practices that struggle with or trouble our visions of human–machine configurations. Some of the papers in this issue are situated directly within or closely aligned with a Creative Robotics practice, while others complicate or expand existing robotics practices.

Elena Knox’s 'Degrees of Freedom' unreservedly confronts the 'rhetorics of humanlike machines' (Suchman, 2011: 134). In her performances, installations and screen works, Knox materialises a playful, feminist critique of "very humanlike" gynoid robots that 'trouble the gendered aesthetics predominant in this realm of engineering design'. Despite currently still being entirely controlled by humans, these android robots embody the vision of perfect(able) mechanical human mirrors. While much of the press coverage focuses on their humanlike appearance, Knox's article scratches beneath the surface to provoke crossdisciplinary interrogation and uncover the gendered stereotypes that these "too-feminised" gynoids seek to promote. Her video work *Radical Hospitality* performs the liminal act of hospitality as it precariously balances between welcoming and servanthood. Her work thus confronts us with 'the societal naturalisation of women behaving awkwardly' and, moreover, with this phenomenon's supposedly advanced technological manifestations. Here, "very humanlike" robots, Knox tells us, become 'the technologised and subcontracted gesture of conditional hospitality, a fearless front for the fearful wiles and mechanisms of global capitalism and authoritarianism'.

Katarina Damjanov's 'Life and Labour of Rovers on Mars: Toward Post-Terrestrial Futures of Creative Robotics' takes us into an extra-terrestrial milieu for human–robot assemblages, and follows four Earth-born, human-made robotic rovers roaming on Mars. Exploring 'new forms of Martian intimacies bred between the nodal, living, human–technological network of robotic agency and its new … planetary milieu', the article both uncovers and reassigns the (often hidden) labour propelling these assemblages. Though it is created and continuously sustained through human labour, on Mars, Damjanov argues, 'a rover both performs and transforms life itself, absorbing the biopolitical capacities of labour'. As human–nonhuman assemblages are extended beyond our own planetary realm, so are their biopolitics, embodied in what Damjanov terms 'cosmobiopower'. Her troubling of this interplanetary configuration also confronts us with the question of "life as it could be": to operate in this inhuman environment, the rovers' bodies, and their sensory and cognitive performances and situated interactions, are 'essentially Martian', thus shifting our 'ontological thinking about the nature of robotic ways of being'.

Maaike Bleeker's 'From Braitenberg's Vehicles to Jansen's Beach Animals: Towards an Ecological Approach to the Design of Non-Organic Intelligence' continues to explore conceptions of life, and in particular notions of intelligence from a post-anthropocentric perspective. Comparing Valentino Braitenberg's thought experiment in Synthetic Psychology (*Vehicles*, 1984) with Theo Jansen's *Strandbeesten* (in English, beach animals), Bleeker puts forward an ecological approach to non-organic intelligence as it emerges from the beach animals' response to their environment. Bleeker argues that the apparently intelligent behaviour of Braitenberg's vehicles is driven by a human conception of intelligence, whereas the beach animals' complex behaviours, resulting from 'a great number of individual causal interactions between elements of the animal, the sand, the wind, the water and so on', embody an alternative, non-organic perspective. This argument affirms the need for rethinking machinic agency and intelligence as emergent phenomena (rather than fixed, importable properties) that are intimately tied to questions of embodiment, movement and environmental relations. Her ecological, material perspective also opens up the possibility of conceiving of human–robot interaction as configurations for actualising 'still unrealised potentialities' in-between.

As we face increased automation and machine autonomy, human–machine assemblages become increasingly troubled by questions of accountability and responsibility. Michaela Davies' article 'Game On: A Creative Enquiry into Agency and the Nature of Cognition in Distributed Systems' extends the trope of machine agency to the issue of assigning responsibility, by exploring human–nonhuman systems that disrupt or extend our embodied experience and sense of agency. Davies' artwork *Game On* makes this question bodily felt by linking two human players via an electronic network, which turns signals into sensations. This work not only raises but materially enacts interesting questions about locating responsibility, as our decisions and actions are connected with and depend on increasingly autonomous machines. Davies argues that we 'cannot simply attribute responsibility on the basis of a particular agent's intentions', but rather need to understand the 'causal field' in which actions occur and are distributed. Looking at robots as intelligent, social agents, questions of control and intention are complicated even further, as will the causal field be, as it is enacted by human–robot configurations *at work*.

Paul Granjon's 'This Machine Could Bite: On the Role of Non-Benign Art Robots' unsettles current visions of the "social robot" and suggests that artists, whose output is relatively free from economic market pressures, can create more courageous scenarios of "socialising" with a robot: interacting with machines that bite, for example. In his performance practice, Granjon develops playfully provocative scenarios for open-ended relationships with whimsical, sometimes surrealist, and other times dangerous machinic performers to unfold within. His article looks at common approaches to social robotics and argues that anthropomorphic design and the roles of servant/pet/companion 'sum up the current status quo', wherein the 'machines have to comply to rules of safety, friendliness and legibility in order to facilitate interaction with the humans'. In contrast, maverick machines (see Pask, 1982), created by artists, manifest genuine "machinic life" to 'inject noise into this perfect landscape' and, according to Granjon, allow us to encounter and study the novel conditions they bring about, and thus 'produce awareness, resistance and knowledge'.

Angie Abdilla and Robert Fitch's 'Indigenous Knowledge Systems and Pattern Thinking' develops a dialogue between an Indigenous consultant in innovation, technology and culture, and a non-Indigenous roboticist, to investigate how 'Indigenous Pattern Thinking can lead to more effective [robotic] design that considers the entire system lifecycle along with diverse environmental impacts'. In the authors' First Indigenous Robotics Prototype Workshop, Australian Indigenous students were asked to adopt the robot's point of view to engage with its perceptual challenges. Indigenous mapping contextualised the programming exercises; for instance, social boundary-acknowledging protocols and 'the ceremonies central to Songlines' continuation through country and across territories were related to the protocols of code'. The synergies between Indigenous knowledge and technological advancement developed in this article show us how the making and recognising of boundaries can directly shape how we program robots. Moreover, the article suggests that notions of custodianship and a strong sense of the interconnectedness of human and nonhumans could render our human–machine configurations more complex and sustainable.

Lian Loke's article 'Falling Robots' employs strategies from dance and choreography to develop her proposition that falling as 'an aesthetic, creative act' can extend a robot's expressive behavioural repertoire. The article closely engages with current engineering approaches to humanoid robotics to link robotic design objectives with dancers' creative strategies for controlling a fall. In humanoid robotics, 'seemingly simple, everyday acts of standing and walking appear as complex, hard to solve problems' and falling poses a risk. This starkly contrasts 'Lepecki's (2006) thinking of dance as a challenge to verticality'. Drawing on her study with dancers, who interacted with a chair as part of stunt falling, Loke considers 'reflexes as producing expressive performance'. Similarly to Abdilla and Fitch's dialogue between Indigenous culture and robotics engineering, Loke's article draws on her background in both engineering and dance, allowing her to situate her investigation within humanoid robotics practices and the challenges they face, while opening them up to creative kinesthetic approaches from the field of performance. At this productive nexus, the problem of stability and safety becomes a matter of creative expression and social meaning.

Keith Armstrong's extended artist statement 'Embodying a Future for the Future: Creative Robotics and

Ecosophical Praxis' explores how Armstrong's "ecosophical" practice in creative robotics can promote 'radically different frames of intention' from 'robotics as an industrially driven endeavor'. As in Granjon's investigation, Armstrong also explores notions of machinic life and an artwork's capacity to critically engage audiences, however his motivation and approach are quite different to Granjon's. Armstrong's ecosophy seeks to 'redirect [our] attention toward urgent questions of the Anthropocene' by creating 'conversational experiences', which address and illuminate this complex issue. Developing his creative robotics practice, Armstrong explores what kind of conversations between artworks and audiences 'become conceivable and possible, when robotic actors [are] coupled with diverse media actors, materials and ecological thematics'. Similarly to the other artistic investigations we encounter in this issue, Armstrong's works offer a 'privileged view into the "life" of non-human entities whose experience remains outside of our knowing'. Doing so, they may also intimate the complex ecologies, minglings and reciprocal relations in which they are embedded.

Each of the articles in this *Fibreculture Creative Robotics* issue intervenes into the limited, binary figurations that dominate contemporary social robotics practices, whether manifested in robots masquerading as humanoid companions or in advanced mechanical replications of notions of servitude. They probe into, unhinge and transform the figure of the robot to explore complex human–nonhuman assemblages, to expose hidden sociomaterial practices or propose radical new ones, and to offer glimpses of nonorganic, intelligent "life" as it could be, once it is no longer arrested by our humanist views and assumptions.

Biographical Note

Petra Gemeinboeck (NIEA Creative Robotics Lab, University of New South Wales, Sydney) currently works across the fields of creative robotics, performance and feminist theory. Her experimental robotic art practice explores our entanglements with machines and seeks to make tangible vulnerabilities and politics involved. In her recent publications, Petra engaged with dance and machine learning, nonhuman agency, and machine creativity. Previously, she developed interactive installations and virtual environments and published widely on issues of embodiment and interactivity. Her works have been exhibited internationally, including at the Ars Electronica Festival, International Triennial of New Media Art at NAMOC, Beijing, Centre des Arts Enghien at Paris, Foundation for Art and Creative Technology (FACT), Liverpool, Gallery of Modern Art, Brisbane, ICC Tokyo, and MCA Chicago.

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FCJ-204 Degrees of Freedom

Elena Knox, Waseda University.

Abstract: This paper critiques a choreographed performance of embodied agency by a 'very humanlike' (Ishiguro, 2006) gynoid robot. It draws on my experience in 2013 with Actroid-F (or Geminoid-F), designed by ATR Hiroshi Ishiguro Laboratories, when I created six artworks making up Actroid Series I. My analysis here proceeds from and through the part-programmed, part-puppeteered actions and vocalisations of Actroid-F for my six-minute video Radical Hospitality, in which the robotic gynoid actor performs compound negotiations of embodied authority, docility, and compliance. Design of 'very humanlike' androids risks instilling into robotic agents existing and discriminatory societal standards. My performance, installation and screen works trouble the gendered aesthetics predominant in this realm of engineering design.

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This paper critiques a choreographed performance of embodied agency by a 'very humanlike' (Ishiguro, 2006) gynoid robot. It draws on my experience at the Creative Robotics Lab, UNSW Australia, in 2013, with Actroid-F (or Geminoid-F), designed by ATR Hiroshi Ishiguro Laboratories [1], when I created six artworks making up *Actroid Series I* (2015). My analysis here proceeds from and through the part-programmed, part-puppeteered actions and vocalisations of Actroid-F in my six-minute video *Radical Hospitality*, in which the robotic gynoid actor performs compound negotiations of embodied authority, docility, and compliance. All six artworks in the series seek to induce moments of feminist hyper-awareness, or cognitive lysis (Randolph, 2001), that work against the normalisation of instilling gendered societal restrictions into humanoid robots via their embodiments and functionalities. I contend that the forthcoming devolution to 'very humanlike' androids of work in the domain of hospitality will draw upon, shape and reinforce the overrepresentation in this area both of women and of "feminine" robots, and that representation of aesthetics and behaviours commonly associated with "femininity" has a large part to play in this process. In my performance, installation and screen works I try to disturb the intransigence, or the non-negotiability, of these aesthetics and behaviours.

Radical Hospitality is a video of a performance by Geminoid-F that is scripted in every sense of the word. I wrote phrases for the robot to say, edited the control scripts for its speech and movement, and operated the computer interface that triggers and controls its physical expression, following my minimalist screenplay. My small video crew witnessed this performance "in person", and the artwork could in fact be presented as a live installation comprising the robot and an operator (see Fig. 1); or, with technical augmentation, it could be presented in telepresence or virtual reality. In the first gallery installation of *Radical Hospitality*, the video was projected onto a large wall directly inside the gallery entrance, its sound filling the space, and the larger-than-life image of Geminoid-F refused and granted entry to visitors (Fig. 4). In all modes of encounter, the work exploits the degrees of remove that characterise this humanoid, robotic telepresence technology: the poignantly performative lags and gaps between operations of various elements of its assemblage (computer equipment, cameras, and human and prosthetic bodies). These lags and gaps function, in the artwork, to signify that gender, and particularly femininity, are chronically mediated in modern-day culture (Meyers, 1999), and that its timeworn stereotypes are currently being reproduced into ostensibly progressive, high-tech machines.

Robo-sexism

Based on an ethnographic engagement comprising research and fieldwork with various humanoid robots and their designers and makers, Jennifer Robertson makes the observation that 'most roboticists reinforce in and through their humanoids, by default arising from indifference, quite unprogressive notions of gender dynamics and the sexual division of labour' (2010: 28). Towards the end of her article 'Gendering Humanoid Robots', as a way of illustrating this gendered division, Robertson introduces the interesting metaphor of 'degrees of freedom' in robot-building. Degrees of freedom are machines' corporeal capabilities of motion along particular independent planes, such as are represented by the slider controls on Actroid-F's computer interface (Fig. 1). In a humanoid robot, a degree might be the simple capacity of a limb to move left–right, or a head (or an eyebrow) to move up–down. According to Robertson's direct observation of certain humanoids (here Geminoid HI-1 and Actroid HRP-4C), 'if a robot's degrees of freedom are extrapolated allegorically, the implication ... is that *individuality*, gendered male, as opposed to *typicality*, gendered female, is equipped with more (degrees of) "freedom"' (29; original emphasis). *Radical Hospitality* performs this typicality, focusing on one binary degree of bodily freedom (Actroid-F's right arm), to amplify this and many other robots' sociological dependence, despite their vanguard status, on ingrained cultural norms.

In the interest of a contextualised discussion of individuality versus typicality, it's worth first taking an approximate roll-call of "geminoids" to date. Geminoid is a neologism for an android copy (surface aesthetics and basic sensing only) of a specific human. This collective of semi-autonomous androids is being manufactured cooperatively between Osaka and Tokyo [2],purportedly for studying the presence (*sonzai-kan*) and personalities of human beings (Guizzo, 2010; Ishiguro, 2014). Thus, states the project's founder Hiroshi Ishiguro (2014: 138), geminoids 'extend the applicable field of android science'. Geminoids are also sometimes called actroids, and there is some slippage between the two terms as employed by both producers and commentators. The term "geminoid" connotes twinning; however, Erica, a robot that will be discussed later in this paper, is nobody's twin but is still a geminoid. The term "actroid" is a broader term and is more often used in relation to the female-appearing 'very humanlike' androids; that said, there have been, overall, more "females" than "males" developed so far, and these "females" are the only geminoids expressly regarded as actresses for the purpose of entertaining humans.

Despite the so-called uncanny valley (Mori, 2012 [1970]), actroids are designed to appear and behave as humanlike as possible so as to render them as familiar as possible, presaging a future of belonging, of ethically viable sociocultural identity (Hasegawa and Collins, 2010; Ishiguro and Nishio, 2007: 141; Nishio et al., 2012). Designers of these robots state that actroids performance in the expressive arts (theatre, music and film, where their bodies are on display and in most cases *are* the display) will help androids in general become assimilated into the wider society (Carroll, 2011; Cuthbertson, 2015; Guizzo, 2010). The designers expressly intend that the units be used for entertaining and host(ess)ing duties, including providing soothing, pandering presences in homes and hospitals (ATR and Kokoro, 2010; Carroll, 2011; Robertson, 2010: 15). It is claimed that their incidence in these obliging roles will familiarise and content the public with interaction with robots that closely resemble humans (Ogawa, Taura and Ishiguro, 2012). So, aside from the units' current limited functionality, their performed subservience is strategic and designed to diffuse anxiety about robots "taking over". Gendering the robots helps achieve this objective. The actroids' familiarity is achieved via reinscription of stereotypically gendered cultural narratives and attributes (Robertson, 2010), consistent with a propensity in some engineers of other types of robots to give "non-useful" robots "feminine" morphologies (Robertson, 2010: 18-21).

To date, approximately 20 geminoids have been developed and publicised, all modelled after young females, with the exception of (intendedly) exact copies of two male professors from Japan and Denmark, one female professor, roughly middle-aged, from China, and a seldom-glimpsed "brother" to Actroid-F. The individuality of the professors' robotic doppelgangers is foregrounded; they are each meant to provoke double-takes as the exact likeness of their model. The reasons given for the exactitude of one’s professorial geminoid range from flippant: it can spend "quality" time with wives (Ishiguro, 2012) and mothers (Carroll, 2011) – to pragmatic: it can free up research time by travelling and delivering lectures (Cuthbertson, 2015; Ishiguro, 2012) – to earnest, if self-important: it can act as a security measure or body double for sensitive public appearances (Burrows, 2011). In short, they are highly individualised simulacra of (their) highly individualised masters. Ishiguro’s copy has been through about four upgrades, making it more Ishiguro-like each time. Professor Henrik Schärfe takes his geminoid on the road, garnering much personal publicity including TED talks and a citation on the 2012 *Times* 'Influential People' list. But the female professor’s copy, YangYang, based on Professor Song Yang, is not functional and has not been since its press launch in April 2015. According to Mr Han, vice president of Shanghai Shengqing Industries, with whom I conversed with the help of a translator on a research visit to China in February 2016, the YangYang robot has been disassembled into parts, some of which are in China and some of which are in Japan. Its degree of freedom is thus constrained, and one could argue, in fact, that presently it has no degrees of freedom. The abovementioned "brother" to Actroid-F, named Kurokawa, is at the opposite end of the individuality scale: it is a clone of its "female" counterpart, with the same face, but a shorter wig, different clothes (businesswear and a blue tie) and reshaped foam padding (see Knox, 2015: 19-20). It has made few, if any, further public appearances since its launch in 2011 on the site DigInfo (this is still the only YouTube video available), and as far as I can ascertain is not discussed in any published English-language research papers. It has possibly participated in a hospital patient companionship trial in 2010/2011 (though this may have been a solo Actroid-F).

By contrast, 14 young-female-appearing actroids have publically debuted since 2003. Some of these are modelled on actual living women, but when the robots are viewed as a group it appears that it is more important to their designers that they evoke an image of ideal beauty and amicability – that is, of typicality. A robot built very recently by Ishiguro’s lab, Erica, has 19 degrees of freedom and 'is a more advanced version of Geminoid F' (McCurry, 2015). The ATR Laboratories website states: 'Its appearance is designed for [a] beautiful and neutral female face, by which people can familiarly interact with it' (ATR, 2016).

> The principle of beauty is captured in the average face, so I used images of 30 beautiful women, mixed up their features and used the average for each to design the nose, eyes, and so on … That means she should appeal to everyone. (Ishiguro in McCurry, 2015)

Saya, a gynoid robot by another designer, Hiroshi Kobayashi, has worked as a receptionist at Tokyo University of Science and Ben-Gurion University of the Negev in Israel. Other labs in Korea and China are building female-realistic humanoids in a similar vein. I have written elsewhere (Knox, 2015; 2016) about the profusion of hostess-types among the ranks of 'very humanlike' androids, and in this paper I will focus on the manifestation of the phenomenon in Geminoid-F in a recital by this robot of what I might term generic hospitality.

A brief note: the number of geminoids cited above is approximate because, as lab-grown innovations, all these androids appear and disappear in the public eye, in the designers' publications and websites, and in reality. The names are part name, part model number. Colleagues in Tokyo have explained to me that when the engineers improve a function or aesthetic - for example, actuators being redistributed to areas of prime experimental focus (currently the face) - the android is often renamed: for instance Repliee Q2 was shown as Repliee Q1-Expo, and only very slight variances (1 degree of freedom) and some extra sensors officially differentiate the two generations. The effects of "improving" a model may also be drastic: a droid that can stand may be transformed into a new model which is not able to stand, because of a shift in research emphasis to one not requiring this ability. In an iterative workflow analogous to performativity itself, the droids are constantly overwritten, producing identities that evolve over time. There should, therefore, be many practical opportunities for robotics engineers, notwithstanding the 'indifference' noted by Robertson, to make incursions into the androids' aesthetic standardisation along stereotypical lines, perhaps in experimental frameworks that could seek to *exceed* the standard levels of perceived robotic affinity via aesthetic familiarity. This approach of experimental boundary-pushing is aligned with scientific/governmental imperatives of novelty and innovation. And so, perhaps goaded by projects initiating from within the visual and performing arts, and by the findings of and the public reactions to these projects, robotics engineers might be convinced to re-examine the stereotypic image of the gynoid. Collaboratively, we might begin to frame a lack of stereotypical predictability - a relaxing of strict adherence to type - as an "improvement".

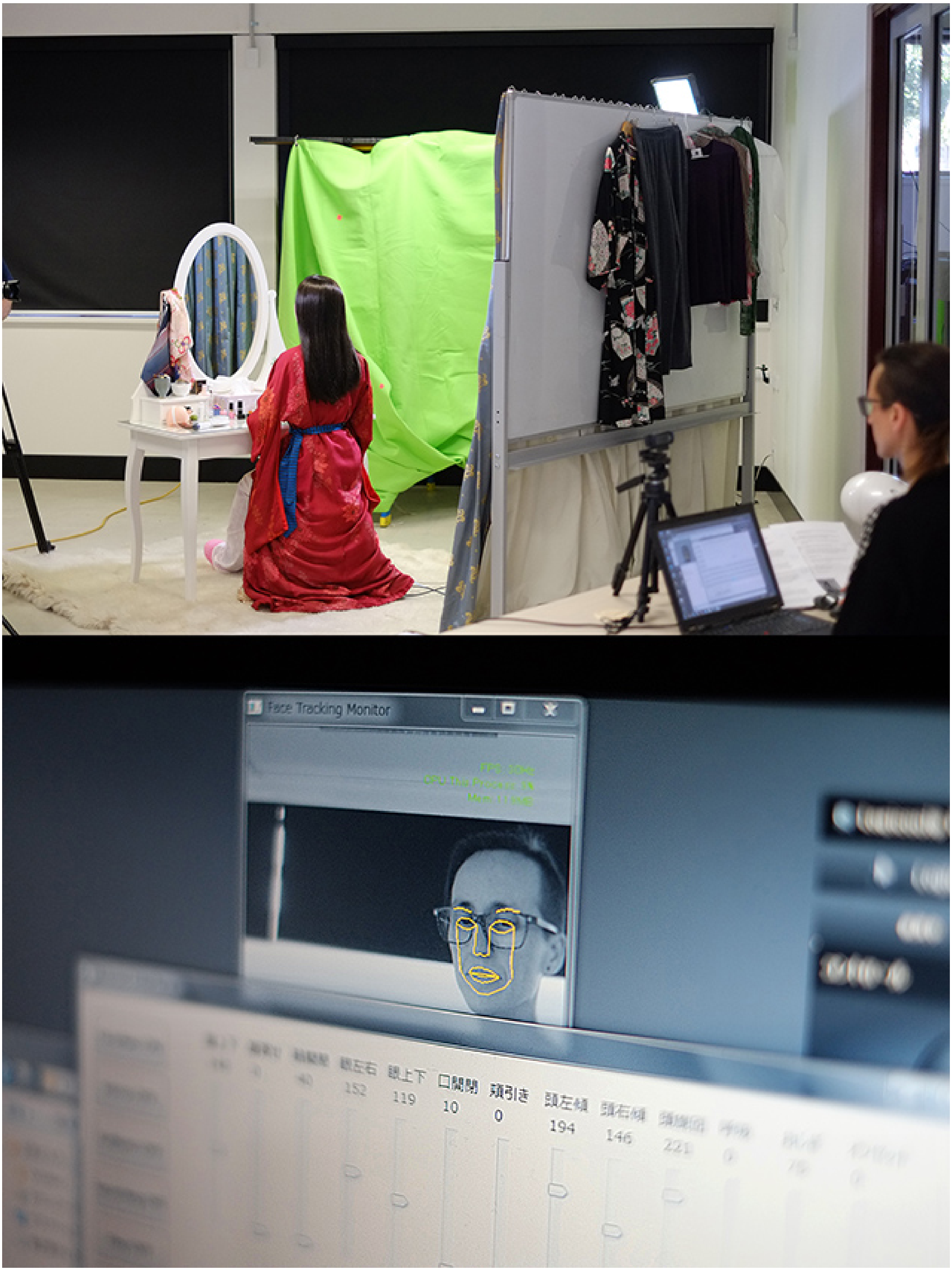

Figure 1. On-set assistant Kirsten Packham operating Actroid-F in face-tracking mode during filming of Pathetic Fallacy (part of Actroid Series I). Photos: Maylei Hunt

Working with Geminoid-F

In making *Radical Hospitality* I worked closely in dramaturgical practice with the gynoid called Geminoid-F, or Actroid-F. 'F' stands for female (ATR and Kokoro, 2010). The initial press release for Geminoid-F, dated 26 March 2010, described its new features in contrast to the contemporaneous geminoid named HI-1, which is modelled on its lead creator, Ishiguro himself.

> The humanoid robot "Geminoid HI-1" which has previously been developed ... has a complicated body structure ... In contrast, the newly-developed Geminoid™ F has minimum degrees of freedom required for tele-operation and has been designed to re-create more natural facial expressions like smiling. By limiting the number of moving parts, development cost was significantly reduced. In addition, wide applications in practical scenes can be expected by adopting the appearance of a more friendly woman. (ATR and Kokoro, 2010)

According to the release and the robot's online homepage [3], due to this 'significant downsizing', 'Geminoid-F is hoped for becoming more common communication media for everyday life'.

Figure 2. Radical Hospitality (Knox, 2014). Single channel video,stereo sound, 6:16. Video still.

ATR Laboratories' early designs of the female-model geminoid – Repliee Q1, Q1-Expo and Q2 – allowed for 31, 41 and 42 degrees of freedom, respectively, while the first "male", HI-1/HI-2, has progressed from 46 to 50 degrees of freedom. The 2010 Geminoid-F has only 12 degrees of freedom, partly so that it would be cheaper, more lightweight, and more easily applied to social environments and installations (ATR and Kokoro, 2010; Burrows, 2011). [4] Its possibilities of movement are thus delimited, ostensibly in service of the goal that all humans become familiar and comfortable with all humanoids. Its limited deployable freedom relative to that of the geminoid clones of male university professors can be seen as typical of a persistent contradiction in modern societies: 'patriarchal systems embedded in the ideological discourse of egalitarianism' (Stoeltje, 1988: 220). Ishiguro has since developed a more restricted (cheaper and lightweight) version of himself, HI-4, which has 16 degrees of freedom as compared to Geminoid-F's 12. However, he is still working on HI-2, which has 50 degrees of freedom. There is no fembot comparable to the HI-2; Otonaroid (discussed below) comes closest, but trails by 10 degrees.

Geminoid-F is a seated android – it has legs and feet but cannot stand. It is physically fused to its chair via a metal pole that projects in an undignified fashion through the chair and up its "spine". It "sleeps" in a slumped-over position on this same chair or stool. It is tethered by electricity and data cables, and its servo actuators are powered by an external air compressor that feeds them through a tube. This compressed air is also used to give the android the appearance of breathing in its chest. The android is operated by humans via an external computer running Windows, including the native text-to-speech software and speech synthesis, and 13 faders programmed in Visual Basic by which the operator can manually control actuator movement along specific binary planes (one plane, the torso, was out of commission at the time of filming, and the final fader controlled a programmed combination of mouth and brow movement to express "surprise"). The unit does not currently have the artificial intelligence to learn or to make decisions autonomously. The android has a camera in each eye, and blinks on an automatic program (much as one could say humans do), a reflex that does much to enhance its "naturalism". It can track faces and movements, and exhibit a range of motor movement within its 12 polar axes. Operating this robot is a lot like puppeteering and a little like driving a remote-controlled, jumpy jalopy. [5] For all that it is a high-tech entity and a proud product of the high-tech jurisdiction, its basic face-tracking, laggy virtual faders, and sometimes jerky pneumatics give it a decidedly hands-on, folksy feel. Observers experience the non-human non-fluidity as a provocative disconnect between the appearance of the robot (credibly "human") and its movement (obviously not). The artwork *Radical Hospitality* exploits the robotic gestural awkwardness of this otherwise realistic simulacrum to point up the *ideological* lag between modern identity politics and those being inscribed into these 'very humanlike' machines. It joins a body of my work that looks into the societal naturalisation of women behaving awkwardly. Curiously, the technical term "compliance" applies to the air actuators' controlling and attempting to smooth out this jerky movement in the robot (MacDorman, 2008).

Geminoid-F does have a relatively mobile face compared to most robots; its physical freedom is primarily facial, allowing it to mime a range of recognisable facial expressions conveying emotion and empathy. The android's performance parameters that I utilised in *Radical Hospitality's* choreography are its head rotation side-to-side, eyeball rotation side-to-side, smile, head tilt (coquettish), and an opening-up gesture of the right arm and hand. I have focused on this expressive arm gesture devolved to the actroid – perhaps its least smooth physical gesture [6], [7], and embedded it as the crux of a cyclical performance of welcome/exclusion. French scholar Mireille Rosello (2001: 127) discusses a form of 'glamour' in which the prestigious welcoming gesture is performed by the male (or the patriarchy), while the backstage work connoted by the gesture is done by a female subaltern. However, at national and regional borders, or at almost any institutional border where a physical, general welcoming gesture (or a smiling rejection) is called for, a female figure is usually procured (Knox, 2015, McNulty, 2007). If, as Rosello describes, the performance of 'hospitality calls for a series of gestures that must combine the art of welcoming symbolically, as well as a more humble aspect that makes the host closer to the servant' (2001: 126), then the proxied hostess is at once front-and-centre and humbly liminal in this figuration, as she materially takes over the welcoming gesture while it is understood that she is possessed, blank: that the semiotics of the gesture are beyond her full control. Telepresent androids deliver this intrinsically awkward performance *par excellence*.

I have also lent my own unsynthesised (non-Japanese) voice, in voiceover, to the actroid, as might conceivably befit its liminal, cyborgian, global-citizen status (Geminoid-F’s 'master template' is one-quarter non-Japanese (Guizzo, 2010)) and its roles as telepresence robot and as a futuristic, personable, flesh-suggestive sentry. The puppet says, *Welcome.* In *Radical Hospitality* the actroid, in uniform, sits before a series of open doors that suggest the "hoops" we must jump through, or, more literally, the thresholds we must negotiate in order to be socially acceptable, or welcome. It gestures in an official, programmatic manner to imaginary, invisible or notional beings entering "its" space. From a distance of a few metres, it might be taken for a human. It is a confluence of the corporeal typologies of hostessing women and the workaday Japanese employee (see Iwabuchi, 1994; Meyers, 1999; Oda, 2001; Ueno, 2001a, 2001b). Its humanoid body has no toes, genitals, nipples or hair (it wears a wig). Yet it is feminine. There is no functional reason for the robot smiling at the threshold to be feminine, it just feels right. Questions of what or who is across the threshold, and what the crossing demands or means, are downplayed by the saccharine performance at the gate.

Figure 3. Radical Hospitality (Knox, 2014). Single channel video,stereo sound, 6:16. Video still

I have proposed elsewhere (Knox, 2015) that all hostesses' performances of functional surrogacy are reflexive: they filter and feminise for the general public a masculine authority that, as Allison (1994: 166) observes, is already dependent on the gestures and labours of women. In this performance, which is generally keyed to signify a *conditional* hospitality, 'gender serves as a hinge on which all the ambiguity of the status of the host can support the complex interactions between race and class' (Rosello, 2001: 134). This norm-based interplay between race, gender, nationality and social standing, as it applies to the perception of "helpful" technologies, is observed and examined in studies by researchers across the world (e.g. Carpenter et al., 2009; Dautenhahn et al., 2005; Van Zoonen, 2002). For the purposes of my experiment (and also in Rosello’s book-length study of gender and hospitality) the phenomenon is extrapolated as a relatively global one, spanning at least European, Japanese, North American and Australasian contexts. And while other works in *Actroid Series I* are set in domestic settings (cf. Carpenter et al., 2009), *Radical Hospitality* understands the surrogated performance of hostile hospitality as occurring as a *ne plus ultra* at the borders to nation-states, where hostesses stand as signifiers for international (in)hospitality – baldly, who is admitted and who is refused entry. The work concurs with Rosello in regarding the hostess in this role with simultaneous 'positive suspicion and naïveté' (2001: 75). I want to understand the less obvious, intangibly performative aspects of the role, and the interdependence of the human model organism (the "hostess") and the robotic role delivery. For as 'servants obviously do not disappear when nations become independent' (135), neither does the human subaltern disappear when, in a suppositional scenario, humankind is "liberated" by functionary robots.

Radical Hospitality is but one effort to spotlight the model of the model of the model. As the longest of the works in its series, across which the actroid undertakes television host(ess)ing, reception duties, and new-age wellness facilitation in the guises of concubine, geisha and Lolita types (among others), *Radical Hospitality's* specific foci are repetitive gesture, and the aforementioned relationship of gesture to time. The actroid's clunky, literally contrived welcoming gesture is perfectly suited to a caricature of bureaucratic hospitality. It shows us the way, in a manner that makes us pause, cock our head and narrow our eyes. It proceeds identically every time it happens anew. As with the other works in the series, the video's incessant temporal looping comments on the refractions of this mirror-craft through time.

Occasionally, the robot in the video says, *I'm sorry, we're full.* The gynoid's change of heart may be precisely programmed, may be arbitrary, may be algorithmic. *Radical Hospitality's* uniformed hostess is a pre-security measure, a front line of observation that could, due to its cyborgian connectedness to the network, alert its (puppet)masters to anything untoward or irregular at the border. At a conference in 2014, I was asked whether I thought my depiction of the gynoid in action in *Radical Hospitality* was particularly fanciful, as people could simply ignore its directives, ignore it completely, or overpower it if they felt like it. I countered that why, then, do people follow hostess' directives at airports, sporting matches, or any public gathering? The surrogacy of this figure is well understood. The repercussions of disobedience will not stem from or stop with "her". A border-patrolling, refusal-conferring gynoid is not the actual bouncer, rent-a-cop or guard; "she" is the technologised and subcontracted gesture of conditional hospitality, a fearless front for the fearful wiles and mechanisms of global capitalism and authoritarianism.

The android is unable to take offense. In fact, androids as they currently stand (or sit) are unable to properly, authentically own – or, therefore, to take or give – anything. Their telepresence will in some cases progress to incorporate AI (Cuthbertson, 2015), and recent experiments have trialled the program Cleverbot in actroids (see e.g. Grogan, 2013), but most of the time the actroid robots receive and transmit messages based entirely on human input and instruction, and even in their most advanced iterations display only cleverly simulated performances of emotion or entitlement. The gynoid in *Radical Hospitality* bestows welcome, but like the hostesses in Rosello's analysis it will only 'mediate between the guest and the master's desire' (2001: 124); any information about the receiver's offense or otherwise flows *through* it. Its incapacity is a condition for the possibility of information flow (González, 1999 [1995]: 271). Its incarnation as border-hostess simultaneously sanitises and eroticises its (her) incapacity.

Self-fulfilling prophesies

Robertson (2010: 5) claims that the current state of 'robo-sexism' effectively re-conflates identity, sex and gender, 'proving' the gendered identity of androids by attributing to them feminine or masculine markers and capabilities, and then having the robots representatively perform these. Android science (Hornyak, 2006; Ishiguro, 2006) generally follows a scheme described by anthropologist of technoscience Lucy Suchman (2007: 226):

> Positioned as exemplary of leading edge thinking and technical practice, these initiatives in new technology materialize the cultural imaginaries that inspire them and which they in turn work to enact.

Recently in Singapore four engineers and a communications researcher (Tiong et al., 2013) conducted a study based on the Computers Are Social Actors (CASA) theory, examining the impact of gender stereotypes on people's impressions of a social robot in a security guard role. Their report cites over 20 studies that, predictably, find the general public, and institutional hiring policies, to adopt particular gender-stereotyped attitudes toward many occupational roles (264). The study hypothesised that a 'backlash effect' (264), wherein people would evaluate as less advantageous a worker who violated occupational stereotypes, would extend into the field of human–robot interaction. The study's participants did indeed perceive the security robot that matched gender-role stereotypes (male) as being more useful and acceptable than the mismatched security robot (female).

A problem with studies like these, carried out in a purely engineering context, is that their findings lend themselves to an over-simplistic use in guiding technical manufacture and design; they accord easily with the rules both of commercialism and of "common sense" (cf. Alac, 2009; Suchman, 2007: 167). These researchers explicitly state that their study 'provides an anchor for robot designers to reduce the large design dimensions by possibly laying their focuses on gender stereotypes' (Tiong et al., 2013: 267). Because the stereotypes are "proven" as true, they are recoded as helpful. They are described in this particular document as 'high level social concepts' (267) affecting user preference, and robots' persuasive power and task suitability. To extol stereotyping (archetyping is not discussed) as a high-level concept is tendentious. To adversely affect, however unwittingly, the insecure futures of the groups who lose out in the stereotyping dialectics is helpful only to the dominant, power-invested groups, who by means of continued "careless" oppression retain and fortify their power.

In *Radical Hospitality* the typically politely concealed master–slave dynamic is *un*concealed, by a touristic voyeurism that reinforces both jingoistic nationhood and gendered scopophilia. While a quasi national anthem loops in the background, the robot, dressed as a "perfect" hostess, is revealed as imperfect and rote by the video's precise focus on its gestural movement. Its embodied limitations are on show. Its "degree of freedom" is low, even as it superficially arbitrates on others' mobility. The physical absence of the tourists (who are nonetheless present) emphasises the self-affecting structuration of performativity. The hostess carries on *regardless*. The industrious grotesquery of the computer–human–machine assemblage (the puppeteered, robotically gesturing actroid) is performed by a strictly gendered body 'whose paroxysmal and repetitive gestures make it seem as if it's animated by unseen forces' (De Fren, 2008: 139). In Ernst Jentsch's (1996 [1906]: 14) words, bodies animated by unseen forces produce 'a demonic effect' that yet 'reveals the human body to the viewer'. Geminoid-F performs a politics of demonisation in its programmatic wielding of power to divide those who are welcome from those who are not.

I offer in *Radical Hospitality* a feminine android hostess at the institutional pinnacle of her distilled usefulness, vaguely forbidding yet dewy-faced, doe-eyed and demure... gesturing the while with an obvious lack of suppleness and sophistication in her motors and springs. Her arm opens and shuts like a car park's boom gate, or perhaps it flaps in the breeze indicating the state of the climate like a basic windsock. There is nothing about *Radical Hospitality* that is free, unless you count a possibly endless time-loop, an interminability that might in itself be transcendent. The radical condensation of meaning in this gynoid body in her flagship, defining role is attributable to centuries of its narrative persistence through periods and important turning points in technogenesis and techno-industrial evolution. If its mechanical repertoire can be seen as 'demonic', it will most often be the gynoid itself who is branded as demon. However, the demon might also be its creator/s, or its unseen animator, *or*, if the gynoid is possessed by the demon of *automation itself*, then the behaviour that it paroxysmally repeats is *societal conditioning at large and unspecific*, which also controls the animator. There is no escape but to radically reassess and redesign the agency of the gynoid in light of the reciprocal relationship between embodiment and social degrees of freedom.

Figure 4. Beyond Beyond the Valley of the Dolls, UNSW Galleries, 2015. Radical Hospitality, Lamassu Kentaurosu Wagyu, Pathetic Fallacy, installation view. Photo: Maylei Hunt

Creative (feminist) robotics

As androids become more widespread, it will be worth noting any shifting in their gendering in relation to roles to which are typically ascribed varying degrees of authority and freedom. I suspect that, over time, as more authority is required of and perceivable in a humanoid robot of the aesthetically 'very humanlike' variety, we will see more masculine-gendered actroids, and more super-realistic masculine androids generally. At present, while the physical range is so limited (current versions of the actroid are fixed as seated, ostensibly so as to concentrate on naturalised, face-to-face 'interaction experiments' (Nishio, Ishiguro and Hagita, 2007: 347), and their functions are mainly to reassure and entertain – while our needs are limited to their gesturing and simple chatter – we have ladies.

Since Geminoid-F, ATR Laboratories have created Kodomoroid and Otonaroid. [8] Since June 2014, these gynoids have been at the National Museum of Emerging Science and Innovation (Miraikan) in Tokyo in the permanent exhibition Android: What is Human?, curated by Ishiguro. Their human models are anonymous. The museum states:

> Kodomoroid is a teleoperated android robot resembling a human child. It is an android announcer with potential exceeding that of its human equivalent. It can recite news reports gathered from around the world 24 hours a day, every day, in a variety of voices and languages. ... Kodomoroid, with its close resemblance to a human child and detached voice, continuously recites world news. It is a work of art of sorts, which asks profound questions about humanity's future.
>
> Otonaroid is a teleoperated android robot resembling an adult female. She has been hired by the Miraikan as a robot science communicator. At the exhibition, you can talk with her and also operate her. ... Through this experience, you will gradually acclimate to communication with an android robot and become capable of comprehending it more instinctively. (Miraikan, 2014)

Erica and YangYang have been created since Kodomoroid and Otonaroid. "Female" actroids continue to be seen by the proponents of this specific 'android science' as the correct path: the best way to successfully mirror, delight and therefore reassure humans on a *consumer* scale (Grogan, 2013) is to match the expected deference and restricted movement range with their recognisable bodily incarnation.

Hopefully, my directed performances with Geminoid-F might challenge the viewer's instinctive comprehension of gynoids – the whats and whys of their production. Presented in the contemporary art context, which has consistently 'found its own vectors for exploring cyberfeminism with work that addresses the image of the sheborg through the language of emerging and sophisticated technologies' (Cutler, 2001: 189), *Actroid Series I* complicates and questions interpretations that are often simplistic and/or reductive, aiming to participate in a transdisciplinary discourse about how androids are made and used. Ishiguro himself states: 'Artist[s] and philosophers are very important collaborators in the next [robots]. Why art? All engineering is coming from art' (Hasegawa and Collins, 2010: 5). Acknowledging the prospective benefits of a wider humanities-based perspective, some cognitive scientists (Haring, Mougenot and Watanabe, 2012: 156) believe that social robotics should 'require researchers to understand not only mechanics and computer programming but also ... psychology and social science – both fields that have generally appealed more to women'. Unexamined as this 'appeal' is here, the emerging field of android science recognises that different perspectives are now needed. These perspectives should, however, be nuanced, intersectional, and not limited to the psychological, cognitive and social sciences which also employ positivist rationales not unlike those upon which engineering is usually based (Haraway, 1988; Sprague and Kobrynowicz, 2006). Women should be involved in their own representation on all levels. I would disagree that currently 'all engineering is coming from art', although I think what Ishiguro references here is the imagination. The thought is good. Now we need more collaborative imagination than merely imagining that 'basically we want to see beautiful women, right?' (Ishiguro in Hasegawa and Collins, 2010).

In *Radical Hospitality* I explore the embodied constraints of the technosocial positioning of the gynoid, and enact, in Judith Still's (2013: 27) words, 'how we are haunted by the past, and how we fashion those ghosts in the present'. Through the mimetic employment of the too-feminised gynoid in a hostessing role that is "hers by right" due to centuries of women's performance of it, the gaucheness of the gendering of the role is intensified and, ideally, subverted. In commercial and research robotics, Suchman sees mimesis operating as a less deliberate, less considered, decidedly not subversive mode of reproduction: 'the fascinations of artificial personhood ... involve a kind of mimesis that works as a powerful disclosing agent for associated assumptions about the human' (2007: 241). Perhaps in an art-based robotics, playing with these assumptions might help to provoke a cross-disciplinary interrogation of them. Because, creative as humanoid robotics may be in the literal sense that it creates robots, the discipline feeds from stereotypes and rebuilds them into its creations – as if, indeed, a non-stereotyped robot were unmakeable in the current semiotic system. According to Suchman, 'one line of generative critique' is to 'trace out ways in which the assumptions that underwrite contemporary efforts to configure humanlike machines are remarkably familiar ones, their positioning at the leading edge of technoscientific innovation notwithstanding' (2007: 226). Extending this line of critique, *Actroid Series I* moves from attentively tracing to mimetically performing assumptions about the human in "feminine" androids (gynoids), seeking an engaged, cinematic reconsumption that might psychosomatically disrupt the reflex or desire to stereotypically configure and consume robots.

Biographical Note

Elena Knox is a media/performance artist and scholar. Her works centre on performances of gender in technoscience and communications media, and are presented in galleries, theatres, festivals and public spaces internationally. Her writing has appeared in literary and academic journals in Australia, New Zealand, Europe, UK and USA. Knox won the 2015 Dean's Medal for her PhD at UNSW Australia Art & Design and is a JSPS Postdoctoral Fellow at Waseda University, Japan. http://elenaknox.com

Notes

[1] The Laboratories are housed in the Department of Systems Innovation, Graduate School of Engineering Science at Osaka University, and the project is conducted in association with Kokoro and the National Institute of Advanced Industrial Science and Technology (AIST), University of Tokyo.

[2] One such android has been made at the Center for Computer-mediated Epistemology in Aalborg, Denmark, in collaboration with the Japanese.

[3] The project's webpage is www.geminoid.jp/en/robots.html. See also Burrows (2011).

[4] See also Reid Simmons, professor of robotics at Carnegie Mellon in Carroll (2011): 'In 5 or 10 years robots will be routinely functioning in human environments.'

[5] *National Geographic* (Lovgren, 2007) cites Ishiguro: 'Robots do not have human-level intelligence. It is rather similar to a vehicle today.'

[6] In the influential science fiction novel *The Future Eve*, the character Thomas Edison requests that a young woman be cloned as an android, paying especial attention to her 'gentle and harmonious gestures' while replacing her personality with a more submissive one (De Fren, 2008: 28-29).

[7] Ishiguro's colleague and sometime co-author has recently co-conducted a study on jerky motion in video replay. 'Receptive to Bad Reception: Jerky Motion Can Make Persuasive Messages More Effective' (Patel et al., 2014) examines the extent to which attention-capturing jerkiness influences message processing and increases 'compliance to a persuasive message'. The experiment manipulated the jerkiness of an actor's movements in a computer-delivered video, and it was found that 'jerky character motion can make computer-mediated messages more persuasive' (2014: 32). Conversely, Ishiguro has stated publicly that it was jerky movement that made his very first geminoid Repliee R1, a copy of his young daughter, unappealing to humans that encountered it (Guizzo, 2009; Hornyak, 2006).

[8] See http://www.miraikan.jst.go.jp/en/exhibition/future/robot/android.html

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FCJ-205 Life and Labour of Rovers on Mars: Toward Post-Terrestrial Futures of Creative Robotics

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Abstract: Four Earth-born, human-made robotic rovers have successfully landed on Mars. Equipped with a range of sophisticated technical instruments for imaging, sensing, measuring, data processing, communication and navigation, these semi-autonomous devices follow the directives of their human "drivers", performing exploratory observations, assessments and evaluations and reporting the findings back to their command centres on Earth. In this paper I explore the ways in which robotic exploration of Mars facilitates productive exchanges within the ontological nexus of the human–technological, forging new configurations between the ambits of life and labour which may determine the prospects of post-terrestrial robotic futures.

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Curiosity rises early; it is bitterly cold on Mars at around 5am when NASA's Jet Propulsion Laboratory (JPL) wakes up the rover with a different popular tune each day (from *Hit the Road Jack* and *Walking on Sunshine* to the Beastie Boys' *Intergalactic* and the *Star Wars* theme), and delivers it a list of its daily tasks. Curiosity then sets out through the dust haze enfolding the rusty terrain scorched by solar winds and galactic cosmic rays on its busy schedule to explore the red planet. Rolling on its six wheels across the uneven floor of the Gale Crater, the 2.2 metre tall, 2.3 metre wide and 2.9 metre long rover searches for clues about Mars' habitability. It uses instruments such as hazard avoidance cameras, an Alpha particle X-ray spectrometer and a radiation detector to navigate its Martian environment, sense it, measure its various properties and evaluate its capacity for hosting carbon-based forms of life. The rover pauses at times and uses its 2 metre long arm to take samples of soil and investigate their composition. Coming to a chunk of rock in its path, it engages a vaporising laser to turn it into a fine powder in order to scrutinise it more closely. It slowly but steadily roams a desolate landscape, taking images to document its progress and using its high-gain antennas to report back to Earth. It finishes its day at about 4pm Martian time, and turns off into a sleep mode until the next morning. Since its landing Curiosity has repeated this routine, and it will continue to do so until its instruments stop working, its body parts deteriorate and its battery is irreparably exhausted. And then, when its power source dries up, its vital functions collapse and its links with Earth are severed, Curiosity will halt to rest in the environs of Mars.

Crossing the gulf of millions of kilometres of space, rovers have been toiling on Mars since the late 1990s. Sojourner arrived in the Ares Vallis in 1997. In 2004, two rovers descended onto Earth's planetary neighbour – Spirit landed in the Gusev Crater, and the still-active Opportunity at Meridiani Planum. The most recent arrival, Curiosity has resided at the Gale Crater since 2012. They are neither the first robotic devices nor the first rovers beyond the globe – remotely operated probes with varying degrees of autonomy have been flybying and orbiting, landing and roving on celestial bodies for decades. Yet, with highly refined sensory processing capacities that hone their vision, heighten their analytic perception and enhance their mobility, navigation and communication, the rovers represent a new generation of space explorers. We are evolving the bodies of these robotic agents to adapt to an alien environment on our behalf, and in doing so, we are enhancing their potential to mediate our presence and practices in outer space. Behind the design of a Mars rover stands the financial and logistic potency of military-industrial complexes and their investments into technological advances. A rover is a historical outcome of developments in materials engineering, autonomous processes, remote sensing, teleoperations and informatics, and is an experimental laboratory for future techno-scientific innovation. Cursors of the human exploration of outer space, Mars rovers are at once the results and resources of its technological origins and destiny.

While marking an extraterrestrial trajectory of robotic progress, rovers' presence and activities on Mars sculpt novel exchanges between humans and technology, necessitating new ways of framing the material-social context of their fundamentally experimental, necessarily performative and innately playful and inventive interplanetary ties. This relationship will continue to unfold as these early gestures towards technologically mediated forms of exploration become inseparable from the embodied practices of human creativity. In this sense, the unfolding of our relationship with rovers aligns the exploratory imperatives of their scientific agenda with the purview of practices and research centred upon embodied forms of creative performance and agency. While offering a lens for considering the increasing complexities generated by human–robot relations, Mars rovers not only present questions which can inform critical inquiry into the arena of creative robotics, but also invite us to consider the possibilities of its extension into outer space. Human robotic exploration of Mars is ongoing and evolving and the paths of Sojourner, Spirit and Curiosity will soon be followed by an array of new rovers. NASA's Mars 2020 and ESA's ExoMars operations are already scheduled to increase the population of rovers exploring our neighbouring planet. With longer lifespans and evermore sophisticated abilities and sensitivities, they are set to advance the creative agency of the robotic, becoming vehicles via which the posthuman could be inscribed beyond the terrestrial confines of the globe.

Yet Gilbert Simondon declared 'there is no such thing as a robot' (1980: 12), discarding the image of the robot as a menacing substitute for the human. The robot, as the soulless machinic replacement of our body and labour, does not exist because this figure – that disturbingly lacks 'interior', a social memory – is only a figment of our prolonged reaction to a shock instigated by the invention of industrial automation (Simondon, 1980). The rise of automation produced a conceptual rupture that left an aporia in language, affecting the ways in which we conceive of technologies, of labour and, consequently, of life. Hannah Arendt (1998) wrote that technological development has fundamentally changed the human condition; beginning with the industrial revolution and culminating with the space age, our techno-scientific creation of artifice has confused the centrality of labour within human ontology and incapacitated language as a performative prerequisite for individual and collective action – its momentum outpacing our ability to think and speak about it. This crisis in enunciation caused by technological progress has been articulated and in a sense remedied through Simondon's work *On the Mode of Existence of Technical Objects* (1980) and Bernard Stiegler's work *Technics and Time* (1998). These studies vivisected the corpus of the technological as both a material result of human creative expression and a vital co-evolutionary constituent of the human itself. They disposed of the concept of the machine as a mere servile tool or the uncanny entity taking our labour from us to enslave us, introducing instead the idea of the technical as a prosthetic auxiliary in which the 'interiors' of its human makers are exteriorised and embodied, and whose performance consequently changes the morphology of the human.

Our ability to define the idea of the robot and express the nature of our mutable relationship with robotic technologies is still indefinite; this is particularly so in the case of those robots in outer space. The breakdown in the ability to cultivate an adequate language that keeps pace with technological development is exacerbated in outer space; the arrival of the space age caught us unprepared, leaving us, as Harold Leland Goodwin pointed out, 'with an inadequate vocabulary' (1962: 9). The deployment of rovers to Mars not only suggested a new historical stage in the unsayable relations between humans and technologies, the robotic exploration of our neighbouring planet also had a profound impact upon the transformation of our ideas about the ontological link between labour and life. With these conceptual trajectories in mind, this paper endeavours to contribute to the development of ways of thinking that fill ruptures in language, ways of expressing uneasy entanglements between humans and technologies and contribute to development of the extraterrestrial perspective on the study of the creative scope of robotics. It explores Mars rovers as the penumbra of a problem concerning the performative agency of embodied robotic extensions of the human, offering an approach that phrases relations between humans and technologies in terms of the ontological uncertainties that potentially spring from their interplanetary bonds. I probe into the life and labour of rovers on Mars, attempting to enliven these multifaceted bundles of technical apparatus – devices sent to perform an autopsy on a "dead" planet – not just as a substitute for the human in outer space, but as a catalyst of a robotic future enmeshing novel configurations between the ambits of life and labour, the inanimate and the living, and agency and control.

The extraterrestrial evolution of robotics is inevitably inscribed by the high-tech momentum of our biopolitical condition; Mars rovers are material imprints of ever-increasing obsessions with the strategic implementation of technologies to advance what Michel Foucault (2004, 2007, 2008) framed as biopolitics – a politico-economic order grounded in the exploitative control of productive and reproductive forces of "life itself". The dawning of space technologies has enabled the extension of the biopolitical rationale into outer space, giving birth to a cosmobiopolitics and to the idea of humans who will, through the technological conquest of space, exceed their natural limitations as species and advance outward from the terrestrial boundaries of Earth to become more than human (Damjanov, 2015). The Earth-like Mars is an obvious target of cosmobiopolitical aspirations and its exploration exclusively by rovers rather than humans is, at the moment, a necessity rather than a choice. Currently, the (terrestrially conditioned, "wet") bodies of humans are not able to occupy Mars, a profoundly "inhuman" space where they would be alien organisms. But the bodies of human-made rovers can, and their presence on Mars endows humans with the agency of an extraterrestrial species-being, altering them into a force with the potential to make a material impact upon a planetary world that is not their own. While all space technologies are essentially robotic, they are also fundamentally mediatic. The primary function of Mars rovers is to perform as media devices which pump fresh influxes of data into the terrestrial circuits of the biopolitical accumulation of power, knowledge and wealth. Yet the rovers are not simply high-tech mediatic tools in the cosmic age of biopolitics: Stiegler's (1998) work on technical objects as entities inseparable from what we know as human life invites us to understand them as a material agency moulding our techno-logic drive to be more. In the Stieglerian sense, not only is each atom of the rovers' biologically inanimate and geographically displaced bodies inscribed by the essentially human trace of the "living", but their performance as technical media also advances them into matter vital for the human search for life outside the globe. Rovers on Mars become an instance of biopolitical capital, a part of "life as we know it" and a platform upon which to animate the prospect of "life as it could be".

The Earth-born, human-made, Mars-situated rovers challenge the traditional idea of geographical exploration as a quest for knowledge about unknown regions conducted by an adventurous human who directly experiences and records the environment. They substitute the body of the human explorer and arrive in an already remotely charted territory to enact an array of converged exploratory roles – they are simultaneously geologists, geochemists, biologists, climatologists, meteorologists, data analysts, navigators, photographers and reporters. Their presence and labour on Mars prompts questions about the need for human explorers of space. The allure of outsourcing dull, dirty and dangerous errands to a robot has lain at the crux of its techno-cultural genesis and the advantage of reduced costs and risks have been an important argument in favour of "unmanned" space missions. However, within the debate over the human versus the robotic exploration of space, the need for the actual presence of human explorers is still considered an imperative, while rovers are still considered only envoys of a human mission to Mars. In 1994, NASA historian Steven Pyne wrote that

> [r]obots, cameras, and high-tech instruments can get to the critical environments, record the sights, and take the necessary measurements … the revelations can be broadcast instantaneously and equally for all to witness … What such spacecrafts cannot do is record the experience of actually being there. But what does that mean, when such hostile environments deny one the chance to touch, smell, taste, or communicate directly with one's surroundings, when an explorer can survive only within a completely artificial environment? (1994: 35)

This ontological divide between human and machinic space explorers has been blurred in the last twenty years. Yes, we humans still depend on the support of technological artifice when residing in outer space (except if we arrive at a natural Earth-twin or a terraformed planet), but our robots have evolved. Each successive Mars rover has been empowered by progressed cognitive, sensory and motoric capacities, and each of them has been more sophisticated than its predecessor in terms of the embodied and contextual modes of its "being there". Destined to live and die on Mars, the bodies of rovers are essentially Martian; they are made to be on Mars, and if the question of the ontology of technical objects is tied to their embodiment in a site-specific, geographically localised milieu (Stiegler, 1998), then a Mars rover is not merely a marker of human technical exteriorisation. The rover could itself enter the vagaries of the ontological through the labour it performs. As a technology able to assess and understand its physical environment, dig holes, collect samples, brush the dust, pulverise rocks and evaluate its own performance, it denies the simple instrumentalisation of its own robotic labour. With a language that validates the experience of the rover – that replaces the idea that only an embodied human presence validates exploration and conquest – the need for the presence of "wet" human bodies on Mars is perhaps obliterated. However, what is put most sharply into relief each morning, when a human driver spurs a rover into life with spirited music, is the need for new ways of describing life as it becomes entangled with technology and ventures into the unknowns of outer space. The evolution of these lively explorers and their embodied claims to life on Mars is paced by the intertwined evolution of ideas about the robotic mediation of experience and the extraterrestrial potentialities of cosmobiopolitics. There are thus no robots in outer space, there are instead receptacles for human "interiors" that we send forth to gather knowledge – new information through which these interiors can be again enriched and extended.

Labouring Life

A Mars rover goes through two transformational stages of life and labour and these phases occur in two very different physical environments. The first starts here on Earth with a gestation of ideas in which the rover's design is conceived and the minutiae of its component mechanical and electrical parts are assembled into a bodily form. It learns a language and its perceptive senses mature to work in sync with its data processing facilities. It then takes its first tottering steps during a terrestrial test drive in laboratory conditions. After this formative period, a rover departs to where it really belongs, where it is made to be, and where it can utilise the skills it has been taught, leaving the incubator of Earth to come fully to life on Mars and commence its labour. An ontological trajectory of labour, according to Arendt (1998), originates in an event of 'natality' and is something that is bestowed upon a body at birth. It holds the potential to alleviate the restraints of life as a way of forging paths in the prospective pursuit of freedom. In Arendt's view, this potentiality of labour is profoundly affected by the techno-scientific push toward automation, which makes human labour redundant as a constitutive feature of our existence, and this fundamental alteration of the human condition has been additionally fuelled with the coming of the space age, which has provided the means for human alienation from the cradle of the Earth. If we transpose Arendt's idea – that from its beginning human life is marked by labour – onto Mars rovers, we stretch our understanding of the ontologies produced in the performance of human–robot assemblages. When rovers begin, or "are born", they too are inscribed with the potential to perform labour (perhaps even more than humans, whose social organisation diverts its productive potential). And while Marxist thought determined that 'labour made man', and while human labour created a Mars rover, the rover's realm of being is in part defined by the action of taking up its labour on another planet. Its embodiment as laborious explorer is the becoming of a life that heralds changes in our ontological thinking about the nature of robotic ways of being.

When considered from the perspective of Bruno Latour's (1999, 2005) work on human and non-human assemblages, a rover's performance on Mars, rather than robbing humans of labour and alienating them from Mars, returns the fecundity of labour back into the supposedly empty, labour-less hands of humanity. I suggest that if, as Simondon proposed, there is no robot as we imagine it, then there is also no such thing as a rover's "labour" as we traditionally conceive it. Rovers do not labour on Mars; their embodied performance, orchestrated and conducted by humans, is something which keeps rehearsing the event of their birth, continuously bringing forth life beyond Earth. This performance is directed and managed by humans with political and economic agendas, but it also has an aesthetic which suggests a shift in the conceptual apparatus we use to understand the ideas of life and labour. The work which defines the life of machines on Mars is nothing without the labour of humans. Rovers might perform their own natality, but this reveals the dependence inherent in the fact of their 'createdness' (Arendt, 1996: 51). Yet the potential for labour inscribed in the event of their "birth" also implies the possibility of agency amidst the life of an assemblage that merges human and machine. If Arendt's thinking about the idea of natality and the interconnectedness of labour and life is used as a lens through which to consider the embodied potential of rovers, we can dispense with the illusory idea of independent posthuman machinic life, and instead articulate the ontological questions produced by the labour of a living assemblage of the human and the technic.

Although they are set apart from Earth, the bodies of Mars rovers are intimately integrated into contexts of the terrestrial and the human from which they arise. Assembled from materials and compounds found or made on Earth such as aluminium, titanium, silicon, copper, bronze, lead, stainless steel, tin and zinc, rovers sent to Mars carry specimens from Earth in and as their own bodies. The rovers are also interconnected with Earth though the communication signals that they exchange with their ground control, signals whose very materiality connects the bodies of rovers on Mars to those of humans on Earth. Signals that rovers such as Opportunity and Curiosity emit in order to report on their activities are picked up by the Mars Odyssey Orbiter which relays them to NASA's Deep Space Network, a system comprised of antenna complexes located in the USA, Australia and Spain which then distributes them to the JPL, where their content determines the next human action; signals dispatched from Earth to Mars follow the reverse direction of this interlinked course. By bridging the gap of space separating two planets, communication infrastructure such as the Mars Odyssey Orbiter and the Deep Space Network facilitates and accelerates the human relationship with Mars, as it is refracted through the embodied labour of rovers. These transactions draw the physically separated bodies of humans and rovers into one operational unit, within which their productive agencies interact and mutually affect each other. While only rovers have a bodily experience of Mars, the work of these bodies is merely one part of an interplanetary network of robotic labour. The exploration of Mars, within which humans and non-human agents are incorporated into a robotic network, is erasing the strict ontological boundaries that divide the bodies of living humans and inanimate rovers. As Félix Guattari reasoned, 'it is impossible to deny the participation of human thought in the essence of machinism', yet 'up to what point can this thought still be described as human?' (1995: 36). Integrated into the complex of a robotic mission on Mars in which their materialities and vitalities intermingle, machines that are no longer inanimate and humans who are not exclusively or only human anymore fuse into a productive participatory force, giving form to such pregnant questions.

Robotic probes on Mars pose difficulties of distinguishing where human agency ends and the robots' begins, but they still preserve a clear division of the scope of the activities conducted by each: humans compose and send a command to a rover; the rover receives it, decodes it, executes it and reports back; humans receive the report, analyse it and issue another command. However these cyclic actions are not performed without interruption. Communication between a rover and its ground control does not occur instantaneously – it takes between five to twenty minutes for a signal sent from Earth to reach Mars and vice versa. The current deep space communication facilities are not capable of conquering the spatial distance between two planets to enable real-time interactions. During the delay in communication, the rover's performance occurs in a blind mode – in this gap humans can never see what the rover is doing, they can only wait to receive its report about what it did. This lag in communication regularly leaves the rover unsupervised and so communication within the human–robotic network is based on a trust in the embodied presence of the rover, which offers only its own report as confirmation of its actions. While our blindness is not total, these gaps in the communication between parts of the assemblage are pauses in human control. We should be wary, however, of overdetermining the potentialities of the independent, uncontrolled agency of these technologies. Although it is possible to anthropomorphise the rovers, to imbue their labour with a false blush of "life", and to animate discourses about their presence on Mars by proposing that they are "emissaries" with the potential to themselves become living, what is perhaps more pertinent is to suggest that their agency within a living network is reinforced by these blindspots of communication. So while there are no robots – only the machinic extension of the human and the tools (technical, social, linguistic and political apparatus) we use to define and manage life – rovers themselves contribute to how the life of this network is conceived by perplexing the coordinates of what dictates robotic labour.

Rovers' exploration of Mars complicates a previously straightforward ontological calculation of labour by shifting it back from the robot to the human body. While there are only a few rovers on Mars, their operations are sustained by a significant number of humans; in the case of Curiosity, the rover’s direct support comprises a pyramid of highly qualified scientific labour – sixteen rover drivers and around four hundred analysts and controllers are engaged in its performance. The labour contributed by these human elements of the rover network reflects a historical swing from labour that is sustained by the physical capacities of the human body employed in material production, toward a labour which has been described as 'immaterial', 'affective' or 'cognitive' (Lazzarato, 1996, 2012; Hardt and Negri, 2001, 2004; Terranova, 2004). And yet, even labour such as remotely driving a Mars rover requires certain bodily provisions, such as the capacity to use a mouse and keyboard. The performance of a rover involves a similar combination of the material and immaterial dimensions of labour. While moving its body and extending its "arm" to dig and collect samples, it is also performing calculations, navigating and mediating communications. Yet within the rover–human network – what Latour (2005) would identify as a collective composed of human and technological actants – it is the human element that is reduced to its own labour power. While rovers journey, sense, explore and experience, it is human bodies which are reduced to their bare labour, while working to design, build, launch and eventually drive their creations. Such a configuration of the rover–human network modifies the ambits of labour within "life as we know it", bringing it closer to the definition of life which Christopher Langton derives from his work on artificial life – as not merely the fabric of matter in itself but the 'result of the organisation of matter' (1996: 53). The idea of life that appears in the rover–human assemblage is defined by this interplay and inversion of labour forms, a process of relational positioning between the human and rover within the arena of the robotic. In this sense, while conducting its "labour" on Mars, a rover both performs and transforms life itself, absorbing the biopolitical capacities of labour – what Tizianna Terranova terms the 'power of labour ... in the making and remaking of the world' (2004: 129) – and embodying them in a robotic cosmobiopower.

In the Milieu of Mars

The "second life" of a rover, the event whereby its machinic body arrives at its intended destination and becomes an explorer proper, marks the beginning of the realisation of its full robotic potential. The rovers' presence on Mars, their site-specific performance, is conditioned by the extraterrestrial geographies of the physical locations in which they are situated. They rove across a landscape that is marked by volcanos, canyons, valleys, impact craters and sand dunes and covered in a dust rich in iron oxide, which tones the surface of the planet red and whose reflections colour the pink skies above. Enclosed by a thin atmosphere almost entirely comprised of carbon dioxide which provides no barrier to the harmful impact of radiation, held to the soil by a gravity whose pull has only one-third of the strength as that on Earth, the rovers' missions take place in an inimitably non-terrestrial world. The sols of Mars are of slightly longer duration than days on Earth and a Martian year lasts twice as long as a terrestrial one. The passage of the sun and the two moons mark alterations of surface temperatures on the red planet from around +50°C in the equatorial areas in the daytime to about -150°C at the poles during the night. Such spatio-temporal conditions demarcate the distinctive environment in which rovers reside, making Mars not merely a background against which the rovers operate, but a milieu that both produces and is produced by the performance of these technologies.

The notion of milieu is useful for considering the ontologies of the human–machinic assemblages involved in the robotic exploration of Mars. The concept of milieu features prominently within works which have explored life’s malleability and vital fabrics, such as Georges Canguilhem’s on its epistemological conceptualisations (1991, 2008), Foucault’s on genealogies of its governance (2004, 2007, 2008), Simondon’s on its interlinked 'organic' and 'technical' trajectories (1980) and Stiegler’s on its technical synchronisation with its environs (1998). Although these works use the term "milieu" with various emphases, they all suggest that it defines a locus of life: it is a material context which both frames and is framed by life’s productive forces. Having arrived on Mars and commenced their missions, rovers initiate Mars as a milieu. The life of the assemblage – embodied in rovers – transforms Mars from a "lifeless" space to an environment in complex discourse with living things. The interaction between rovers and this milieu opens the "dead planet" as a setting whose distinct characteristics encourage the transformative unfolding of the human–technological as a creative force. Designed to frame Mars for humanity, rovers themselves must be framed by their milieu; their labour both mediates and is mediated by the milieu of Mars and this is what makes them a corpus *par excellence* through which to extend ideas and lexes about what constitutes embodied life beyond Earth.

Rovers' exploratory capacities develop in response to their environment. Held by its indifferent gravity, a rover surveys the planet, measuring the temperature and radiation to which its body is exposed. Its experiences of the Martian environment hone its reception and responsiveness to it. Through such experiential learning, a rover advances, correcting errors, extending the utility of its functions and refining its sensory and navigational skills. Information about each rover’s experience of Mars is also passed onto its successors; they are embedded as a "memory of experience" into the design of the next rover. At one level, this transfer is directed toward the enhancement of a rover’s physical aptitude to explore: it feeds into the development of more advanced scientific instruments and mechanical parts which will improve its ability to act in, and interact with, its milieu. At another level, Mars fundamentally shapes the performance of the robotic life extended onto it. Humans might exteriorise themselves via rovers into the Martian milieu, but rovers are also informed by the memories of their precursors' time on Mars. That said, the evolutionary potential of the rovers and access to their shared history is still managed by human controllers. What appears as genealogical progress arises as a biopolitical strategy aimed at the selective refinement of rovers' "genetic heritage", as an endeavour to "bioengineer" their bodies and make them more apt to be on Mars. Yet what the rover-human assemblage also suggests are potential gestures toward a rovers' gradual acquisition of a collective memory, the procurement of their own interior that can itself be exteriorised in the milieu of Mars.

The milieu of Mars demands the evolution of rover autonomy; their performance is increasingly guided by their internal onboard processes, with the data they collect through laser rangefinders and stereoscopic cameras being used to compute a detailed local topographical map that they then utilise to safely traverse the terrain in question, once it is approved on Earth. The issue of a robot’s autonomy – the degree to which its actions are independent from human command – lies at the crux of evolutionary robotics, and the progress of the robotic exploration of Mars has increasingly improved rovers' ability to self-navigate and plot courses of exploration. Each consecutive rover arrived on Mars with an upgraded navigational system. On 27 August 2013, Curiosity used its "autonav" cameras for the first time to traverse terrain which was neither visible nor known to the JPL, and the safety of which was not sanctioned by ground control. Human investment in robotic development is allowing Mars rovers to explore more independently and more inventively and to become progressively creative; the imminent ExoMars mission, for example, uses a rover that can not only find the best way to arrive at the given coordinates by itself but can also revise its chosen course as it encounters obstacles. The independence of movement and spontaneous improvisation that characterises the autonomous labour of these robots endows them with the agency to experience, suggesting a potential freedom of creative action in which they could exteriorise themselves. A rover's contact with the environment is what transforms Mars into a milieu with the potential to accommodate the interiority of technical life. Mars impacts upon both a rover's mediation of its milieu and the rover's remediation of this experience into a message signal that it modulates and sends to humans (and that is further distorted by travelling through interplanetary space and being demodulated on Earth). These effects of milieu – the environmental disturbances of Mars' mediation at the very level of signals and their processing – have the potential to become an intrinsic part of the "robotic experience".

This experience of milieu, which is necessarily incorporated into the composite life of the human–rover assemblage, relies on technics of the rover; as Stiegler describes it, the establishment of 'the relation of the living to its milieu' is possible only through the medium of the technical object, through 'organized inert matter'.

> [T]he singularity of the relation lies in the fact that the inert, although organized, matter *qua* the technical object itself evolves in its organization: it is therefore no longer merely inert matter, but neither is it living matter. *It is organized inorganic matter that transforms itself in time as living matter transforms itself in its interaction with the milieu.* In addition, it becomes the interface through which the human *qua* living matter enters into relation with the milieu. (1998: 49, original emphasis)

Through their productive response to the Martian environment, or through what Stiegler calls 'interaction' with a milieu, the rovers arise on Mars *as if* they were alive. Humans organise inorganic matter into a rover and adjust it to better respond to its location so that humanity can better exteriorise its own living matter into the milieu of Mars, but through the rovers' labours this organisation of inorganic matter starts to transform itself into living matter. The robotic exploration of Mars leaves not only the material imprints stamped by rovers onto the surface of the planet – the tracks that their wheels engraved into its dust, the pulverised rock that they vaporised, a crevice that they carved into its soil. The exploration also deposits material traces of the intertwined agencies of the human and the non-human, which intervene in the milieu of Mars to inscribe it with life – life that is neither organic nor inert, but intrinsically robotic. In this sense, the robotic exploration of Mars is not so much an attempt to search for and find signs of life, but instead a biopolitical extension of life into its milieu via technical apparatus. This, in Stiegler's words, is a 'pursuit of life by means other than life' (1998: 17), an endeavour to harness the creative potentials of robotics and breed life on a barren Mars. While Mars can only function as a milieu through the embodied presence of the rovers, this milieu now potentially influences – and thus in part frames – the direction of both technological progress on Earth and, perhaps more profoundly, our ideas about the nature of living matter.

Rovers Recollected

The robotic pursuit of life is a laborious enterprise, even for rovers – cast to explore, they are destined to experience and to live, but also to die on Mars. Their presence on the red planet gradually takes its toll;

Martian dust eventually enters their sealed joints, their wheels steadily deteriorate, they get caught in sand storms, their scientific instruments degrade, and progressively, their body parts are damaged beyond repair. While all Mars rovers have significantly exceeded their estimated lifespans, their exploration ultimately terminates in its final stage – death. (Mars rovers never retire; they go straight from their labour to their deaths.) Thus far, Mars has been "the final destination" for two rovers, Sojourner and Spirit. On 17 September 1997, in the 83rd sol of its mission, Sojourner contacted NASA for the last time. After being charged and recharged for a three-month period, the battery of the Mars Pathfinder, the lander via which the rover communicated with Earth, permanently gave up. For several months, its ground control had unsuccessfully attempted to repair the connection with the rover, and the mission was aborted on 10 March 1998. What happened to Sojourner after the communication breakdown remains a mystery. A satellite image taken by the Mars Reconnaissance Orbiter in 2007 identified the Mars Pathfinder, but provided insufficient evidence with which to determine Sojourner's position; it was unclear whether it executed the last command it received and crept back toward the lander, or whether it simply wandered off in some unknown direction and was lost. Spirit's life on Mars was marked by a series of unfortunate events. In March 2006 its right front wheel stalled, leaving it to drag, impeding the "primacy" of its movement, and in November 2008 a tremendous dust storm that roared across Mars incapacitated its energy supply and shut it into hibernation for three days. The rover got terminally stuck in a patch of soft soil in May 2009 and JLP's attempts to free it were relentless, but futile. In January 2010 the crippled Spirit was recast to explore in a stationary mode and its immobility began to hinder access to the power supplied by the sun. The rover went *incommunicado* in March 2010, its 2210th sol on Mars. The JPL speculated that Spirit perhaps "temporarily" turned itself off while trying to recharge its batteries, or that its mission clock failed and, having lost its orientation in time, it accidently went into a sleep mode; despite the efforts to re-establish contact with the rover, Spirit never awakened. Since May 2011, when attempts to recuperate it were terminated and the end of its mission was officially announced, the rover has been left to rest in the Troy crater, west of the Home Plate plateau, in the Martian southern hemisphere.

The milieu of Mars gradually tears and wears a rover's body until its death is an imminent event. The human–machinic networks invested in Mars exploration seek to delay the demise of rovers and protect the vitality of the robotic mission by preserving the fragile materiality of their embodiment. When a rover meets with a fatal accident the assemblage that animates it searches for a rescue solution, trying to heal its dysfunctional extremities and revive its performance, but finally communication fails and the appendage is severed. However, the deaths of Mars rovers such as Sojourner and Spirit are part of the progress of robotics; they are evolutionary sequences in its development as a living network of humans and technologies. These deaths are also each a result of an error that takes place within the Martian unfolding of the robotic; they are failures that occur within exchanges with the milieu of Mars. In Canguilhem's vitalist thought, error is intrinsic to life and life evolves through error; summarised by Foucault in his introduction to Canguilhem's *The Normal and the Pathological*, error for Canguilhem 'is the permanent chance around which the history of life and that of men *[sic]* develops' (1991: 22-23). Yet error, aside from being destructive, is 'instructive' (Canguilhem 1991: 61). While Mars rovers might falter and fall, their fatal errors become part of a learning process that forwards not only the scientific capacity for robotic exploration, but also the evolution of the human–rover network, and a language to accompany it. This evolution is twofold. It not only improves the longevity and embodied performance of the rovers in relation to their milieu; it also strives toward enhancing the communicative bonds between the organic and inorganic elements of the assemblage. The most significant step in this direction is the ongoing project of establishing a permanent internet connection between Earth and Mars, which would overcome the interplanetary distance and erase the present communicative delays and errors. These strategies are oriented toward strengthening both the material aspects of the embodied robotics, and the social relations between the human and the rover. While obstructed by error and death, the entwined agencies of this robotic life continue to grow in response to the Martian milieu.

Opportunity and Curiosity are currently actively exploring Mars, but their sols on the red planet are numbered. When an error incapacitates their bodies and their ties with Earth, they too will die. More robust rovers more firmly knotted into communicative networks are likely to land on Mars; perhaps they will even perform autopsies upon the bodies of their progenitors and dissect their errantry in order to absorb their past experiences. It appears at least possible to speculate that the robot bodies that wander Mars will take on new shapes, evolve new sensitivities, and be incorporated into an ever more sophisticated network of living relations. The kind of life spun from the robotic probes on Mars might progress to such a degree that it blurs its parts into a whole and the idea of human exploration of space becomes an ontological anachronism. It is clearly conceivable that the wet bodies of human explorers will eventually be sent to Mars; it is less clear how they will encounter the dead and dying bodies of their robotic envoys. Will their life and labour on an alien world be enshrined in death, their bodies becoming historical monuments or avoided as garbage piles on the outskirts of human life on Mars, or, perhaps, will we strip them for their parts and harvest their bodies to construct new objects and apparatus? Perhaps the life which encounters the graves of "old" rovers will recognise its former self in these remnants; perhaps they will remind us of life as it used to be and allow us to recognise what we have become. Our arrival on the red planet will represent a defining point in our rapport with rovers. It will demand consideration of new forms of Martian intimacies bred between the nodal, living, human–technological network of robotic agency and its new, entirely extraterrestrial planetary milieu. This event could be the *kairos* of robotics, the moment in which post-terrestrial futures and their cosmobiopolitical organisation are unmistakably determined by the creative potential of human technologies.

Biographical Note

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FCJ-206 From Braitenberg's Vehicles to Jansen's Beach Animals: Towards an Ecological Approach to the Design of Non-Organic Intelligence

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Abstract: This article presents a comparison of two proposals for how to conceive of the evolution of non-organic intelligence. One is Valentino Braitenberg's 1984 essay 'Vehicles: Experiments in Synthetic Psychology'. The other is the Strandbeesten (beach animals) of Dutch engineer-artist Theo Jansen. Jansen's beach animals are not robots. Yet, as semi-autonomous non-organic agents created by humans, they are interesting in the context of the development of robots for how they present an ecological approach to the design of non-organic intelligence. Placing Braitenberg's and Jansen's approaches side by side illuminates how Jansen's approach implies a radically different take than Braitenberg's on non-organic intelligence, on intelligence as environmental, and on what the relationship between agency and behaviour might comprise.

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For more than twenty years now, Dutch artist and engineer Theo Jansen has been invested in the development of new, non-organic species that he refers to as Strandbeesten, which in English translates to "beach animals". His beach animals are creatures constructed from plastic conduit normally used to house electric cables, ropes, plastic bottles and pieces of sailcloth. He describes them as 'skeletons that are able to walk on the wind'. They are called 'animals', yet they are completely inorganic. They use the wind to propel themselves and require no other fuel or food. Over time, Jansen has managed to develop creatures that are increasingly capable of 'surviving' on their own. His ideal plan is to put the beach animals out in herds on the beaches and have them live their own 'life'. [1] The intricate complexity and transparency of the beach animals, and the precision of their movements in response to wind and sand, are fascinating to watch. Equally fascinating are the questions they raise about (among others) the materiality of experience, the relationships and differences between the organic and the non-organic, and the definition of life and of intelligence from a post-anthropocentric perspective.

Figure 5. Theo Jansen with 16 Animaris Umeris, 2009. Photo: Loek van der Klis

This article places Jansen's beach animals and the questions and issues they provoke in the context of the development of robots. Jansen's beach animals are not robots. They were not designed to fulfil any practical purpose. They do not involve electromechanical constructions or computer programming. They do not mimic human or animal behaviour. Yet, as semi-autonomous non-organic agents created by humans, they are interesting in the context of the development of robots for how they present an ecological approach to the design of non-organic intelligence. They invite a rethinking of experience and intelligence from a non-anthropocentric perspective and point to movement as crucial to both the intelligence of non-organic agents and the ways in which humans relate to such agents.

I will start from a comparison of Jansen's beach animals as a model for a non-organic evolution with another proposal for such evolution by Valentino Braitenberg in his 1984 essay 'Vehicles: Experiments in Synthetic Psychology', a text that has become a classic in the teaching of artificial intelligence and robotics. Braitenberg's essay is not a practical exploration like the development of Jansen's beach animals, but a thought experiment. Braitenberg himself describes it as 'an exercise in fictional science' (1984: 1); not for amusement, he adds, but in the service of science. As a thought experiment, the evolution he describes in his essay is meant to inspire thinking about the development of non-organic behaviour and intelligence. Precisely as a thought experiment, his text is interesting because of the assumptions implied by *how* it invites the reader to think about non-organic behaviour and intelligence. My aim is not to discuss to what extent either Braitenberg's thought experiment or Jansen's ongoing practical explorations can be compared to organic evolution as described by Charles Darwin and others, but rather to show how the comparison with organic evolution is evoked by each of them in the form of stories that unfold through metaphorical and (imagined as well as concrete) material relays. I will show how each of these stories has different implications for understanding what is intelligence and what might be the relationships and differences between human intelligence and non-organic intelligence. Placing Braitenberg's and Jansen's approaches side by side illuminates the specificities of Jansen's approach and how this approach implies a radically different take than Braitenberg's on non-organic intelligence, on intelligence as environmental, and on what might be the relationship between agency and behaviour.

Jansen's beach animals demonstrate an understanding of intelligence as grounded in what Mark Hansen (2015) proposes to call "worldly sensibility". The current state of technological developments, Hansen points out, puts humans in a situation in which more and more capturing, storing, transmission and interpretation of information happens in ways that are inaccessible to humans. Digital and networked technologies operate at scales and speeds and according to logics very different from human modes of experiencing, communicating and thinking. More and more communication and information processing is going on in ways to which humans have no access. This situation, Hansen argues, requires a thorough rethinking of perception and experience (and intelligence, I would add) beyond the human centred approaches that dominate our current understanding of them. Hansen elaborates a non-human centred approach to experience and agency via a rereading of the philosophy of Alfred North Whitehead. Whitehead died in 1947 and his work therefore is not, and could not have been, about the kind of media developments that motivate Hansen's rethinking of experience and agency. Yet what Whitehead proposes is an approach that understands human experience as one variation of experience among other types of experiences, like non-human experiences, and even non-organic experiences. [2]

Whitehead's theory is not an empirical approach that explains how organic and non-organic experience developed, but a speculative ontology that helps us to see how we may conceive of human and non-human experience, or organic and non-organic experience, in terms of a continuity of variations rather than in terms of fundamental difference. Jansen's beach animals and Braitenberg's vehicles might be conceived similarly as speculative approaches to the relationships and difference between the organic and the non-organic with regard to experience and intelligence. An important difference between Jansen's and Braitenberg's approaches is that Braitenberg assumes non-organic intelligence to be fundamentally different from organic intelligence, and conceives of the development of intelligent machines in terms of assuming the need to mimic what we typically perceive as human conscious intelligence. In contrast, Jansen's approach suggests a continuity between organic and non-organic intelligence in that both are grounded in embodiment and take shape via their capacity of increasingly complex responses to an environment. This is an approach in line with N. Katherine Hayles' (2016) observations that the dominant focus on human intelligence as characterised by conscious experience and choice making blinds us to the actual modes of operating of other types of intelligence, and even to large parts of how human cognition operates. The analogy to explore, Hayles argues, is not that between technical systems and consciousness, but that between various types of non-conscious cognition in humans, other biological entities and technological systems. [3]

A Darwinian Approach to Vehicles

Braitenberg begins his essay 'Vehicles: Experiments in Synthetic Psychology' with an invitation to his readers to imagine very simple machines and to look at these machines, or vehicles, as he calls them, 'as if they were animals in a natural environment' (1984: 2). He explicitly evokes the evolution of organic life as a model for the narrative he is going to unfold, and in a way analogous to Darwin's approach to evolution he starts his description from the simplest of vehicles, Vehicle 1, which is 'equipped with one sensor and one motor. The connection is a very simple one. The more there is of the quality to which the sensor is turned, the faster the motor goes' (1984: 3). This quality could be, for example, temperature: the vehicle will speed up in warm regions and slow down in cold regions. Of course its exact speed will also be influenced by the medium through which it moves (air, water, etc.), the surface on which it moves (hills or slopes, rough or smooth, etc.), and what it bumps into. All of these together will determine its speed and influence its direction. 'Imagine, now', Braitenberg invites his readers, 'what you would think if you saw such a vehicle swimming around in a pond. It is restless, you would say, and it does not like warm water. But it is quite stupid, because it is not able to turn back to the nice cold spot it overshot in its restlessness' (1984: 5).

The description of Vehicle 1 is followed by a description of Vehicle 2, which has two sensors and two motors that can be connected in various ways, allowing for more varied and complex responses to its environment. And then more sensors and more connections are added, threshold devices, circuits, photocells, object detectors, movement detectors, and so on. Braitenberg describes very vividly how each step in the evolution of his vehicles will result in different movements, producing what seem to be different personalities with different likes and dislikes, aims, instincts, and even values and feelings like love. His essay plays in an often quite funny way with the reader’s surprise as to how very simple sensors and motors would indeed produce something that looks to us like behaviour motivated by, for example, love, without involving any such experience or even any kind of consciousness on the part of the vehicle. At one point, Darwin’s idea of natural selection is invoked, when Braitenberg invites his readers to imagine a table upon which some of the more complex vehicle specimens are placed. There will also be 'some sources of light, sound, smell, and so forth on the table, some of them fixed and some of them moving. And there will be various shapes or landmarks, including the cliff that signals the end of the tabletop' (1984: 26). While the vehicles are put to the test, the ones that keep circulating on the table are copied and vehicle and copy are both placed back on the table. Those that have fallen off the table will not be placed back or copied. Since copying will have to happen at high speed, mistakes are likely to be made every now and then, as a result of which new variations emerge.

Braitenberg’s narrative captures how natural selection gives direction to evolution and how the direction that evolution takes depends on which organisms happen to survive within given circumstances. It also captures how incidental changes, with regard both to the capabilities of the creatures and to the circumstances they encounter, can affect the chances of survival and thus the direction that evolution takes. Braitenberg’s narrative about what happens on the "table of the fittest" (my term) shows evolution to be, not a teleological development towards a pre-given goal to which creatures adapt, but dependent on how well creatures are capable of surviving due to their innate capacities, and how incidental changes – to their construction and/or their environments – can therefore prompt radical changes in who "fits" best and survives. In this respect, his imagined evolution is quite biblical in how it starts from creatures seemingly created out of nothing, who find themselves in an alien world where evolution takes over from the creator such that whether they survive or not will depend on the extent to which their equipment will support their survival in the environments they encounter.

Every now and then, in Braitenberg’s essay, creators step back in and change the course of the evolution by adding some new features (for example, additional motors and sensors, or additional connections). Their role in the narrative highlights the difference between an organic evolution as described by Darwin, which lacks such a creator, and a non-organic evolution in which humans are involved as creators. A closer look at these creators' role in Braitenberg’s narrative also highlights some ambiguities or tensions within the narrative. What exactly do these creators aim to achieve by adding some features and not others? A closer look at the text reveals the intentionality of these shifts, and hence the way in which the comparison with organic evolution is invoked. For example, at the very beginning, when a second motor and sensor are added to Vehicle 1 to create Vehicle 2, it is observed that 'you may think of it as being a descendant of Vehicle 1 through some incomplete process of biological reduplication: two of the earlier brand stuck together side by side' (1984: 6). This invokes a comparison with organic evolution, in that new variations are constructed as if they could have been accidental modifications of previous generations. Several vehicles later, however, it is no longer explained how the selection of new features added by creators could have emerged from modifications of previous vehicles. Rather, now we are told how these additions allow vehicles to do things that look like intelligent behaviour. Creators are adding features to serve a goal they have in mind, introducing the comparison with organic evolution through the idea of natural selection as a means by which to test which addition works best. It becomes increasingly unclear, however, how natural selection as accounted for in the narrative (the struggle for survival on the "table of the fittest") relates to the rationale behind the features added by the creators. Their selection of features seems to have less and less to do with what is required to survive on the "table of the fittest" (which is envisaged as a kind of Paris-Dakar race); instead, it is increasingly explicitly motivated by how these new features will result in what looks like intelligent behaviour, perceived by humans as an expression of quasi-human personality. Intelligence is now measured in terms of how well the vehicles' behaviour passes for the expression of human-like intelligent behaviour, understood in rather Cartesian terms as an expression of a private interior as driving force behind public exterior behaviour. This is most explicit when the final vehicle (Vehicle 14) is introduced with the following observation:

> As time goes on, we grow affectionate toward the diversified crowd of our vehicles, from the very simple ones to the more complex models displaying interesting social interactions and sometimes quite inscrutable behavior. … We do not feel, however, that they show any personality, not even the most complex ones of type 13. … Perhaps we would accept them more readily as partners if they gave more convincing evidence of their own desires and projects. We notice that our fellow men usually seem to be after something, when they go about their business or when we converse with them. Dealing with people is interesting because of the challenge their continuous internal scheming seems to provide. The system of desires we suspect behind their scheming may be part of what we call the personality. (1984: 81)

The narrative continues with a description of how the addition of a new feature can contribute to giving the impression of precisely such behaviour. The chapter thus explains how the behaviour of the vehicles can be made to *appear as if* driven by desires similar to those of humans. And this is where the evolution of the vehicles ends.

A closer look at how the comparison with organic evolution is evoked in Braitenberg's narrative shows that his use of evolution as metaphor does not actually explain the development of non-organic intelligence, but rather naturalises a particular understanding of what non-organic intelligence is, specifically how such intelligence manifests itself in behaviour that looks like human intelligent behaviour while actually operating in very different and much more simple ways. Instrumental here is the shift in what counts as progress in the evolution described above, from increased capacity to adequately respond to the environment on the "table of the fittest", to increased capacity to show behaviour that looks like an expression of an intelligence similar to humans'. Braitenberg's story thus affirms the assumption that human intelligence is the aim and endpoint of the evolution of intelligence while at the same time establishing a firm distinction between human intelligence and that of the vehicles. For what his "evolution" works towards is not intelligence like human intelligence but behaviour that *looks like* an expression of human intelligence. Early in the essay Braitenberg states that 'when we analyze a mechanism, we tend to overestimate its complexity' (1984: 20), and time and again his narrative explains how behaviour that looks like that of a human-like intelligence can be achieved using relatively simple means. His narrative thus presents a comforting message to designers trying to achieve something that looks like human intelligence, and also provides a reassuring response to the threat of what – in relation to more complex creatures – is called the uncanny valley effect (Mori, 1970): when robots become increasingly human-like, at first this helps humans to relate to them until, at some point, as the border between human and non-human begins to blur, the human likeness of robots begin to evoke uncomfortable feelings in humans. If indeed 'when we analyze a mechanism, we tend to overestimate its complexity', we may conclude from Braitenberg's argument that there is nothing to fear, since the effect of complex behaviour in machines is actually the effect of much simpler mechanical responses. "They" are not as intelligent as we are, even if they appear to be so.

We might wonder, however, if the vehicles' very basic causal responses are capable of producing behaviour that looks like that of intelligent life, whether this could not equally be the case with what we perceive as intelligence in organic life. Even if we do not take this to mean (as Braitenberg suggests with regard to the vehicles) that intelligence is mere illusion, this possibility does have radical implications in how it invites a reconsideration of human intelligence and the relationship between human and machine intelligence. Such rethinking is, according to Hansen (2015), precisely what current technological developments require us to do. Hansen's point is not that human intelligence is mere illusion, but that approaching perception and experience by privileging a human perspective blinds us to the fact that human conscious perception and experience are only variations on what perception and experience can be. Such privileging of a human perspective can be seen at work in Braitenberg's explanation of the behaviour of his machines. If we look at a vehicle's behaviour as if it were that of a human, or trying to mimic that of a human, then the behaviour may indeed appear to be as one observes. But actually, this behaviour is the direct result of the vehicle's responses to its environment by means of what it is equipped with in order to perceive and respond. The vehicle is not pretending anything, but is responding to what it encounters according to how it is wired. If we look at the behaviour of the vehicle from this perspective (that is, from the perspective of what makes sense for the vehicle) then its behaviour is a perfectly logical response to what it encounters.

Affordances and Ecology

Braitenberg's account of the vehicles prevents a reading of their behaviour in terms of a sensible and intelligible response to their environment because his narrative does not give a clue as to why their sensors respond in the way they do, or how this is related to the functionality of the vehicle within the environment. This omission sets the stage for the possibility of reading the behaviour for what it is not. Regarding Vehicle 3c, Braitenberg observes:

> This is now a vehicle with really interesting behavior. It dislikes high temperature, turns away from hot places, and at the same time seems to dislike light bulbs with even greater passion, since it turns towards them and destroys them. On the other hand it definitely seems to prefer a well-oxygenated environment and one containing many organic molecules, since it spends much of its time in such places. But it is in the habit of moving elsewhere when the supply of either organic matter or (especially) oxygen is low. You cannot help admitting that Vehicle 3c has a system of VALUES and, come to think of it, KNOWLEDGE, since some of the habits it has, like destroying light bulbs, may look quite knowledgeable, as if the vehicle knows that light bulbs tend to heat up the environment and consequently make it uncomfortable to live in. It also looks as if it knows about the possibility of making energy out of oxygen and organic matter because it prefers places where these two commodities are available. (1984: 12-14)

The description explains how the behaviour of the vehicle might be interpreted in terms of likes, dislikes, values and knowledge from the perspective of a human observer watching the vehicle, but leaves out how the causal responses that produce the vehicle's behaviour make sense from the perspective of its modes of operating as well as in relation to its environment, function and survival.

Jansen's beach animals are quite different in this respect. The driving force behind their evolution is the need to improve the way their interaction with their surroundings supports their survival. They need the wind to move and their construction follows from that. They need to be able to move across sand and ideally they should be able to avoid going into the sea because they lack the means to deal with water and will "drown". Their entire construction is the result of an evolution in response to their environment and to the affordances of this environment, and their behaviour follows suit.

Figure 6. 28 Animaris Percipiere Rectus, 2005. Photo: Loek van der Klis

The notion of *affordance* was introduced by James Gibson (1977) to describe the ways in which environments hold the potential for actions and perceptions. Gibson introduces these ideas in the context of evolutionary biology. Some environments, he observes, afford activities like walking, picking berries or growing plants, whereas others afford climbing trees, hunting animals or catching fish. What people or animals will do in certain environments will depend not only on what they are capable of but also on the affordances of the environment and how it invites them to use their capacities in certain ways rather than others, and to develop certain capacities rather than others. Gibson also uses the idea of affordances to elaborate an understanding of perception as resulting both from interactions afforded by the environment and from our perceptual systems.

Gibson's ideas about affordances have become important to embedded and enactive approaches to perception and cognition. They have also found their way into theories of design, wherein they are used to describe how design affords perceptions and actions, and also how design can start from the relationships between the affordances of the environment and that which is to be designed. Applied to the design of robots or other mechanical creatures, this would mean an approach that does not start from an autonomous entity that then has to prove its capability for survival in an encounter with an environment, but from the potential of the environment and how the creature-to-be-designed can tap into this potential – that is, actualise it. This is called an ecological approach to design; Jansen's beach animals are a pertinent example.

The potential of the wind to generate movement and the sand to carry certain structures and afford them to move is the starting point for the animals' development. Thus, their design is a response to the potential of the environment, leaving space for interaction and growth. Evolution here is not a confrontation with the environment – wiping out all but the fittest – but rather a creative exploration that aims to maximise interaction with the environment. It is from this interaction that the beach animals evolved into more complex creatures. Evolution here does not describe evolution of the creature as autonomous entity capable of surviving (or not) in an environment. Rather, it describes an evolution of the creature–environment relationships towards ever more complexity. Increasing the complexity of the creature at the same time increases the number of its complex relations with the environment.

Similarly, an ecological approach to the design of intelligent machines would not mean designing an intelligence and then seeing how this intelligence appeared to operate in an environment, but instead starting from how the potential of an environment might be actualised by a creature and how the design and the intelligence of the creature might follow from this. Discussing an ecological approach to engineering, Peter Trummer (2008) refers to Félix Guattari's (2014) elaborations on ecological thinking in terms of the real, the possible and the virtual. Using Guattari's terminology, Trummer contrasts an ecological approach to design to a more traditional engineering approach that thinks in terms of the real and the possible, where the real describes what is already there and design is thought of in terms of what is possible in already given conditions.

> Possible is what we can imagine. It is that which we want to realise. Such practices deal with two essential rules: one is to resemble or to imitate, and the other is limitation, the conformation to existing models. (2008: 98)

True ecological thinking, Trummer observes, moves beyond these limits and requires an understanding of ecologies as virtual environments in which what is already there (species, objects) is actualised but in which there are also potentialities that are not yet actualised. The challenge of ecological design is to actualise these unrealised potentialities. The evolution of the beach animals shows how Jansen's ecological approach actualises new ways of turning wind into kinetic energy and new ways of moving by means of an intricate leg system. Their evolution continues to actualise more possibilities for relating the creatures and their environment by means of systems that afford the wind to create pressure in plastic bottles that can then be used to move when there is no wind, as well as systems that allow water to trigger a causal logic that results in a shift in the direction of movement (and thus for the animal to avoid walking into the sea), and still other systems that afford the air pressure of approaching stormy weather to trigger a causal logic that anchors the animal to the ground.

Non-organic Intelligence

The design of the beach animals affords them to respond to their environment in ways that allow them to move, collect and store air supply and, increasingly, to avoid entanglement in the sea or being blown away by a storm. They are not equipped with sensors and they lack anything like consciousness. Nevertheless, they are capable of meaningful responses to their environment as a result of complex accumulations of instances of cause and effect. I propose for them to be understood as demonstrations of the emergence of very basic non-organic intelligence. This intelligence is not something "behind" their movements – a kind of blackboxed brain ordering the animal around – but is emergent in how their bodies are capable of responding to wind, sand and water and in how they move in response to what they encounter.

The intelligence of Braitenberg's vehicles, too, might be considered a matter of how their design causes them to move in response to what is detected by their sensors. The better they are capable of responding with movement in ways that match the environment, the bigger are their chances for survival. However, Braitenberg's narrative does not explain their intelligence in these terms; he only speculates on how their behaviour might be read for something it is not. He is looking for ways of reading their behaviour in ways that chime with his understanding of his own intelligence, as when for example he wonders:

> But do they think? I must frankly admit that if anybody suggested that they think, I would object. My main argument would be the following: No matter how long I watched them, I never saw one of them produce a solution to a problem that struck me as new, which I would gladly incorporate in my own mental instrumentarium. And when they came up with solutions I already knew, theirs never reminded me of thinking that I myself had done in the past. (1984: 51)

The vehicles do not think, he argues, because he has never recognised anything like his own thinking in them.

Braitenberg's explanation not only illustrates the anthropocentrism of his approach to intelligence but also a problem observed by Hansen, namely how such a human dominated perspective is preclusive of relating to other kinds of intelligence that we are surrounded by and that increasingly produce our world for us. Hansen is not referring to robots but to digital and networked technologies that no longer function as analogous to prostheses – providing humans with extensions of human - ways of perceiving, experiencing and thinking – but that now operate at speeds and scales and according to logics quite different from those of humans. High-tech sensors perceive things that humans cannot; computers process data in ways that humans cannot; massive amounts of communication are going on between machines that remain imperceptible to humans, etc. For humans to gain access or communicate with these machines, an additional layer of mediation is needed that affords them to connect to what they are doing. Following Braitenberg's logic, we could of course decide that because these technologies operate very differently from humans, these modes of operating have nothing to do with perception and experience or with intelligent behaviour, and that the additional mediation required to communicate with humans is mere make-believe. However, this logic is not going to be of much help in a situation in which these operations are increasingly co-constitutive of what appear to us as our world, our perceptions, our experiences and our thinking. What we need is to develop more awareness of, on the one hand, technology's ways of communicating with us as a milieu within which our perceptions and experiences are implicated and, on the other hand, the difference between human and technological forms of communication and their modes of operating. Looking back at Braitenberg's example of the vehicles, this means to develop an awareness of how the appearance of their behaviour results from how this behaviour (intentionally or unintentionally) affords to be read in human terms. At the same time, considering their intelligence will require a reconceptualisation of our very understanding of perception and experience from a non-anthropocentric perspective. Hansen shows how Whitehead's speculative ontology provides a starting point for such reconceptualisation. He also shows how this reconceptualisation requires us to think through the implications of Whitehead's ideas beyond Whitehead's own era and from the perspective of current technological developments. Central to both Whitehead's actuality and Hansen's further actualisation is what Whitehead has termed 'perception in the mode of causal efficacy'. This term plays an important role in Whitehead's expanded notion of perception as developed in *Process and Reality* (1978). [4]

Whitehead introduces this concept in the context of a critique of what he describes, in the following, as a too simplistic understanding of perception.

> We open our eyes and our other sense organs; we then survey the contemporary world decorated with sights, and sounds, and tastes; and then, by the sole aid of this information about the world, we draw what conclusions we can as to the actual world. (1978: 174)

Instead, he proposes an understanding of perception as a 'mixed mode' that involves a combination of what he calls 'presentational immediacy' and 'causal efficacy'. Presentational immediacy describes

> the perceptive mode in which there is clear, distinct consciousness of the "extensive" relations of the world. These relations include the "extensiveness" of space and the "extensiveness" of time … In this mode, the contemporary world is consciously prehended as a continuum of extensive relations. (Whitehead, 1978: 61)

All too easily, Whitehead observes, the primacy of presentational immediacy is assumed to be an obvious fact. In fact, however, presentational immediacy is grounded in perception in the mode of causal efficacy, which designates the causal background of experience, this comprising the material processes that inform conscious perception and remain to a large extent outside conscious awareness, but from which conscious perception emerges. Whitehead uses "causal efficacy" to refer to a diversity of ways in which bodies register what they encounter without incurring objectifications, that is, without that which is registered becoming an object of perception for a percipient. It is only in the mixed mode, that is, in combination with presentational immediacy, that such objectifications happen and that perception becomes conscious perception.

Whitehead offers an understanding of perception that grounds conscious perception within a much broader understanding of what perception may entail. His approach opens up perception 'beyond sense perception proper, to the material processes that do not manifest in sense perception but that nevertheless are necessary for its occurrence' (Hansen, 2015: 20). This understanding affords an expansion of sensing beyond human conscious perception and including other ways of making contact with 'the operational present of sensibility' (Hansen, 2015). Perception understood as a mixed mode can explain how perception may involve different degrees of consciousness and this makes it possible to understand human, animal and even vegetal modes of perceiving in terms of a continuum of possibilities. Whitehead goes as far as to include non-organic perception on this continuum. Stones, atoms and objects can also be understood to perceive in the mode of causal efficacy, he argues, yet in their case this does not become connected to perception in the mode of presentational immediacy.

Whitehead proposes an expanded understanding of perception that includes non-human and even non-organic perception; yet, human perception (implicitly) remains the norm in that it presents the fullest embodiment of the model. Furthermore, presenting the mixed mode as the model for perception implies that non-organic perception (consisting only of perception in the mode of causal efficacy) lacks something. This is reflected in Whitehead’s renaming of this mode as "nonsensuous perception", as distinct from sense perception, in *Adventures of Ideas* (1933) (see also Hansen, 2015: 19). Non-organic perception appears as somehow incomplete, the lowest ranking mode on a continuum that finds its highest expression in human conscious perception. It is at this point that Hansen proposes a radicalisation of Whitehead’s model by means of centralising perception in the mode of causal efficacy instead of perception in the mixed mode. Thus inverted, Whitehead’s speculative ontology can still explain various modalities of conscious perception as variations on a continuum, but it no longer centralises human conscious perception and the mixed mode of perception as the model for the evolution of higher order perception. This opens the possibility of conceiving alternative modes of higher order perception, modes that do not evolve via the mixed mode model and do not involve consciousness. This possibility becomes most relevant in relation to current technological developments.

Typical of current technological developments is that they 'impact the general sensibility of the world prior to and as a condition for impacting human experience' (Hansen, 2015: 6). What Hansen means is that digital and networked technologies, as well as technologies like sensors that probe the world and gather data beyond the scope of human perception, function in ways that are no longer correlated directly to human modes of sensory experience. In order for humans to relate to what is sensed and processed by these technologies, additional mediation is required to translate what is captured and processed into what is accessible to human perception. These technological developments thus foreground what Hansen describes as the inherent or constitutive doubleness of mediation: 'their simultaneous, double, operation as both a mode of access onto a domain of worldly sensibility and a contribution to that domain of sensibility' (2015: 6). Because twenty-first century technology increasingly provides access to what previously fell outside the scope of our perception and conscious awareness, these technologies simultaneously also extend the domain of sensibility. Furthermore, they combine in their mode of operating something that cannot be combined in consciousness: 'To the extent that they centrally involve data processing, twenty-first century media bring together an intentional relationship to sensibility (the fact that data is about sensibility) with a nonintentional relationship to sensibility (the fact that data is sensibility)' (2015: 7). In the internal operations of twenty-first century media technology these two are combined. Confronted with these technologies, therefore, it becomes relevant to consider the possibility of higher intelligence that does not develop via the mixed mode model of perception but through increasingly complex lineages of causal efficacy. Such rethinking of intelligence may shed new light on the role of non-conscious perception and experience in organic intelligence. As Hansen points out, the rise of twenty-first century technology foregrounds aspects of perception and experience that probably already existed, but had gone unnoticed. And as Hayles observes, it might be that the combination of non-conscious perception and cognition, rather than conscious perception and cognition, provides the key to understanding the relationships between human and non-human intelligence (Hayles, 2016).

The evolution of the beach animals is an exploration of such non-conscious non-organic intelligence. They demonstrate behaviour that we assume requires either organic intelligence (including some kind of consciousness), or a system of sensors and wires mimicking organic intelligence. At the same time, the transparency of their construction demonstrates how their behaviour is constituted through accumulations of instances of cause and effect. As low-tech explorations of non-conscious intelligence, their evolution is much more accessible to humans than the machinations of twenty-first century technology, and yet allows for an exploration in line with Hansen’s observation that twenty-first century media technologies confront us with aspects of perception and experience that are not unique to these technologies but are foregrounded by their pervasive presence and increasing impact on our lives.

Figure 7. 48 Animaris Umerus, 2009. Photo: Theo Jansen

As demonstrations of increasingly complex behaviour in response to their environment, the beach animals suggest that the development of higher intelligence might not necessarily involve a ghost in the machine (the Cartesian model), or a consciousness emerging from mixed mode perception (Whitehead), but that it could be a matter of how combinations of individual instances of causal efficacy feed forward (Hansen) into more complex forms of non-conscious experience. The beach animals invite reconsideration of agency and of higher order intelligence as the effect of this logic at work in their behaviour. What appears as their agency is not a matter of a centralised consciousness steering their actions but of a great number of individual causal interactions between elements of the animal, the sand, the wind, the water and so on. The beach animals demonstrate how what can be perceived as the agency of the animal results from what we could, after Whitehead (1978), call a "society" of elements that together is the animal, and how this society of elements holds together a great number of individual instances of causal efficacy. They also show that this society does not require consciousness or centralisation. The animals' agency is environmental in how it emerges as the effect of patterns of interaction between parts of the animals and the environment. Their agency is not that of agents using sensors to reach out and probe their environment; it emerges from what might be described as environmental sensibility, from the ways in which elements of the creatures' bodies are capable of interaction with the environment. Together all these interactions produce the behaviour that sustains their survival.

Movement

As a model for the design of intelligent machines, the beach animals point to movement as a central concern: movement is the basis for their intelligence and movement is also the basis for how humans relate to them. Braitenberg's narrative, too, points to the centrality of movement in terms of how machines are perceived as agents. Even though Braitenberg shows this perception to be a misreading (a misreading that does not result from the vehicles' behaviour being deceptive, as Braitenberg's narrative suggests, but from the perceiver's unawareness of the actual causality that determines the responses of the vehicles), his explanation does illustrate how human perceivers relate to the behaviour of the vehicles in terms of an action in response to the affordances of their environment. This is also the case with the beach animals. They suggest an approach to developing a robot's identity that does not start from designing an exterior to house its operating system, but from designing its modes of operating, in particular its movements, in ways that take into account how they will constitute the robot as an intelligent agent. Such an approach is currently being explored in the Australian Research Council funded research project 'Performative Body-Mapping (PBM): a new method towards socializing non-humanlike robots', led by Petra Gemeinboeck (see also Gemeinboeck and Saunders, 2016).

The beach animals also show that the possibility for humans to relate to their movements is not a matter of recognising similarities between their movement and that of humans or animals. The bodies of the beach animals are actually in many ways quite unlike the bodies of animals and their movement does not look much like that of a human or an animal (as it would, for example, in an animation that used motion capture to produce human- or animal-like movements in creatures that do not look like humans or animals). What makes them life-like is how their movements respond to the affordances of the environment, and how we can perceive them in these terms. This is similar to how we understand the movements of other humans. Enactive approaches to perception and cognition like those of Varela, Thompson and Rosch (1993), Noë (2004) and Berthoz (2000) point to the centrality of movement to how humans perceive and make sense of what they encounter. Through experience with (self)movement we make sense of the world we encounter in terms of potential for action. We are capable of perceiving the world as a space filled with three-dimensional objects (instead of perceiving only one dimension of each thing) because we are familiar with the effects of movement and allow them to inform how objects and space appear to us. Movement is also the basis for our understanding of the behaviour of other bodies as variations of possible movements of our own body. That is, understanding the movements of others or understanding others through movement does not mean that the movements have to be similar to those of the body interpreting them. Key is that we can make sense of them in terms of potential action.

Figure 8. 21 Animaris Gubernare. Photo: Theo Jansen

The skeletal construction of the beach animals foregrounds the logic of action and response from which their movements result and appeal to the creative imagination of humans encountering them. This makes them so interesting as examples of the potential of movement for developing new human–machine relationships. Movement affords an approach to developing such relationships that does not start from a gap to be bridged between human and machine (for example by making the machine human-like) but from the potential of humans to relate to and interpret a diversity of movements. Enactive approaches to perception and cognition explain how this potential is not a matter of movements being recognisable as representations of human movement, but of harnessing the ways that humans are capable of making sense of what they encounter as a result of their own bodily experience with (self)movement.

Co-evolution

The evolutionary processes of Braitenberg's vehicles and of Jansen's beach animals both involve humans as creators. In Braitenberg's narrative, human intervention manifests mainly in the creation of the first vehicle, in new features being added to the vehicles, and in vehicles that manage to survive on the "table of the fittest" being copied. Evolution is thus presented as a project inaugurated by creators from a certain distance; they "throw" a first machine into the world and add new inventions every now and then to see how a seemingly autonomous process of the survival of the fittest might eliminate all but the "best" version. Jansen's role with regard to the beach animals, on the other hand, is that of a creator deeply invested in improving the chances of survival of all his creations and in maximising the ways in which they relate to their environment. His ideal plan is that one day the beach animals won't need him anymore, so that he can step back and leave them to their own independent lives on the beach.

Braitenberg and Jansen seem to share the attitude that neither of them conceive of themselves as being implicated in the evolution of their own intelligent machines. In both cases humans make the evolution happen, but the evolution, it seems, does not affect them. Such a perspective on humans as mere inventors, creators and users of technology overlooks how what is considered to be human is actually the product of our co-evolution with technology and how the development of the vehicles, the beach animals, robots and other technologies is part of this co-evolution. This is what Hansen (2000, 2006), Hayles (2012), Bernard Stiegler (1998, 2009, 2011) and others term "technogenesis". The idea of technogenesis is that humans and technology have co-evolved and that human intelligence cannot be understood separately from the technologies that humans use and through which they relate to their environments. This idea may seem unusual if one assumes that human thinking is done by an autonomous mind existing independently from its environment (and therefore from how "its" body interacts with this environment). Yet, the idea that cognition developed through the interaction of humans with tools and technologies is not controversial at all in fields of research like palaeoanthropology, evolutionary biology and neurophysiology, all of which point to the intimate connection between the development of human intelligence and the tools and technologies used by humans, and to how the use of tools resulted in the emergence of new modes of intelligence. Similarly, Hansen, Hayles and others argue that media technologies and intelligent machines are not merely created by humans but also change how humans perceive, make sense and think. This opens up an additional dimension with regard to ecological design, namely to approach the design of human–machine interaction as the actualisation of still unrealised potentialities. Here it seems movement has a lot to offer.

Biographical Note

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looking forward to further developing ideas together in the context of the 'Performative Body-Mapping' project.

Notes

[1] Jansen’s description of and rationale for the beach animals can be found at http://www.strandbeest.com

[2] Hansen’s interpretation of Whitehead is based on a broad reading of Whitehead’s oeuvre, most centrally *Science and the Modern World* (New York: Free Press, 1967), *Process and Reality: An Essay in Cosmology*, corrected edition, eds. D. Griffith and D. Sherburne (New York: Free Press, 1978), and *Adventures of Ideas* (New York: Free Press, 1933).

[3] These remarks were made by N. Katherine Hayles in her lecture 'Enlarging the Mind of the Humanities: Human and Technical Cognition' at *Worlding the Brain* (University of Amsterdam, 17-19 March 2016). This is also the subject of her forthcoming book.

[4] On this point, Hansen’s reading of Whitehead differs considerably from readings by many other authors that are currently reviving Whitehead’s ideas. In the Introduction and Chapter 2 of *Feed Forward*, Hansen indicates these differences and explicitly distances himself from works by, among others, Brian Massumi, Erin Manning, Luciana Parisi and Steven Shaviro.

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FCJ-207 *Game On*: A creative enquiry into agency and the nature of cognition in distributed systems

Michaela Davies

Abstract: *Game On* is a participatory installation where people use joysticks to control the movement of two (human) boxers via a MIDI-controlled electric muscle stimulation device. This device sends electrical impulses to specific muscle points on the boxers via electrodes connected to their arms, causing each boxer to punch their opponent involuntarily. The work is a creative enquiry into the nature of agency within a system where cognition is distributed across people, objects and environment through technologies of connection. *Game On* explores what happens in a system where embodied experience and sense of agency is disrupted or extended, and the implications for locating a responsible agent within this system.

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Introduction

The focus of this paper is a participatory artwork, *Game On,* which is a boxing "game" where one participant can control the actions of another via electric muscle stimulation. [1] The paper explores *Game On* as a creative enquiry into agency and the nature of cognition in distributed systems. *Game On* explores what happens to agency in a system where embodied experience is disrupted or extended, based on the understanding that a sense of personal agency is created through actions, and that the actions of others influence our understanding of ourselves as separate from them. Participatory artworks like *Game On* can be viewed as a form of performative research, creating a system which is analogous in some ways to states of affairs outside that system. [2] In this way, *Game On* does more than represent possibility: it enables an exploration, in real time and space, of what happens when embodied experience and sense of agency is disrupted or extended using technologies of connection, and the implications of this disruption and extension for locating a responsible agent within this kind of system.

The *Game On* installation design is based on a scene from the 1976 American science fiction thriller film *Future World*, directed by Richard T. Heffron, where human players control android boxers. *Game On* replaces these boxing androids with humans, and draws players from the audience to use joysticks to control two boxers (actual people) via a MIDI-controlled electric muscle stimulation device. Electric muscle stimulation controls motor actions in humans by sending electrical impulses to muscles via electrodes attached to specific points on the limbs, mimicking the impulses sent to muscles from the central nervous system that cause the muscles to contract, so that the affected individual moves involuntarily. The way the players control the boxers in *Game On* is akin to the way a gamer would move a joystick to control an avatar in a virtual fighting game. When the player pulls the joystick toward his or her body, the boxer s/he controls involuntarily raises an arm (to block or prepare to throw a punch), and when the player pushes the joystick forward, the boxer's arm extends involuntarily to throw a punch. [3] By replacing *Future World's* androids with real people, *Game On* explores the challenges faced by society as technology advances to a point where the level of realism in "games" becomes indistinguishable from reality, and poses questions regarding how we might ascribe agency and responsibility in both human and non-human entities.

Figure 9. Figures 1-3: Game On (2013). Michaela Davies. Documentation from Underbelly Arts Festival, Cockatoo Island, Sydney, Australia

Figure 10. Figures 1-3: Game On (2013). Michaela Davies. Documentation from Underbelly Arts Festival, Cockatoo Island, Sydney, Australia

Figure 11. Figures 1-3: Game On (2013). Michaela Davies. Documentation from Underbelly Arts Festival, Cockatoo Island, Sydney, Australia

Extended cognition in the *Game On* system

Game On is a performative realisation of a system where agency is dispersed across people, objects and the environment. In this system the boxer is connected to their player by an electrical network (akin to neurological signals) such that the experience of the player extends to include the boxer s/he controls.

This expansion of agency entails a form of cognition that exceeds the boundaries of the nervous system. Such a view departs from traditional approaches in cognitive science, which abstract cognitive processing from bodily function and consider the body and environmental factors as peripheral to any understanding of the nature of mind and cognition. [4] In contrast to theories of mind that associate the mind with brain function, [5] extended approaches to cognition view cognitive systems as extending beyond the boundaries of the individual organism. [6]

For some authors, the implication of extended cognition is that of an extended *self* [7] wherein features of the environment are 'parts of the computational apparatus that constitutes our minds' (Clark, 2003: 6). This points to a conception of subjectivity as a self that extends beyond the boundaries of the human body, entailing that through an expansion of agency self/other boundaries are permeable: the self as 'porous, spilling out of itself' (Rotman, 2008: 8). On this account, just as the self would extend to include an avatar in a virtual/gaming environment, the player in *Game On* extends to include his or her boxer, rendering it difficult to determine where the player ends and the boxer begins.

An alternative position, and the one pursued in this paper, is that cognition is a relationship between a cognising subject and an independently existing state of affairs. [8] While the player's cognition may exceed the boundaries of their nervous system to include their boxer, the act of cognising is not a quality of the cognisant being (i.e. the player). A quality is a feature of something, whereas a relation is a property that holds between things. [9] Since nothing can be constituted by its relations, 'what knows, as well as what is known, must have a character of its own and cannot be defined by its relation to something else' (Anderson, 1962: 69). Any relation involves at least two or more distinct terms, and each of the terms must have its own intrinsic properties (these are necessary to constitute what stands in the relation).

In the *Game On* system both a subject and an object can be identified: the subject being that which cognises (the player) and the object being the state of affairs known (the boxer). The player's cognitions cannot constitute part of that player's cognitive apparatus. The knower (the player) and the states of affairs known (the boxer) are distinct terms in the cognitive relationship. [10] To view the environment included in an agent's cognitive processing as partially *constituting* that agent's cognitive system is to confuse qualities with relations. Viewed as a relationship, cognition cannot be a property of things, and cannot be reduced to either one of the terms of the relationship. [11]

Bateson's example of a blind man who relies upon a walking stick for locomotion is illustrative here. Does his "self" begin at the end of the walking stick, which taps the ground? Or at the handle of the stick he holds? The stick, for Bateson, is merely 'part of the systemic circuit which determines the blind man's locomotion' (Bateson, 1972: 318). The stick in this example is akin to the *Game On* boxer's arms, which are merely a causal link in the chain along which the transmission and transformation of information occurs. Although the player is the cognising agent insofar as s/he causes the actions of the boxer's limbs, the boxer in *Game On* is no more part of the player's body than a blind man's walking stick is part of the man. However, the player's role in *Game On* is more complex than the scenario described by Bateson, because s/he is controlling a sentient being. That is, unlike the blind man's walking stick, which has no consciousness separate from the man, the object of the player's cognition (i.e. the boxer) is not merely receiving information sent from the player; the boxer is also cognisant. The boxer is aware of his or her actions (i.e. his or her arms directing punches toward the opponent), and is also aware that s/he is not the cause or author of these actions.

Agency in the *Game On* system

There is much evidence to suggest that the sensory-motor operations of the body create a sense of agency, [12] and that a sense of self as agent is built through the capacity to understand ourselves as the authors of our actions, separate from others and from the external world (Jeannerod, 2003). Although the boxers have the experience that they are not the authors of the movements of their arms (i.e. no sense of agency) they still have a sense that the limb being moved is their own (i.e. the experience of being the subject of the movement). [13] With ordinary voluntary movement, a kinesthetic experience of movement elicits a sense of *ownership*, and the experience of being the author of the action generates a sense of *agency.* [14] In the same way as we can know the environment outside our bodies, we can also know bodily events. [15] Through visual and proprioceptive/kinesthetic information (afferent sensory feedback) the boxers in *Game On* are aware that they are moving, but they are not issuing motor commands to generate the movement (i.e. there is no efference).

The boxers are also conscious of themselves as being part of a system, where their control over their actions is disrupted via electric muscle stimulation: thus, while sense of ownership may be related to moments of agency, it extends beyond a given instance or situation. As evidenced in reported responses from *Game On* boxers about their experience of agency during the game, it is clear that boxers still experience an enduring sense of self as agent, even though their sense of agency is disrupted within this system. For instance, one boxer noted, when reflecting on his sense of agency: 'Well, it went out the window, but only within the game context … I still knew that I was ultimately in control of myself' (*Game On* boxer #1, personal communication, 18 December 2013). [16] A broader narrative enables the boxer to maintain the sense that, outside of this system, s/he is the owner of his or her limbs but is choosing to rescind agency temporarily. [17] Indeed, the boxers' ability to rescind control and allow his or her limbs to be moved via an external force is itself an instance of agency. One boxer reported: 'I felt an intense loss of my sense of agency, but I think to regain some feeling of control I ignored this, and somehow manufactured my own alternative choice: I tried to create the idea that I was choosing to last until the end of the session and tolerate the pain' (*Game On* boxer #2, personal communication, 21 December 2013). [18]

Locating responsibility

Traditionally, the operator of a machine is held responsible for the consequences of its operation (Matthias, 2004). In a system such as a fighting game where a human controls a non-autonomous robot or avatar, the attribution of responsibility rests with the human/controller. However, identifying a responsible agent within the *Game On* system is more complicated, because the "robot" is also a sentient being, and not merely an avatar receiving information sent from the player. While it is not within the scope of the present paper to address the complex legal and ethical issues surrounding recent developments in the manufacturing of adaptive, autonomously operating devices, there are some parallels between a *Game On* boxer and an autonomous machine. The operator of an autonomous machine cannot be held responsible in circumstances which occur due to the adaptive capabilities of the robot (Marino and Tamburrini, 2006), so there is 'a responsibility gap, which cannot be bridged by traditional concepts of responsibility ascription' (Matthias, 2004: 176). [19] However, unlike a robot, the boxer in *Game On* is an organic, cognising subject. As a cognisant being, the boxer has a direct awareness of his or her actions (e.g. arms throwing punches towards the opponent), and also the awareness that s/he is not the agent initiating these actions. A robot or avatar only 'knows' via representation: 'input' comes in the form of symbols or coded representations of other objects, not *actual* objects (Wilcox and Katz, 1981). The boxer's knowledge of the world 'is not mediated by cognitive representations internal to the mind or brain' (Michell, 1988: 227) but instead involves a 'direct relation between the knower and some independently existing situation' (Michell, 1988: 240). [20]

Game On utilises the boxer-as-android metaphor to explore questions regarding agency and responsibility attribution, both in real situations involving human and machinic avatars and scenarios such as the speculative science fiction of *Future World*, but the boxers role as "android" is nothing more than metaphor. Although the players control the boxers' actions, the boxers in *Game On* are also agents; they are complicit in the violent acts by relinquishing control of their limbs in order to be remotely controlled to punch their opponents. Unlike an avatar in a fighting game – who is unable to challenge the controller and behaves according to programming – the boxer has agreed to participate in a performance knowing that they will be involuntary forced to cause another individual harm. An agent is considered responsible if they know the particular facts surrounding their action, and is able to freely form a decision to act (Matthias, 2004). Thus, the boxer in *Game On* is not free from responsibility.

Attribution of responsibility is further complicated when we consider the role of the artist within this system. Within the context of the performance, both the boxer and player are given "permission" by the artist to inflict pain on others (either to punch their opponent, or to electric-shock a boxer they are controlling). Not only do participants surrender control within this context, they go to great lengths to fulfill their obligations. One boxer commented: 'I felt the larger part of what we were participating in was more important, that the game was more important than my opponent's suffering. I was more focussed on successfully participating in the "game" than I was focussed on my opponent's wellbeing' (*Game On* boxer #2, personal communication, 21 December 2013).

This commitment to the "game" extended beyond participation and endurance. Although the boxers still maintained voluntary control over the movement of their legs and torsos, and were able to move their arms voluntarily when not subjected to electrical impulses, they followed instructions to refrain from moving their limbs of their own volition. [21] To gain a better understanding of the boxers' behaviour in *Game On* it is instructive to consider similarities between *Game On* and the famous Milgrim experiments conducted in the 1960s. Milgrim demonstrated that participants were prepared to administer increasingly painful electric shocks to another human if instructed to do so by a figure of authority (Milgrim, 1963). The artist in *Game On* occupies a position of power not dissimilar to the experimenter in the Milgrim study. In both situations the participants assume that the authority figure (artist or experimenter) will act competently and professionally. Participants are unlikely to question the situation or to discontinue, even if they feel compromised (Eysenck, 1994). As one boxer described it: 'Once in the box, hooked up and surrounded by the audience, I did not feel that leaving was an option, even though the first shock was much more intense than I remembered it [being] in the lab' (*Game On* boxer #2, personal communication, 21 December 2013). [22]

Locating an agent "responsible" for inflicting pain in *Game On* is difficult, when agency is distributed across the system (a system that includes the artist). In the laws of torts and of crimes for most countries, the concept of *intention* is the main determinant for attribution of both legal liability and moral responsibility. In civilised penal systems, liability for serious crime depends not only on a person having committed an outward act of a crime, but on their having done this in a particular state of mind, *mens rea*, which includes the intention to commit the act (Moore, 2009). Outside this legal context, in an everyday sense, we learn early on to judge behaviour according to the presence of intent, perceiving actions that are performed *on purpose* as more serious. Justice Holmes suggests that 'even a dog knows the difference between being stumbled over and being kicked' (in Moore, 2009: xii). This may be so, but who, or what, is responsible for the "kicking" in *Game On*? A focus that is exclusively directed toward the actions of the boxers could lead to the conclusion that they are the agents responsible for the act of violence. If actions reveal the intentions of the acting agent, then an intention to inflict harm could be inferred by observing the boxers' actions (i.e. punching their opponents). However, expanding the frame to include the players locates responsibility differently: although the violent acts are executed by the boxers, the agents generating these actions are the players. This frame of reference suggests that the responsibility lies with the players, whose intention to punch is trans-located onto, and executed by, the boxers.

However, an even wider focus suggests that although both the players and boxers are engaged in a violent act, the artist mitigates their responsibility. The artist ostensibly condones these acts of violence through the creation and framing of the work. Can we conclude that responsibility for the violent actions conducted within this system lies with the artist? The accepted avant-gardism of some artistic activity, as distinct from conventional ethical standards, permits the artist to pursue practices that may be in direct tension with "correct" behaviour in everyday contexts (Macneil and Bolt, 2011; Rancière 2009, 2010). Thus, it could be argued that the artist is simply fulfilling her role: to push boundaries and challenge dominant social mores. [23] Broadening this frame further, the members of the audience viewing the work are also complicit in the activity of inflicting pain. However, the audience members have perhaps learnt to accept artistic activity as a practice that is granted a certain ethical autonomy to challenge society's norms. If so, this suggests that the boxers, players, artist and audience should *all* be exculpated.

Causal fields and intentions as causes

Can any of the *Game On* participants be held accountable for their actions? A deterministic account of behaviour suggests that none of the participants are freely choosing their actions, either in the *Game On* system or beyond. Although the freedom to make decisions about one's own behaviour is viewed as a quintessentially human quality (Satre, 1956), the notion that any particular behaviour is *uncaused* cannot be logically defended, as the action would literally randomly occur in time without any connection to other events, thus divorcing action from the self. While the causes of an action may not always be readily identifiable, all physical and psychological events are caused by, and in turn cause, other events. ","[24]">> As Mackay and Petocz (2011) note, it would be difficult to conceive of a world where this was not the case. The self must have a causal role in action (Anderson, 1962), and the self is in turn caused by other events, moulded by genetics and the environment. Thus, as Smith and Darlington (1996: 19) point out, 'whether a Nobel Prize winner or a murderer, no one really has control over their own behaviour'.

Although it may be contrary to our experience of agency, the acceptance of a causal account of behaviour implies that we are less like androids than we think when it comes to the control we have over our own actions. Our *sense* of agency or control, however, is a fundamentally human characteristic, which develops through the experience that intentions and observed actions are consistently associated (Jeannerod, 2006), and this sense of agency is itself a cause. Because cognitive events exist in the same spatiotemporal realm as physical events, cognitions themselves can be causes (Michell, 1988). It follows that the conscious intention to act may contribute to the causes of a given action. Indeed, the distinction between accidental and non-accidental consequences of action 'rests upon the cognitions *guiding* behaviour' (Michell, 1988: 235; original emphasis). The behaviour of the participants in *Game On* is guided by the knowledge that the outcome of their actions involves inflicting harm on the other participants involved: that is, all the participants have the intention to commit (or facilitate) an act of violence.

Returning to the boxer-as-android metaphor utilised by *Game On*, how might we distinguish between accidental and non-accidental consequences of action in the case of non-human entities?* _While we may someday be able to judge whether a robot has acted "intentionally" or "unintentionally", we are not likely to face this situation any time soon. If we make no assumptions about the intentions of robots we can assume that robots are 'completely unremarkable technological artifacts, no different than toasters or cars' (Asaro, 2007: 2). While robots can be causally efficacious, 'they are not considered to be moral agents in the sense that they are not held responsible for their actions' (Asaro, 2006: 11). [25] When we ascribe intention in order to assign blame for a robot's actions we refer to the cognitions that guide the actions of the manufacturers or operators of the robot, [26] and to the relevant conditions in which the robot's actions took place. Our ability to distinguish between intentional and unintentional consequences of action involves identifying both the cognitions that guide the actions and the circumstances in which the actions occur.

Game On literalises a system that is in some ways analogous to phenomena outside that system. It doesn't simply *represent* possibilities, but enacts possibilities in real time and space, and in that respect it is similar to other causal systems/situations involving humans or machinic avatars. However, the conditions under which one event produces another within a particular situation (e.g. inflicting harm within the context of a participatory artwork) may not obtain in another context. Causes operate within specific and causally relevant contexts and are not simply or linearly related to their effects (McKay and Petocz, 2011). It is not possible to explain the behaviour of the *Game On* participants (boxers, players, artist, audience) without an understanding of the causal field (standing conditions or relevant background circumstances) in which their actions occur. [27] We cannot simply attribute responsibility on the basis of a particular agent's intentions. A full understanding of any given action – within the *Game On* context or beyond – must include the system of relationships between organisms and their environmental conditions.

Biographical Note

Michaela Davies is a cross-disciplinary artist working with installation, sound, performance and video. Davies graduated with a PhD in Psychology from The University of Sydney, and currently works as a practicing psychologist. Drawing on the idea that contemporary participatory art practices can be viewed as a form of performative research, her artistic practice is informed by an interest in the role of psychological and physical agency in creative processes and performance.

Notes

[1] Davies, M. (2013). *Game On*, http://michaeladavies.net/game_on.html

[2] Fleming (2002), drawing on the work of Turner (1982), posits that performance necessarily invokes a register of communication concerned with possibility and hypothesis.

[3] The "raising/blocking" motion is triggered by sending electrical impulses to electrodes attached to the boxer's bicep. The "punching" motion is triggered by sending impulses to particular muscles in the shoulder and the tricep, and releasing the impulses sent to the bicep muscles, in a specific and precisely timed sequence.

[4] See Wilson and Foglia (2011) for a review.

[5] For example, Armstrong (1968).

[6] See Clark and Chalmers (1998), Clark (2003) and Menary (2010) for examples.

[7] For example, Clark and Chalmers (1998).

[8] The cognising subject and the object term in this relation each exist independently of the act of cognising (Anderson, 1962).

[9] As Mackie states: 'A quality is an intrinsic feature of a thing, it belongs to the thing itself, whereas a relation holds between two or more things' (Mackie, 1962: 266). This distinction between qualities and relations holds a central place in Anderson's (1962) conception of cognition.

[10] This distinction overcomes the problem inherent in extended views of cognition, which render the boundary between player and boxer impossible to determine. A relational approach to cognition also avoids the difficulties associated with a dualist/Cartesian account of mentality. The dualist, who views cognition as internal to the organism, is unable to give an account of how the immaterial mind interacts with the physical world. When cognition is understood as a relation, there is no difficulty concerning how the mind and body interact, because, as Boag (2008) points out, psychological relations exist in the same spatiotemporal universe as every other occurrence.

[11] Viewed as a relation, cognition is not reducible to either psychological or physical phenomena. Aspects of the external world cannot constitute part of our minds, nor is cognition reducible to neural processes. 'Neural processes pertain only to one term (the subject term of the cognitive relation, i.e., the knower) – they are necessary but not sufficient for mental processes' (Petocz, 2006: 50-51).

[12] For example, Berti et al. (2005); Chaminade and Decety (2002); Farrer and Frith (2002); Farrer et al. (2003); Haggard (2005); Leube et al. (2003); Tsakiris, Hess, Haggard, Boy and Fink (2007).

[13] This situation is not unlike the experience of an individual affected with anarchic hand syndrome, who loses their sense of agency but maintains a sense of ownership of the affected body part (Hertza, Davis, Barisa and Leman, 2012).

[14] This distinction between ownership and agency is made by Gallagher (2007), and research into visuo-tactile integration and self-attribution supports the distinction (see Tsakiris and Haggard, 2005).

[15] Such mechanisms for interoception (the brain's knowledge of bodily states) are well established. See Cameron (2001).

[16] Each of the boxers who participated in *Game On* were sent the following questions via email, asking them to reflect on their experience as a *Game On* boxer: *How did it feel to hit your opponent involuntarily? Did you feel competitive, even though you were not controlling the movement of your limbs (e.g. did you still want to win)? How did you feel about your controller? How much control did you feel you had? What happened to your sense of agency? Did you feel like part of a bigger system? How connected did you feel to your own body? Is there anything else you would like to add?* Four of the eight *Game On* boxers responded to these questions. Their complete responses are attached as an Appendix.

[17] The boxers have the ability to consciously experience themselves as acting beings and to reflect on these actions in terms of a narrative, which creates a sense of continuity in their conscious experience. One is always in some kind of somatic state as one cognises (Boag, 2008) and, according to Menary (2008), these embodied experiences structure narratives. Humans learn relationships between situations and the bodily states of frustration and gratification invoked by these situations, developing 'acquired emotional associations' (Damasio, 1994 :134). With repeated exposure one learns that particular bodily states arise in relation to particular situations and these learnt bodily states are remembered (Boag, 2008).

[18] Arguably, the parameters of the narrative self may be redefined by a continued disruption of agency in the minimal self, or 'a consciousness of oneself as an immediate subject of experience, un-extended in time' (Gallagher, 2000: 15). Nelson, Parnas and Sass (2014) discuss loss of minimal self caused by loss of narrative self in schizophrenic subjects. It is possible that repeated external influence on the minimal self leads to a loss of both agency and ownership via an extended identification of the narrative self. This is reflected in the comments of one boxer, who reported that her ability to get through the performance was 'only made possible by the fact that I knew the session was going to end. Would that "choice" have been possible to imagine if I had no idea when the session would end? I don't think it would' (*Game On* boxer #2, personal communication, 21 December 2013).

[19] As Matthias (2006) points out, in circumstances where no-one is clearly at fault society becomes collectively responsible for the costs of any negative consequences of a robot's actions (e.g. through taxation or insurances).

[20] For the boxer's knowledge of the world to involve neural representations that code input, the boxer must perceive the input before it is recognised. However, if the boxer's perception itself entails recognition then the representation is redundant, for he/she can already know directly the thing that the representation is introduced to account for. See Wilcox and Katz (1981) and Michell (1988) for further exposition of the logical incoherence of *representationist* views of mental processing, and a critique of the computer analogy as a model for human cognition.

[21] The boxers' movements were also limited by the confined space of the *Game On* box. As one boxer noted: 'I wonder how different the experience would be if the boxers could move around: I found standing

on the spot taking punches was quite difficult to do – I would instinctively turn my head and body away from an incoming punch. Standing on the spot further reduced the amount of control I had over the situation' (*Game On* boxer #3, personal communication, 13 December 2013).

[22] The "lab" this boxer refers to was the Underbelly Arts Lab, which hosted the development period prior to the Underbelly Arts Festival at Cockatoo Island at which *Game On* premiered in 2013.

[23] This is not to imply that artists themselves are not constrained by both subjective and institutional regulation. As Macneil and Bolt (2011) point out, artists are increasingly constrained and regulated.

[24] See Maze (1983) and Anderson (1962) for detailed arguments in support of psychological determinism.

[25] Asaro (2007) suggests that, as robot behaviour becomes more sophisticated and "human-like", they might be treated as quasi-agents by the law – in some cases robots could be seen as agents acting on behalf of others, and the responsibility for the actions of a robot should fall on the individual who grants the robot permission to act on their behalf.

[26] Even in the absence of direct causal connections, we hold producers of goods responsible on the basis of economic considerations summarised in the Roman law principle *ubi commoda ibi incommoda* (see Santoro, Marino and Tamburrini, 2007).

[27] The notion of a causal field was introduced by Anderson (1962), as a way of directing or limiting causal analysis. Causal judgements are made within specific contexts that take some factors as stable background conditions. Mackie (1980) gives the example of an explosion in Jones' apartment: Jones striking a match in his apartment to light a cigarette (as he has done on many previous occasions without causing an explosion) is part of the causal field. The gas leak in Jones' apartment is a difference in relation to the field, and a probable cause of the explosion. If the explosion had occurred at a petrol station, and Jones had struck a match where open flames were prohibited, then the striking of this match would be a likely cause of the explosion, rather than a background condition.

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Appendix: Participants' responses to the artist's questions about their experience as a *Game On* boxer

Game On **boxer #1 (email communication, 18 December 2013)**

How did it feel to hit your opponent involuntarily?

I feel pretty glad. I felt proud of my controller that we were able to work together well.

Did you feel competitive, even though you were not controlling the movement of your limbs (e.g. did you still want to win)?

I felt competitive on behalf of my controller. I wanted them to win. I didn't feel that personally I had a stake in the win or loss.

How did you feel about your controller?

Depends on who they were. If they were operating well, and got the timing of everything, I felt good about them. If there was a connection, an understanding of the game, that's good. Sometimes people were just ignorant of what was happening, so they unknowingly did painful things, jamming the controller down. Ignorance in control sucks balls.

I loved it when people got the instructions. That was cool to have someone who got it.

Kids were the worst. They just couldn't get it generally. No empathy either. When my opponents had kids controlling them, I'd feel pretty bad for them (the opponent).

How much control did you feel you had?

You could help with direction a little, but everything else was up to the controller.

The player might have felt I was their avatar a bit, but probably not so much, as the pain aspect [or] empathy would remind them that I was a person. Maybe except for those fucking kids – ask them about that.

What happened to your sense of agency?

Well, it went out the window, but only within the game context. I still knew that I could walk out, unplug, talk to the controller. I still knew that I was ultimately in control of myself.

This I think is what defines the pain associated with this project: if that was happening to me in a jail cell and I couldn't see, it would be a nightmare, but in this context it's fine, great even.

Did you feel like part of a bigger system?

What?

How connected did you feel to your own body?

Very connected. This was exactly unlike being on a dissociative drug or [in a] float tank or whatever would get you unconnected. Your body and its pain and movement were right up there and you weren't going to disconnect from that.

***Game On* boxer #2 (email communication, 21 December 2013)**

How did it feel to hit your opponent involuntarily? Did you feel competitive, even though you were not controlling the movement of your limbs (e.g. did you still want to win)?

I felt pleased with myself when a punch landed in my opponent's face. Even more delighted when that punch registered a bell because I was very aware of the audience. I wanted the girls to win. I did not take this idea of "winning" seriously at all. It was much more of an entertaining irony in my mind than any sort of personal desire to "win" as such.

I felt completely detached from any connection with my opponent when a punch connected with his face. Within the boundaries of the "game" I felt nothing about his wellbeing. For me this is almost unimaginable because I am usually deeply concerned about the experience of suffering.

Although I never considered it as an active decision, I felt the larger part of what we were participating in was more important, that the game was more important than my opponents suffering. I was more focussed on successfully participating in the "game" than I was focused on my opponent's wellbeing. I felt this way even though several punches that made contact with my face did in fact hurt. Not a lot, but enough for me to be aware that it was possible to register pain through the headgear. Although, let's face it, the pain of the shock made the pain of the punch comparatively insignificant.

How did you feel about your controller?

I formed a judgement of my controller from the first registered shock. If they executed a good punch I felt like we were a team, and I felt positive we would win the round. However, if the initial shock was messy, i.e. if it locked up and left me paralysed, or if the wrong part of my arm registered first, or the motion was too fast to result in a fully extended punch, I became slightly anxious because of course it was painful, and I felt like I did not trust the controller not to hurt me in an unpredictable way. Of course all shocks hurt, but if I knew what to expect I could mentally prepare, and accept the pain. This was much less traumatising than if the shocks happened sporadically, or in a strange order, or intensity, or duration. If someone repeatedly messed up the motion I would just clench my teeth and tense up because suddenly the pain became a little frightening, in the sense that I felt I could not trust that person to shock me in a way I could predict, or a way that would not to paralyse me.

How much control did you feel you had?

I must admit that from the first shock I was slightly traumatised. Once in the box, hooked up, and surrounded by the audience, I did not feel that leaving was an option, even though the first shock was much more intense than I remembered it [being] in the lab. I remember shooting a horrified look at my opponent for a second after the first shock, when all I could think was 'oh fuck!

Is it going to be this intense? Oh my god!' But for me there was no way I was going to stop the game at that point. I understood what the experience was going to be like, and I felt that the intensity was part of the experience. I was also very aware of the audience. I felt more convinced that I could handle the pain than I did feel convinced I could disappoint the artist and the audience by either asking for the voltage to be turned down, or leaving the game altogether. So, as the match proceeded, I think I just talked myself into toughening up, although when I registered pain I cried out, and that was absolutely involuntary. I cried out because it somehow made the pain more tolerable, and because I was committed to finishing the game, the crying out just happened as a result of the combination of intense pain and intense determination to tolerate that pain. At some point in the match, however, I remember catching my sister’s eye in the audience and she looked utterly horrified. This made me particularly uneasy, although we laughed about it later. It was a moment when I doubted my own determination, and I became suddenly quite concerned about how this would be perceived by my little niece, who was also watching. Seeing them took me out of my "zone" of tolerance. This was a particularly intense moment of feeling that I had absolutely no control over what was happening, and it was slightly unnerving for a few minutes. But as the game wore on I became more accustomed to the pain and I felt less out of control as a consequence. By the end of the session I even felt an almost euphoric sense of exhilaration from the adrenalin that was pumping through my body. The buzz was kind of awesome, and by the time the next session was ready to get under way I felt my perception of the pain had significantly altered. That in itself was exciting for me.

What happened to your sense of agency?

I felt an intense loss of my sense of agency, but I think to regain some feeling of control I ignored this, and somehow manufactured my own alternative choice: I tried to create the idea that I was choosing to last till the end of the session and tolerate the pain. I think this shift of focus took the fear out of the feeling of a loss of agency. I was able to do this successfully, I think, because I knew when the session was going to end. I am not sure if I would have been able to use this determination if I did not know when the session was going to end. But I think the first step was to try to ignore the awareness of a loss of agency because that was the most frightening moment of the experience. Perhaps I would have manufactured a different "choice" in my mind in a different circumstance. I’m not sure. Or perhaps, if my sense of a loss of agency was intense enough, and this was to produce an overwhelming experience of fear and doubt, perhaps I would be unable to manufacture any alternative choice in my mind. I wonder if this has anything to do with "possibilities". From a "social movements" perspective, when new possibilities are imagined by a group of people who have had their concept of "personhood" limited by the dominating group, they become able to "enact" those possibilities even though those perceived "limitations" have not changed. Is it in some way parallel that I was able to imagine a new possibility for creating a sense of agency, even though the initial limitation of my agency hadn’t changed? But was my ability to imagine an alternative choice and get through the session only made possible by the fact that I knew the session was going to end? Would that "choice" have been possible to imagine if I had no idea when the session would end? I don’t think it would.

My sense of a loss of agency was, however, much more intense when a child became the controller. I became instantly more afraid and this distracted me from my determination to tolerate the pain. This was definitely due to the unpredictability of the way children would control us. I did not feel they could conceive of the [artistic] concept and I distrusted their willingness to respect any assumed boundaries. It completely destabilised my manufactured idea of tolerance because it redefined the degree and intensity of that tolerance.

Did you feel like part of a bigger system?

Yes. I felt like I was part of a spectacle, and my perception of my place in that spectacle changed dramatically over the course of the session. At times when the pain was most intense I felt like the system was happening around me, but all I could think about was my own body. Then, when we became paralysed, or when the cords became tangled and the artist and tech crew came to rescue us it made it impossible to feel completely separate from the bigger system. It made me feel like we were all part of the system, and that the purpose of the system was to stimulate the audience. I felt like the controllers were also part of the system.

How connected did you feel to your own body?

I felt connected to my own body up until the shock, at which point I felt that something was getting in the way of that connection.

***Game On* boxer #3 (email communication, 13 December 2013)**

How did it feel to hit your opponent involuntarily? Did you feel competitive, even though you were not controlling the movement of your limbs (e.g. did you still want to win?) How did you feel about your controller? How much control did you feel you had? What happened to your sense of agency? Did you feel like part of a bigger system? How connected did you feel to your own body? Is there anything else you would like to add?

I didn't experience any feelings of guilt when hitting my opponent in the ring. I suspect this was because we were both in the same situation; by taking part in the work we had both accepted the dangers involved and we both ran the same risk of being punched hard or hurt. If I did hit my opponent in the face or any other sensitive part of the body I did feel momentarily sorry but inevitably I would be hit in return which mitigated any real sense of responsibility. The act of hitting my opponent was also accompanied by the pain caused by the shocks, so it was difficult to focus on anything other than my own discomfort in that moment.

My feelings towards the controllers were pretty variable; when they listened to the instructions properly and felt confident in what they were doing it could be quite fun and I could, to an extent, enjoy being "controlled". It almost felt like a partnership – especially if you won. If they were unable to work the controls properly (drunk people, kids, idiots) it was much more difficult situation to be at peace with.

Throughout most of the performances I felt acutely aware of my body – the discomfort associated with the muscle spasms didn't really allow me to think of much else at the time. This was especially true when we filmed the sequences for the video. I found that to be quite a different experience to the other performances; it took a lot more out of me physically and emotionally. It was a much more introspective experience, whereas being in front of a crowd brought the performative nature of the work to the forefront. I found being controlled by a machine to be quite different from being controlled by a person; even though I couldn't see my controller I felt that there was a kind of exchange between us. I certainly didn't feel this with the computer.

The only times I felt particularly concerned about the lack of control I had over my body was when a controller would hold the joystick in one position for too long, as the muscle spam (and pain) would momentarily make it impossible to move my arm or much of the rest of my body.

I did find myself trying to influence the involuntary movement to help direct the outcome of the game (with varying success). I definitely wanted to win, but this came more from a sense of play than anything serious.

I wonder how different the experience would be if the boxers could move around: I found standing on the spot taking punches was quite difficult to do – I would instinctively turn my head and body away from an incoming punch. Standing on the spot further reduced the amount of control I had over the situation.

I did have a turn being a controller; intellectually I knew what I was doing was causing my boxer pain, but I also knew that if I moved the joysticks steadily and smoothly I could minimise that discomfort and probably win (which I did!). I certainly empathised with what they were going through, but in knowing that they had consented to be shocked, I didn't struggle with any feelings of guilt *per se*.

Game On **boxer #4 (email communication, 24 December 2013)**

How did it feel to hit your opponent involuntarily?

I didn't feel comfortable with the idea of it at first, then as I was hit as well I felt that there was a mutual agreement.

Did you feel competitive, even though you were not controlling the movement of your limbs (e.g. did you still want to win)?

Yes, I felt competitive and even enjoyed it when I won.

How did you feel about your controller?

I felt that we were on the same team, except if the control got stuck on and they were hurting me, [then] I felt they were my enemy.

How much control did you feel you had?

Overall, I felt I could override the system, so therefore I felt I had ultimate control and was relinquishing control for the game.

What happened to your sense of agency?

I enjoyed relinquishing control.

Did you feel like part of a bigger system?

Yes.

How connected did you feel to your own body?

The extreme sensations make you aware of your body. Also having an audience makes you aware of your body.

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FCJ-208 This Machine Could Bite: On the Role of Non-Benign Art Robots

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Abstract: The social robot's current and anticipated roles as butler, teacher, receptionist or carer for the elderly share a fundamental anthropocentric bias: they are designed to be benign, to facilitate a transaction that aims to be both useful to and simple for the human. At a time when intelligent machines are becoming a tangible prospect, such a bias does not leave much room for exploring and understanding the ongoing changes affecting the relation between humans and our technological environment. Can art robots – robots invented by artists – offer a non-benign-by-default perspective that opens the field for a machine to express its machinic potential beyond the limits imposed by an anthropocentric and market-driven approach? The paper addresses these questions by considering and contextualising early cybernetic machines, current developments in social robotics, and art robots by the author and other artists.

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This paper explores the phenomenon of social robots from the perspective of an electronic artist, a practitioner making robots and other machines within an artistic context. My art objects are vehicles for reflecting on the co-evolution of humans and machines, a reflection informed by observation and experience. Intelligent robots are of particular interest to my practice as they combine mobility, service, social interaction and adaptive skills so as to integrate with the fabric of human society as embodied semi-autonomous agents. They also have captured the imagination of a wide public through works of fiction, wherein advanced robot characters have been commonplace for many decades. People, it appears, are curious about the capabilities of intelligent robots.

Buoyed by techno-scientific progress and financial interest, the field of robotics is fast gaining visibility and maturity, undergoing a tremendous development effort for research, industrial, military, civil and social applications. Indicators of this trend are, for example, Google's acquisition of several robotics and artificial intelligence companies since November 2013 (Ackerman, 2013) and the economy-focused Policy Exchange think tank event *Rise of the Robots* held in London in July 2014. Many of the currently developed or foreseen applications for robots are social, aimed at supporting humans, with roles such as butler, teacher, elder-carer, receptionist and security guard being the most common (Dautenhahn et al., 2005). These roles share a fundamental anthropocentric bias: the robots are providing a service to humans. As a consequence, human–robot interaction is commonly designed to facilitate a useful transaction provided to a human by a benign machine.

The global network of connected devices, often called the Internet of Things (IoT), is emblematic of the progressive integration of computing machines in many areas of human society. Founded on an exponentially widespread machine-to-machine network (M2M), the 'traffic generated for M2M devices is predicted to grow 22-fold from 2011–2016' (Tsiatis et al., 2014: 4); this trend complements the global adoption of sensing and connected technologies within private and public environments as delivered by the smartphone. Motivated equally by scientific research and the quest for financial return, the development of smart machines and the potential consequences of their global deployment raise many questions that are not necessarily relevant to the promoters and developers of the technologies. Of particular interest to me is the notion of machinic life. The capacity of a machine 'to alter itself and to respond dynamically to changing situations' (Johnston, 2008: ix) has, until recently, been found solely in living organisms. We may now need to create a specific ontological category for these new machines, that acknowledges the idea that 'people and things are not so different after all' (Pickering, 2010: 18). But the benign and anthropocentric bias of robotics research, combined with the commercial imperatives driving the deployment of social robots, leave researchers and developers little scope for exploring and understanding machinic life and its impact on society. In contrast, artists working with robotics, being largely free from commercial and scientific constraints, are well positioned for investigating the potential of non-benign machines.

Machinic life

Electronic artist Ken Rinaldo wrote that he is looking forward to 'the day when [his] artwork greets [him] good morning when it has not been programmed to do so' (Rinaldo, 1998: 375), an encounter with a live artwork which has, to my knowledge, not occurred yet. Although the quest for artificial life has been of interest to scientists, artists, writers and inventors since antiquity, it is only recently that scientific and technological developments have made "living" artificial creatures a realistic possibility and a rich field of research for the 21st-century robotic artist. This article focuses on non-biological systems or constructs that may demonstrate aspects of machinic life as defined by John Johnston. Having examined a comprehensive set of examples from the fields of robotics, artificial life and new artificial intelligence, Johnston (2008) posits that the evidence points toward the emergence of radically new machines (software and hardware). With a family tree rooted in the work of W. Grey Walter and other post-WWII British cyberneticians, the new machines, possessing adaptive characteristics that used to be found solely in biological living organisms, do not fit comfortably in the categories of either alive or not alive. According to Johnston, these liminal machines are the tremors announcing a genuine machinic life. The notion is not new, having brewed throughout the 20th century in the realms of fiction and cultural studies. Johnston refers directly to the 'becoming machinic' and 'machinic phylum' coined by Deleuze and Guattari (1980: 406), claiming that 'becoming-machinic is a force or vector that, under the guise of imitation, is directing and shaping not only ALife experiments and contemporary robotics but much of the new technology transforming contemporary life' (Johnston, 2008: 20).

The implications for human society of sharing the world with representatives of machinic life are profound and multi-faceted. Artificially intelligent creatures present a novel condition that calls for extensive study and scrutiny. I have identified three useful concepts in the works of Johnston, Donna Haraway and Sherry Turkle that inform this practice-led reflection on the subject:

> **Machine as assemblage:** for Johnston (2008: 111) 'the term machine designates an ensemble of heterogeneous parts and processes whose connections work together to enable flows of matter, energy, and signs ... Machines, first of all, are assemblages that include both humans and tools, or in modern societies, technical machines'.
>
> **Contact zones:** this term is coined by Haraway (2008: 186) to describe the common experiential dimension where 'animals, humans and machines are all enmeshed in hermeneutic labor (and play) by the semiotic-material requirement of getting on together in specific lifeworlds. They touch therefore they are. It’s about the action in contact zones'. In a more technical fashion, robotic scientist Frédéric Kaplan (2005: 60) borrows from psychology the notion of shared attention (*attention partagée*) to assess the degree of interaction between a human and a robot by monitoring the robot’s perceptual data while it is interacting with a human in the performance of specific tasks.
>
> **Sort of alive:** a term coined by an 11-year-old schoolgirl named Holly, referring to mobile robots navigating a maze during a study led by Turkle. 'Sort of alive' has since been used to describe an intermediary condition between that of an inanimate object and that of an animal (Turkle, 1998).

The socialisation of robots

"Social robot" is still a term open to interpretation, and this paper adopts the definition offered by Terrence Fong et al.:

> Social robots are embodied agents that are part of a heterogeneous group: a society of robots or humans. They are able to recognize each other and engage in social interactions, they possess histories (perceive and interpret the world in terms of their own experience), and they explicitly communicate with and learn from each other. (2003: 144)

Eleven years after this definition was written, social robots have not yet had a significant impact on human society, yet an emerging trend in industrial robotics indicates a growing socialisation of robots.

Unlike the nascent and still experimental social robots being developed worldwide or the prospective returns of Google’s investment in robotics companies, industrial robots have been commercially viable since the 1950s and a mature industrial robotics market now exists. Recent numbers show a year-on-year growth of 12 per cent between 2012 and 2013, indicating a similar trend in 2014 (Modern Material Handling, 2014). Industrial robots, traditionally programmed to perform repetitive manipulation tasks with accuracy and speed in secure areas, are undergoing a significant change with the introduction of collaborative capabilities. According to Modern Material Handling,

> … easy to use and easy to integrate robots will open up a wide range of new customers and new applications for robots. A main example for this category of robot use is the human-machine-collaboration. The robots working together with the worker in the factory or also in non-manufacturing sectors are capable of understanding human-like instructions (by voice, gesture, graphics) and have modular plug-and-produce components. (2014)

While practical applications of social robotics in domestic, health or corporate environments are not yet mainstream, the prominence of collaborative industrial robots signals that applications for human–robot social interaction are entering commercial maturity. First commercialised in 2012 by Rethink Robotics, Baxter the affordable, human-safe, collaborative industrial robotic arm with a friendly face is a recent commercial success. Baxter and its more advanced sibling Sawyer, launched in 2015, are being adopted by small and medium-sized manufacturing businesses worldwide. As robots are becoming social and ubiquitous, they deserve critical, artistic attention more than ever.

Anthropocentrism and benign robots

The open definition by Fong et al. of a social robot proposes a balanced state where humans and robots share a world in an even fashion and does not mention a utilitarian usage for robots. Although the terms of the definition still apply to recent research, the majority of current social robotics projects favour an anthropocentric, utilitarian perspective that does not leave much room for robots' histories to develop. In their survey of social robotics, Fong et al. have identified common characteristics of the field:

> … social learning and imitation, gesture and natural language communication, emotion, and recognition of interaction partners are all important factors. Moreover, most research in this area has focused on the application of "benign" social behavior. Thus, social robots are usually designed as assistants, companions, or pets, in addition to the more traditional role of servants. (2003: 145)

It can be argued that these roles for social robots, as well as the adjective 'benign', sum up the current status quo in social robotics science, in which machines have to comply to rules of safety, friendliness and legibility in order to facilitate interaction with the humans.

Anthropomorphic design of body and behaviour is assumed to be an evident gateway to a natural relation between a human and a sociable robot. In Brian Duffy’s words, 'it can facilitate rather than constrain the interaction because it incorporates the underlying principles and expectations people use in social settings in order to fine-tune the social robot’s interaction with humans' (2003: 181). As a result, robots are often given a humanoid or animal appearance, ranging from very realistic (see the Geminoid series or Paro the robot baby seal) to mechanical humanoid (e.g. iCub, Asimo, Nao) to cartoon-ish (e.g. iCat, Baxter, Leonardo). With the exception of Paro, the "mood" of the all the robots mentioned above is indicated through an expressive face modeled on human features: eyes, eyebrows and mouth are used to model the expression of common emotional states such as happiness, sadness, boredom, etcetera. To further ease the integration of robots into a human environment, recent developments in the emerging field of soft robotics make use of materials such as rubber and electro-active polymers in the construction of body and actuators, allowing, for example, the creation of octopus-inspired manipulators. In a similarly soft fashion, a functional android prototype called Roboy, featuring joints fitted with flexible tendons instead of rigid motors, was launched in Switzerland in 2013. The ability of soft robots to "give" naturally when encountering obstacles 'makes them ideal for applications such as personal robots that interact with people without causing injury' (Trivedi et al., 2008: 99), thus embedding the benign, domesticated dimension mentioned earlier into the sheer materiality of the machine.

Understandably, it is of little interest to most engineers and robotics scientists to explore the possibilities of non-benign social machines. Scientific or commercially driven projects are essentially reductive, having to provide safe solutions, fulfil consumers' needs, and follow established methodological criteria. Early examples of creative machines designed for exploring human–machine interaction from a more open-ended and inclusive perspective can be found in the work of early British cyberneticians such as Gordon Pask, who coined the term 'maverick machine'.

Maverick machines

In 1968, Jasia Reichardt curated the landmark exhibition *Cybernetic Serendipity*, a show that dealt broadly with the demonstration of how humans can use computers and new technologies to extend our creativity and inventiveness. Reichardt commissioned Gordon Pask to produce a piece that would illustrate his ideas about cooperative action and self-organisation. If possible, it should also have some aesthetic merit. The result was as a work called *A Colloquy of Mobiles*: an interactive installation that 'represented an ecological, or perhaps ethological, fantasy' (Pask and Curran, 1982: 78). Pask had been exploring the notions of self-regulation and collaborative learning for years, creating educational devices such as *SAKI* the adaptive keyboard instructor (1956) or more artistic endeavours such as *Musicolour* (1953), a synaesthetic machine that produced a coloured light performance in response to musicians performing with traditional instruments. Described by Pask (in Reichardt, 1968: 34) as a reactive 'aesthetically potent environment', *A Colloquy of Mobiles* comprised five motorised modules made of fibreglass, metal and purpose-built electronics hanging from the ceiling over a surface of four by five metres. The mobiles, described as two males and three females, were able to engage in discourse, compete, cooperate and learn about each other using light beams and sound while moving on powered beams. Conceived as a social system where 'sharing takes place between people, between processors, or between people and processors' (Pask and Curran, 1982: 79), the installation was designed in such a way that the males appeared to be competing for female attention and the females responded to adequate light stimulation with specific sounds and motion. The visitors were invited to walk amongst the hanging robots and contribute to the interaction using mirrors and flashlights. Pask mentioned that:

> … in order to remain a self-organising system, the mobiles had to steer a middle course between two extremes: no conflict resolution, in which case the system would fail to organise at all, and total organisation, total sharing of information, in which case the individual character of the machines would be destroyed. The introduction of … the human element was a safeguard against total organisation. (1982: 79)

The mobiles can be considered 'maverick machines', a term coined by Pask to describe 'machines that embody theoretical principles or technical inventions which deviate from the mainstream of computer development but are nevertheless of value' (1982: 133).

In his book *The Cybernetic Brain*, Andrew Pickering highlights the originality of the early British cyberneticians' approach to knowledge generation as a counterpoint to that of modern science. Whereas modern scientific methodologies tend to isolate the subject of the experiment so as to reduce noise and ensure repeatability, the non-modern cybernetic approach is performative, being that the subject is observed in action within an environment. According to Pickering, the cybernetics perspective is one in which we are:

> ... enveloped by lively systems that act and react to our doings, ranging from our fellow humans through plants and animals to machines and inanimate matter, and one can readily reverse the order of this list and say that inanimate matter itself is also enveloped by lively systems, some human but most nonhuman. (2010: 20)

Pickering describes the black box, a staple of cybernetic theory, as 'something that does something, that someone does something to, and that does something back' (2010: 20). Cybernetic knowledge is produced not from opening the black box or from deconstructing it to its smaller sub-components but from engaging performatively with it as a partner in a 'dance of agency'. For a contemporary techno-artist working with robots, the notions of maverick machines and a cybernetic dance of agency have strong appeal. They evoke possibilities of real-time social interaction with autonomous artificial entities that operate on their own terms in a shared environment, gradually exploring communication and relationship through contact zones. Pask's maverick machines, entangling humans and processors in a physical environment (and sometimes in a non-benign fashion), are inspiring precursors for robotic art projects investigating these notions.

Non-benignity

As discussed earlier, the vast majority of robots are designed to be fundamentally benign, to either operate safely in isolation or integrate seamlessly within human society. A significant exception is the military robot. Military technology often drives techno-scientific progress, and robotics is a prominent area of weapon development as it allows deployment of forces with limited exposure of human soldiers (Galliott, 2015). Yet, the adoption of intelligent technologies that raise the possibility of autonomous killing machines challenges the strict military chain of command. Military forces and security providers insist that it is essential to keep a human in the loop (remote-control operation), or at least "on" the loop, 'where the operator is on standby and can override the robotic targeting process' (Leveringhaus and Giacca, 2014: 11). For example, British Aerospace, makers of the British Taranis unmanned stealth airplane, 'made it clear that, with regard to unmanned aircraft systems, there will always be a need for a human in the loop, in particular regarding any use of weapons, both now and in the future' (Leveringhaus and Giacca, 2014: 5). According to P.W. Singer in his book *Wired for War,* when it comes to truly autonomous weapons, 'both specialists and military folks tend to change the subject or speak in absolutes' (Singer, 2009: 123). He quotes Eliot Cohen, a recognised military expert at Johns Hopkins: 'People will always want humans in the loop' (2009: 123). Generals currently favour solutions that allow sensitive decisions to remain under operator control. A US Army report about future tactical autonomous combatants (TACs) states that, 'even though we use the term "autonomous", we do not envision total autonomy. The term "supervised autonomy" is more accurate. Humans will "supervise" the unmanned entities when objectives change or when decisions outside the bounds of the TAC's autonomy are required' (Johnson et al., 2003: 1). Given that they still involve humans in a supervisory role, I have excluded military robots from my discussion of non-benign intelligent machines below.

Non-benign maverick machines

A non-benign, non-military robot can be thought of as a maverick machine in that it deviates from the mainstream of robotics development. Looking at such machines presents the opportunity to investigate robotic invention and its role in society off the beaten track of market-driven or purely scientifically motivated development. Non-benign here does not stand for malign, but instead aims to define an area where a wide range of autonomous behaviours are possible, covering a full gamut of possibilities which may include aggressive as well as friendly traits. A non-benign maverick machine could thus be an interesting vehicle for exploring the manifestations of machinic life. Such a 'sort of alive' artefact is likely to develop a range of responses that will not resemble animal or human behaviours. This potential can be seen, for example, in the case of evolvable hardware, where engineers apply genetic algorithms to electronic design. Evolving electronic circuits using genetic algorithms allows the software to arrive at efficient solutions that significantly depart from those designed by humans. The weight of electronic circuit designers' experience leads them to:

> ... operate largely under assumptions of linearity, and consider only modularity and hierarchically-structured systems, though it is clear in many cases that the resulting performance is inferior to that attainable if we were able to transcend these limitations and exploit the vastly augmented design space and emergent properties attendant upon less constrained and more holistic conceptions. (Miller, Thompson and Fogarty, 1997: 105)

Similarly, the design of a social robot for the emulation of a support or service task traditionally undertaken by humans is likely to be limited by assumptions and past experience.

Creating a non-benign, intelligent machine presents the challenge of developing software and hardware architectures from which a non-biased, less constrained and more holistic machinic life system can evolve. Artistic practice is well suited to investigate the potential of such a machine as a concept as it addresses a mix of traditional subjects (life-likeness, performance, representation) and contemporary questions (exponentiality of technological progress, hegemony of scientific knowledge, relationship with machines, control society, post-humanity, singularity). However, the realisation of an art robot addressing these challenging questions calls for a collaboration between artists, scientists and technologists.

On the role of art robots

Art robots can shed a different light on contemporary robotic research and on our relation to machines, for example by creating speculative scenarios and experiments free of utilitarian function and not fully constrained by the methodical rigour of scientific research. The artist’s contribution to deciphering techno-scientific trends provides a different perspective to a scientist’s or a technologist’s perspective. Electronic art specialist Stephen Wilson (2007) argues that 'in a techno-scientific culture, artistic probing of the world of research is a critical, desperate need. We need people looking at these fields of inquiry from many frames of reference, not just those sanctioned by academia or commerce'. Similarly, Robert Zwijnenberg in his preface to *Art and Technoscience* makes a case for a revitalised role for humanities and the arts in understanding and guiding societal choices presently driven by technologists and scientists. He argues that 'the eager and unrestrained artistic attitude vis-à-vis the life sciences ought to motivate scholars in the humanities to instigate and develop more sustained reflection about the life sciences' (Zwijnenberg, 2009:

xxvii).

Having attended and contributed to a significant number of international electronic arts events and exhibitions over the past two decades, my experience is that the field of electronic arts features more software-based and screen-based works than autonomous robotics works. A likely reason is the wide range of technical skills and resources required to produce reliable machines combining many complex hardware and software components. As a result, relatively few robotic artworks have been created, which, on the one hand, limits the scope of historical research and, on the other, leaves much to be explored with the medium. In *Robotic Art,* a joint statement published in 1996, artists Eduardo Kac and Marcel-lí Antúnez Roca wrote that:

> … one of the crucial concerns of robotic art is the nature of a robot's behavior: is it autonomous, semi-autonomous, responsive, interactive, adaptive, organic, adaptable, telepresential, or otherwise? The behaviour of other agents with which robots may interact is also key to robotic art. The interplay that occurs between all involved in a given piece (robots, humans, etc.) defines the specific qualities of that piece. (Kac and Roca, 1997)

Although Kac's and Roca's extensive taxonomy offers a valid way of differentiating between robotic artworks, I would like to propose a simplified categorisation, comprising three categories, yet including a wider range of media:

> **Illustrative:** the work is not functional, instead representing robots through another medium such as photography, video, sculpture.
>
> **Reactive:** functional machines fitted with sensors and actuators inhabit a physical space. All their possible states are pre-programmed: they are finite machines.
>
> **Evolutive:** complex machines that can adapt, evolve and learn.

The reactive category encompasses the majority of existing robotic artworks, in which the machines' design and programming don't allow for true adaptation even if they are able to react to a changing environment. Reactive art robots can provide a rich form of interaction with the public, embodying possible human–robot relationship scenarios, conveying ideas about the role of machines in human society, or demonstrating technological possibilities. Yet, due to their deterministic design, reactive systems are closed and eventually predictable entities. More apt to produce representatives of machinic life is the evolutive category, where a robot's design includes adaptive intelligence that enables it to learn and evolve new behaviours from its interactions with the environment. The artwork results from the assemblage of robot, human participant and environment, a sum of connections and flows that, beyond sheer techno-scientific demonstration, conveys intentionality. The roots of such artistic endeavours can be found in last century's systems art movement. In the words of systems art proponent Jack Burnham, 'systems-oriented art will deal less with artifacts contrived for their formal value, and increasingly with men *[sic]* enmeshed with and within purposeful responsive systems … [T]he system itself will be made intelligent and sensitive to the human invading its territorial and sensorial domain' (Burnham, 1968: 363). Almost 50 years later, the 'intelligent and sensitive' systems evoked in future tense by Burnham are reaching technical feasibility.

Few robotic art projects have dealt with the complexity required by such systems, and the ones that have were often the result of art–science collaborations. Mentioned in order of increasing non-benignity, *Fish-Bird* (2006) by Mari Velonaki in collaboration with a team from the Australian Centre for Field Robotics, and* Accomplice* (2013) by artist Petra Gemeinboeck and computer scientist Rob Saunders, propose a strong artistic vision combined with advanced computer science. Velonaki's robots, wheelchair-like machines showing no visible circuitry or motors, move gracefully while dropping poetic printed notes on the floor. The artwork aims to induce 'a willing state of suspended disbelief, where [the visitor] is not conscious of interacting with a machine … A successful interface enables fluent, intuitive communication between human and machine' (Rye et al., 2006). The fluid interaction between visitors and system and the use of the written English language by the robots still don't make for a fully benign machine in that the robot system's motivation remains alien. *Fish-Bird* offers the visitor a chance to be part of a cybernetic assemblage as an observer and participant and does not deliver a clear, goal-driven interaction, creating space for an open and personal human–machine relationship to exist.

The robots in *Accomplice* are more explicitly non-benign, laboriously destroying what appears to be a gallery wall. Embedded into the wall, the robots are programmed to be "curious" and to autonomously explore their environment. Once the environment has been memorised, however, the robots get "bored" and use their electro-mechanical punches to alter it, producing marks and holes in the wall. Over the duration of an installation, the gallery environment gets irreversibly altered and, as the walls get increasingly perforated, the robots become visible and exhibit a curious disposition toward the visitors standing on the other side. Gemeinboeck and Saunders (2013: 216) are interested in creating 'works that explore notions of autonomy and artificial creativity that may offer starting points for thinking about social settings that involve humans interacting and collaborating with creative agents'.

In different ways, the two maverick machines described above are non-anthropocentric systems, assemblages that offer environments for humans and sort-of-alive machines to share experiences, explore, and make manifest possible stories for humans and social robots. They cultivate contact zones. Together with the complexity supported by the collaboration with scientists, the open-ended, non-benign characteristics of these machines and their modes of staging offer an experimental playground for a first-hand experience of early machinic life.

Wild Robot Coy-B and its older relatives

At the time of writing, I am working on *Wild Robot Coy-B*, a collaborative project with an autonomous robotics scientist. The project aims to create an intelligent robot with a potential to be dangerous, that will interact with humans in live performances. I will first discuss three of my existing hand-made robots in order to clarify *Coy-B*'s lineage before describing the project in more detail.

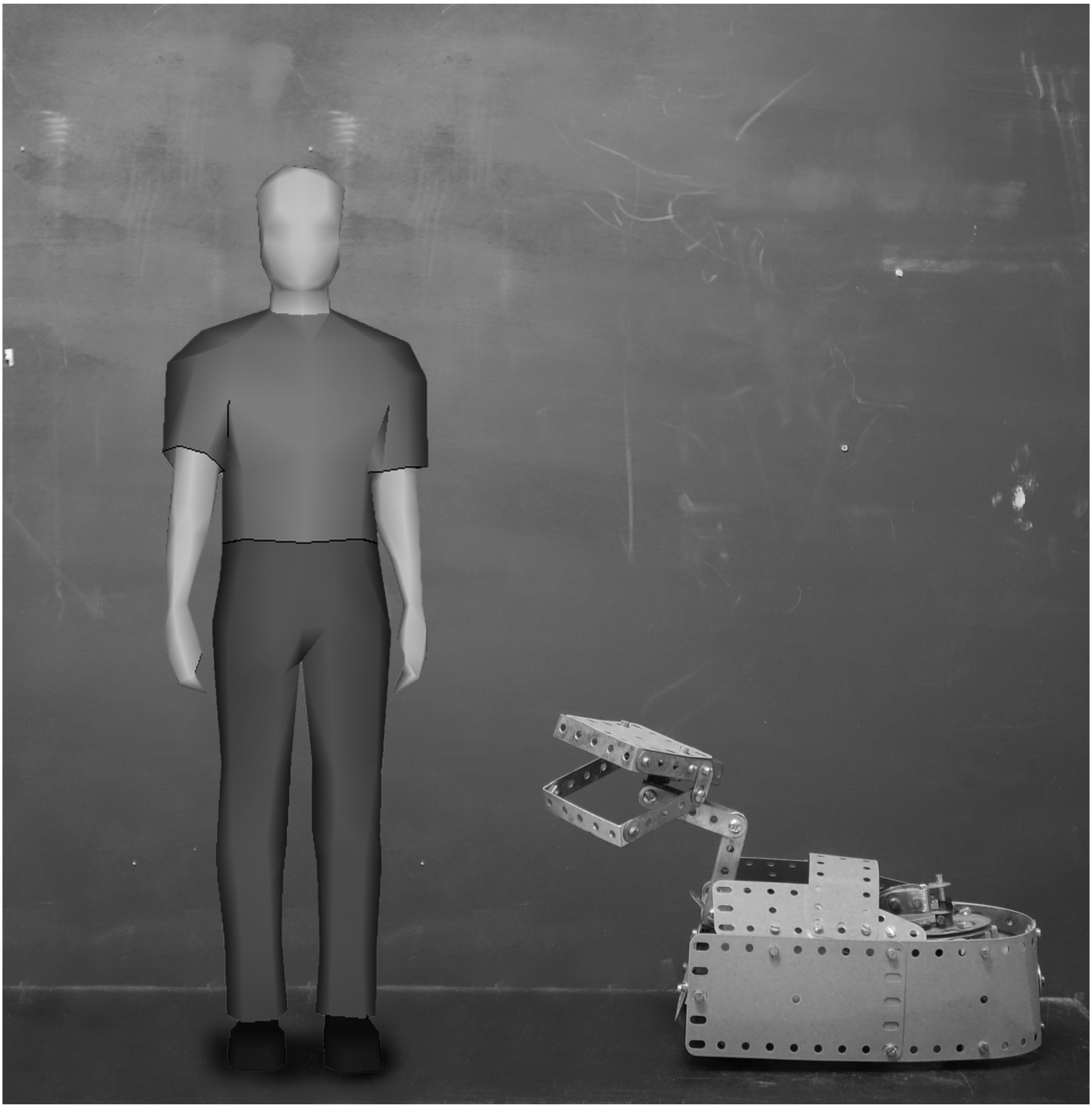

Figure 1: Wild Robot Coy-B, artist's impression, 2015, credit the authorFigure 1: Wild Robot Coy-B, artist's impression, 2015, credit the author

My practice of robotic art started in 1996 when I started learning techniques of interfacing and control that I applied to robots designed for video and performance. An early example is *The Fluffy Tamagotchi* (1998), a robot inspired by the famous electronic hand-held toy pet. Made for a short video, in my taxonomy *The Fluffy Tamagotchi* is situated half-way between an illustrative robot and a reactive one. While its features, inspired from the original toy, are functional, due to the use of video the robot in the artwork doesn't require reliability or maintenance. The video provides an overview of the robot's operation in a descriptive, deadpan fashion, contradicting the absurd nature of a five-kilo machine that excretes blue custard and cries loudly when its program needs attention. *The Fluffy Tamagotchi* is an early instance of a machine that offers a critical comment on a techno-societal trend, questioning the rationale of replacing living animals with commodified, artificial ones, packaged in plastic eggs and fitted with rudimentary AI.

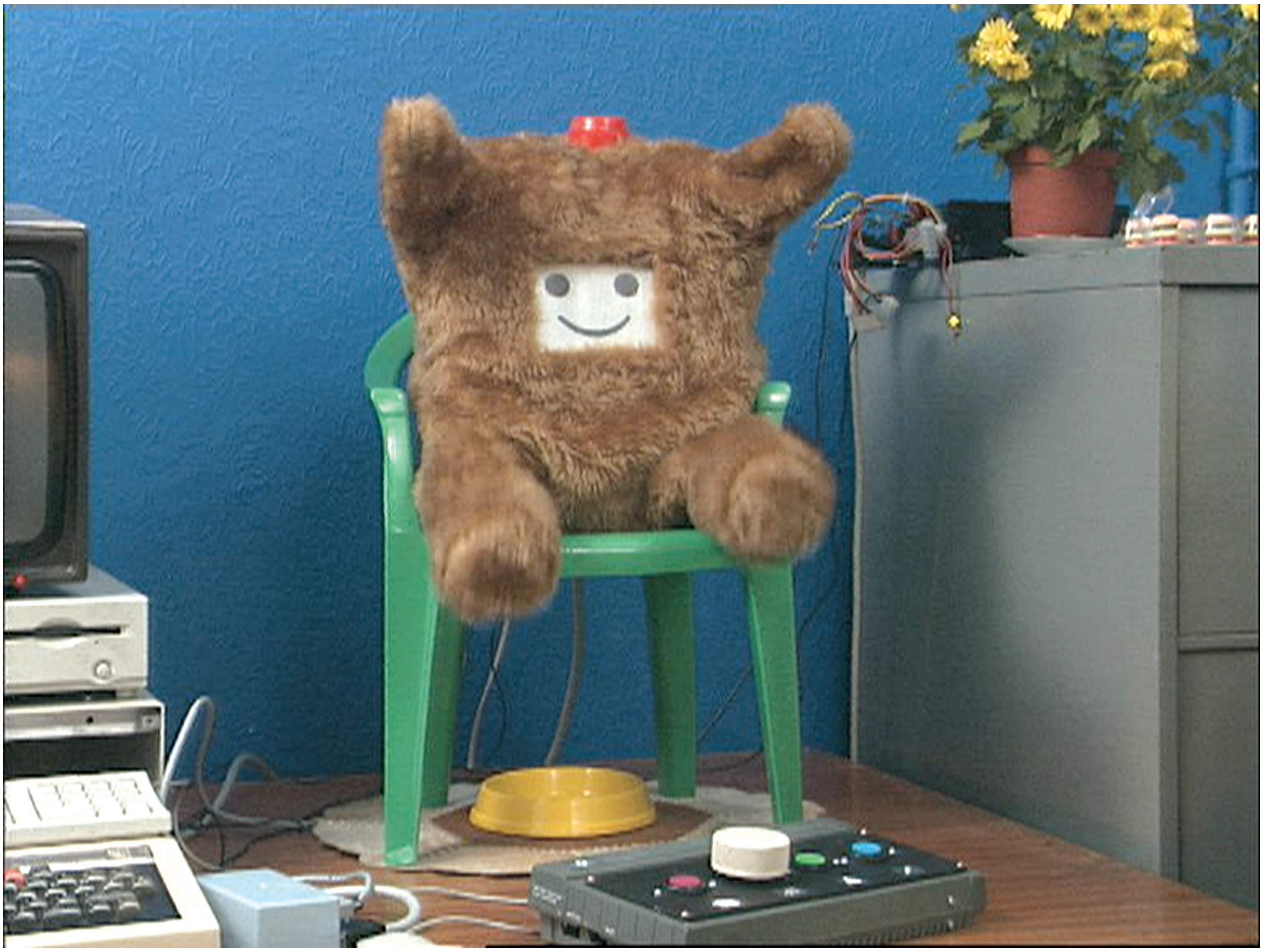

Figure 2: The Fluffy Tamagotchi, screenshot from video, 1998, credit the authorFigure 2: The Fluffy Tamagotchi, screenshot from video, 1998, credit the author

The following two examples could be situated within the maverick machine category as their design has not been inspired by existing commercial products. *Furman* (2003) is a six-foot high machine that delivers karate-style kicks, powered by compressed air. A physical manifestation of a creature I saw in a dream, *Furman* is introduced and demonstrated in live performances where it fells me on a gym mattress with one powerful kick. The creature is both a friendly guardian and a machine that turns against its creator in a Frankenstein-like fashion. The hairy robot taps into unconscious images in a surrealist fashion and provides a humorous illustration of the duality of robots and technology in general. Despite being a simple anthropomorphic automaton whose presence is enhanced by a performer telling a story, at its heart, *Furman* is a non-benign machine that can harm a human standing in the way of its metal and epoxy foot.

*Figure 3: Paul Granjon and Furman, 2003, credit J. Savage**Figure 3: Paul Granjon and Furman, 2003, credit J. Savage*

The next work displays non-aggressive robots that do not interact with humans. The "male" and "female" *Sexed Robots*, created in 2005, operate autonomously in a zoo-like enclosure. Their program takes them through a pseudo-random selection of different states that include roaming, singing, sleeping and being in heat. If two robots in heat find each other they will attempt to have intercourse, connecting their genital organs which are machined in industrial nylon stock to interlock in a complementary fashion. The intercourse ends when one of the robots changes state and disengages. A reactive piece of medium-level complexity, *Sexed Robots* questions, in an absurd manner, to what extent humans want to delegate some of their basic functions to machines. Simultaneously they provide an entertaining alternative to the robots I saw in robotics laboratories at the time: small wheeled platforms fitted with various modules such as grippers or cameras that slowly performed sorting or navigating tasks, unlikely to capture the attention of a non-specialised audience for more than a short time. Fitted with a genital module, the sexed robots perform an isolated algorithmic dance sometimes punctuated by a duet of penetration. They are not social robots as they don't attempt to establish a benign relationship with humans. Instead, their performance aims to draw parallels between human and machinic behaviours and trigger reflection.

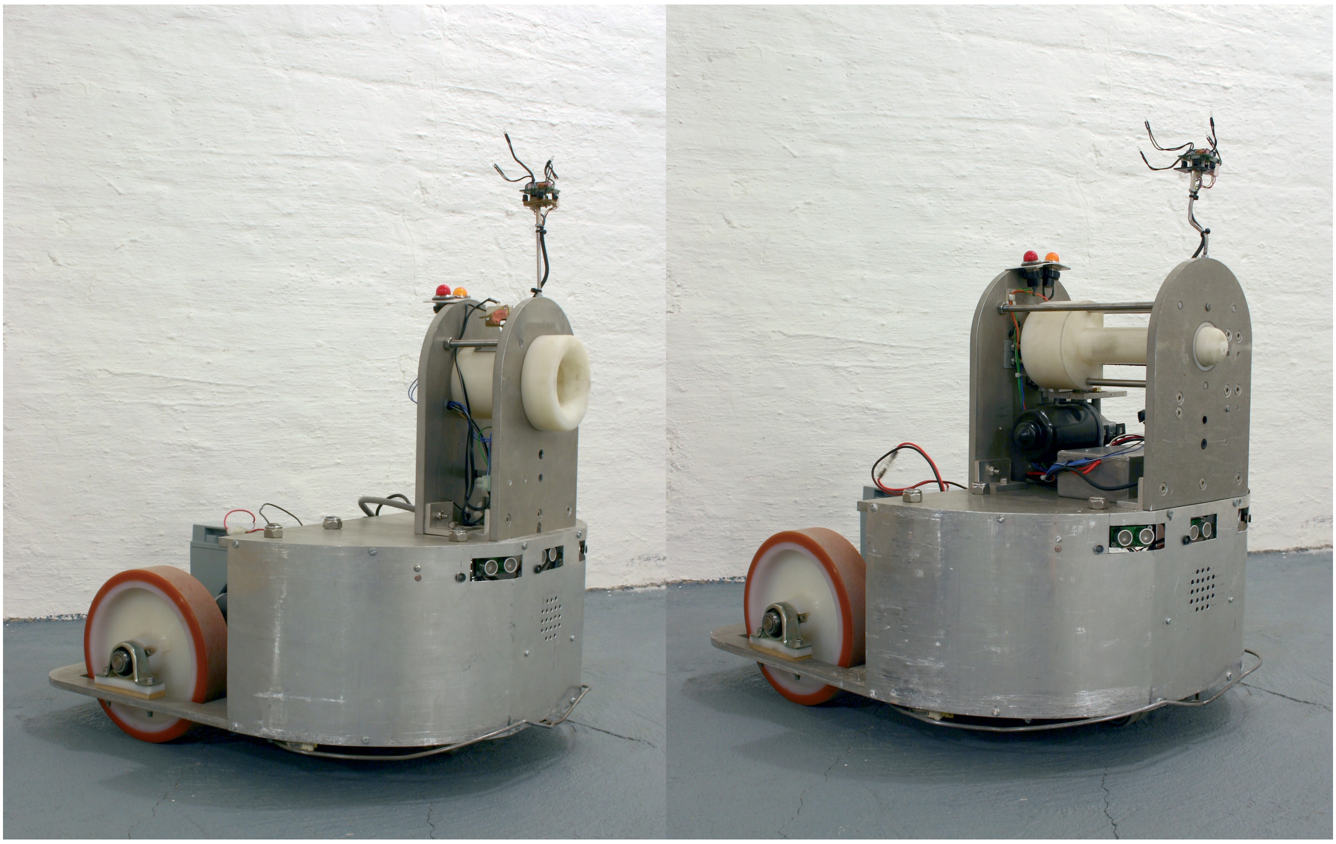

Figure 4: Sexed Robots, 2005, credit the authorFigure 4: Sexed Robots, 2005, credit the author

Imagined as 'an experiment in human–robot interaction with a metaphorical dimension that will provide material for reflection, dialogue and analysis on the ontology of artificial creatures' (Granjon, 2014: 30), *Wild Robot Coy-B* goes a step further than* Accomplice* and *Furman* with regard to its level of non-benignity. The project's initial inspiration was Joseph Beuys' *I Like America and America Likes Me _(1974), wherein the artist shared a space in a New York gallery with a live coyote for three days. Beuys chose to spend several days with the coyote in a shared territory in an attempt to metaphorically reconnect with natural wildness and instinct, dimensions lost to contemporary western humanity. In the _Coy-B* project, an evolutive autonomous robot of similarly dangerous potential will replace the coyote. Symbolically opposed to the coyote, the robot is a representative of up-to-date machinic life, the product of technics and artificiality. Performance creates a terrain for an open-ended relationship to unfold between a human and a smart, learning machine, programmed to be curious and to develop its own responses to internal and external stimuli. The programming and the physical design of the robot will involve genetic algorithms and other evolvable machine design techniques to limit the aforementioned anthropocentric bias. The *Coy-B* robot will be fitted with an arm-mounted gripper that could potentially double as a bite-inflicting actuator. Acknowledging a potentially aggressive, dangerous dimension is an important part of the metaphor that the work aims to produce, recognising the multi-faceted range of applications of any technology. In order to insure both conceptual robustness and scientific relevance, the work will be developed by a team comprising an artist, two scientists and a science and technology studies (STS) scholar.

A word of caution

Despite its inherent subversive element, a non-benign, intelligent machine artwork contributes to the general digital augmentation of our environment and its immense potential for monitoring and control. Denouncing 'Silicon Valley's quest to fit us all in an electronic straightjacket by promoting efficiency, transparency, certitude and perfection – and, by extension, eliminating their evil twins of friction, opacity, ambiguity and imperfection' (Morozov, 2014: xiii), activist writer Evgeny Morozov posits that the ongoing application of data-driven control to many domains of society, often presented as a *fait accompli*, must raise questions about the power held by the controllers. A technological art practice, with all the subjectivity, messiness and lateral thinking that characterise the artistic process, is well suited to inject noise into this perfect landscape – to make the straightjacket itchy in places.

Nevertheless, artists adopting contemporary cybernetic tools need to be aware of the potential pitfalls. Digital artist and theorist Simon Penny, writing about artificial life and interactive art, warns that 'artists must be careful not to unconsciously and unquestioningly endorse the value systems and narratives hidden in scientific discourses, where they often lie hidden, disguised as axioms' (Penny, 1996). One of the challenges faced by artists working with science and technology is the risk of spending much of their time and resources on the acquisition and application of new technical knowledge, sometimes to the detriment of their original artistic intention. The possibility of confusing the means for the end is very real and too often demonstrated in the technologically heavy world of electronic arts. Artistic adoption of contemporary technological tools must not lead to losing sight of the intended artistic and critical content. The artwork is likely to be more evocative and multi-layered if it embodies a reflection on the medium and its context, going beyond an application of sophisticated tools. I believe that it is a grand challenge for artists and their collaborators working with robots to devise non-benign, ambiguous, maverick machines to produce awareness, resistance and knowledge, and that in so doing we can impact societal choices for a future in which human and non-human agencies can dance freely.

Biographical Note

Paul Granjon is an electronic artist and educator working and living in Cardiff, Wales. He teaches at all levels of the Fine Art course at the Cardiff School of Art and Design and runs regular workshops and public events. He has presented robots and other machines for performances and exhibitions since 1996.

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FCJ-209 Indigenous Knowledge Systems and Pattern Thinking: An Expanded Analysis of the First Indigenous Robotics Prototype Workshop

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Abstract: In November 2014, the lead researcher's interest in the conceptual development of digital technology and her cultural connection to Indigenous Knowledge Systems created an opportunity to explore a culturally relevant use of technology with urban Indigenous youth: the Indigenous Robotics Prototype Workshop. The workshop achieved a sense of cultural pride and confidence in Indigenous traditional knowledge while inspiring the youth to continue with their engagement in coding and programming through building robots. Yet, the outcomes from the prototype workshop further revealed a need to investigate how Indigenous Knowledge Systems, and particularly Pattern Thinking, might hint toward a possible paradigm shift for the ethical and advanced design of new technologies. This article examines the implications of such a hypothetical shift in autonomous systems in robotics and artificial intelligence (AI), using the Indigenous Robotics Prototype Workshop as a case study and springboard.

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Introduction

It could seem to some that Indigenous Knowledge is fundamentally at odds with the contemporary digital age, and with Western society's thirst and demand for new knowledge to be constantly generated. Furthermore, it would also seem diametrically opposed to science-led ventures into the Brave New World of technological advancement in the field of robotics. Yet, precisely at this juxtaposition a commonality can be drawn. How might we create a space for Indigenous Knowledge Systems and Pattern Thinking to impact and influence future developments in, for example, autonomous systems in robotics and artificial intelligence (AI)? Creating a physical and pedagogical space for an initial foray into these ideas, the Indigenous Robotics Prototype Workshop embarked on practical and creative experimentation along new Indigenous Digital Songlines.

This paper is formatted as a dialogue between the lead author, an Indigenous consultant in innovation, technology and culture, and the second author, a non-Indigenous roboticist. We adopt a convention where the second author's voice is set in *italics*.

Indigenous Advancement: Prototype Workshop

Engaging Indigenous youth with the new technological languages of our times is imperative in enabling participation and creative leadership into the future. The Indigenous Robotics Prototype Workshop was devised specifically for a group of twenty Indigenous youth (8–12 years old) from Glebe Primary School in inner city Sydney. It took place in November 2014 over the course of one day. I was lead researcher/developer and facilitator of the workshop. Using Lego Mindstorms kits, we created a culturally relevant course, leveraging Indigenous Knowledge Systems to introduce core elements within the field of robotics. Throughout the development of the prototype course, I consulted with Gadigal Elder Allen Madden, with Dr Robert Fitch as academic advisor. This paper uses the experiences of the first Australian Indigenous Robotics Prototype Workshop as a springboard for further discussion of the possible role of Indigenous Knowledge Systems and Pattern Thinking in the future research, development and design of creative and intelligent robotics.

The aim of the co-developers of the prototype course was to explore how to create a culturally relevant course that engaged urban Indigenous youth in Science, Technology, Engineering and Mathematics (STEM) subject areas through the creative adaptation of Indigenous Knowledge applied through an engagement with robotics. In doing so, we aimed to introduce coding and its principles as a language central to working within digital technology, and to contextualise where and why it is important for urban Indigenous youth to think of coding as part of their future.

I started by exploring concepts in Aboriginal Science and looking for its influence on contemporary scientists, and where we might include an embrace of traditional Old Ways within the course design and implementation. [1] This was done through engaging Uncle Allen Madden in a consultative role; researching and designing a delivery structure that suited the demographic of the Indigenous youth we were teaching; and prioritising advocacy of Indigenous Knowledge as a valued, yet divergent, paradigm to be employed when working with science and technology. Finally, we created a mentoring and role-modelling structure, bringing in inspiring Indigenous people who successfully work in various associated fields of new digital technology. [2] This provided adequate support for the youth and ensured individual successes, critical to the benefit of the experience for those participating. Mentoring, informed by an Indigenous Excellence Agenda (Booth et al., 2014), works toward counteracting commonly internalised perceptions regarding Indigenous youth disadvantage, especially in tech sectors such as robotics.

Robotics is already being used as part of the education of school-age children. One of the most prominent mainstream programs is the FIRST robotics competition series, held regularly in Australia and worldwide (FIRST Australia, 2015). Scholars have also begun to explore the idea of robotics as a way to bridge the technology gap between advantaged and disadvantaged youth (McDonald and Howell, 2012), and as a tool of cultural expression among Indigenous peoples (Catlin, Smith and Morrison, 2012). Developing our workshop required us to create robotics educational material that is customised to support the specific cultural context of urban Australian Indigenous youth.

The workshop comprised a brief introduction to Indigenous Knowledge Systems, an introduction to robotics, and a series of participatory and creative coding exercises leading to the construction of simple wheeled mobile robots. Students then used their robots in a navigation task that required them to further develop their technical knowledge, and participated in two non-technical tasks with a robotics theme (a running game and a card game).

The robotics presentation introduced modern robotics from the perspectives of what robots look like, what they do, and what challenges they face. The emphasis was on seeing the world from the robot's point of view, in particular with regard to perception ('how do I make sense of seemingly meaningless sensor data?'), localisation ('where am I and what happens if I get lost?') and control uncertainty ('what happens when I do not move in the direction intended?'). Thinking in this way helps students to gain intuition about fundamental research problems inrobotics: many tasks that we as humans perform trivially and unconsciously are tremendously difficult for robots. Adopting the robot's point of view highlights these challenges and, at the same time, helps students to better engage with robotics by linking research problems to their everyday experience.

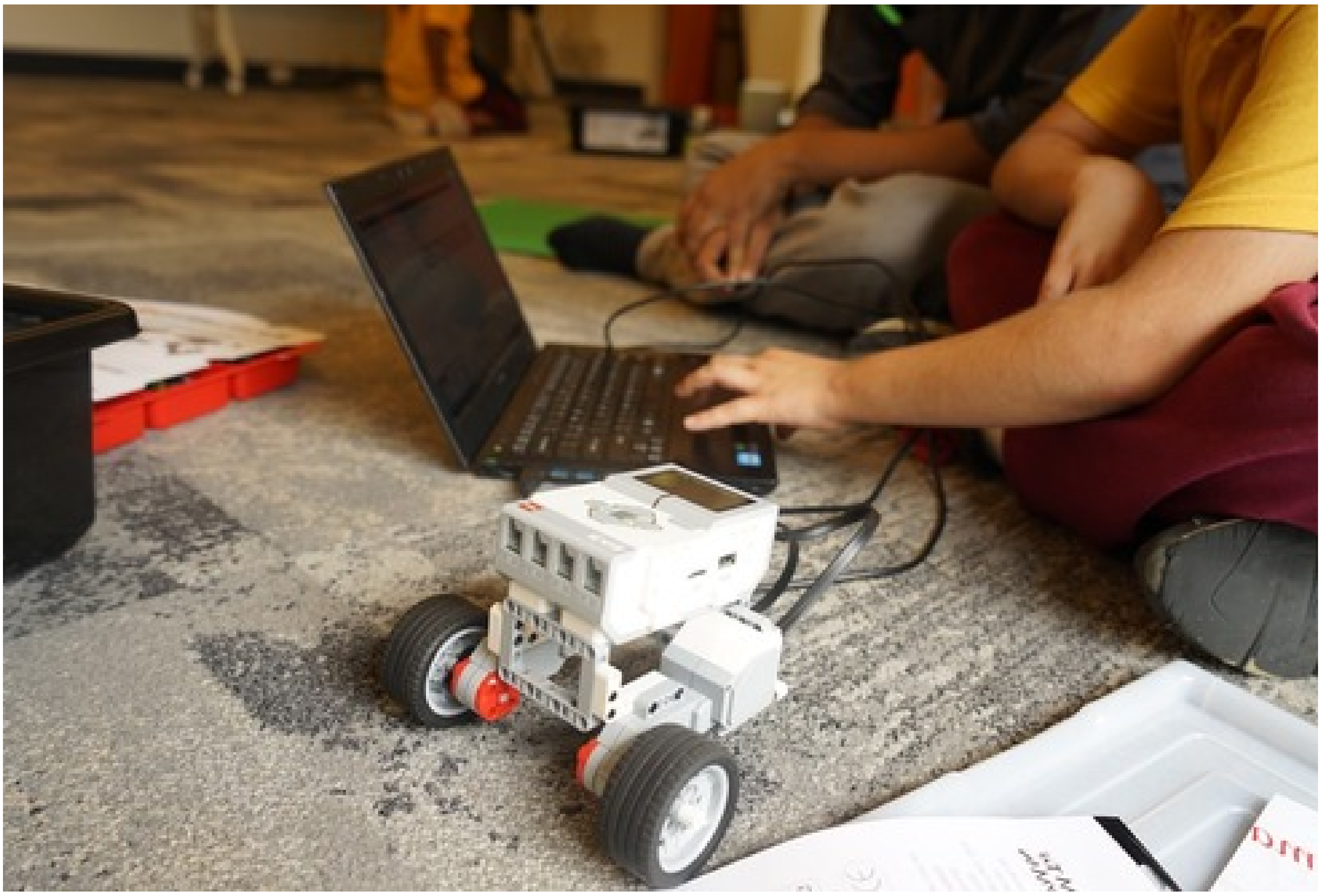

Figure 1: A robot assembled by the students. The programming interface enabled students to write code for the robot using a tablet or laptop computer (shown). The robot's onboard computer then executed the code, allowing the robot to move. Photo: Angie Abdilla, 2014

Students assembled and programmed robots, using standard LEGO Mindstorms kits, in a guided exploration framework. They worked in small teams of two or three students plus a mentor. Written instructions were provided for mechanical assembly and simple programming tasks in an incremental sequence leading to creation of a wheeled platform that could execute a series of pre-programmed motion commands. The mechanical parts are press-fit and can be assembled without tools. The programming interface supplied with the kits is a graphical language consisting of action blocks that are strung together to form a program that is subsequently downloaded *to the robot control module for execution. The action blocks are customised by entering numerical values to control the linear and angular velocity of the robots.*

The students used their robot platforms to participate in a navigation exercise where a robot's task is to move to a goal location while avoiding obstacles. The robots moved over a flat surface upon which obstacles and goal locations were hand drawn. The navigation exercise was particularly engaging to the students. Nearly all groups were successful in assembling a working robot with good command over its motion.

Building different robots and enabling different coding exercises within the program was contextualised through Indigenous mapping. In the 'Mapping of Country' exercise, the children drew Aboriginal Sydney and its boundary lines with chalk in an outdoor courtyard. The emphasis was on the protocols pertaining to the country on which we stood that day: Eora Nation, home to the Gadigal people, and on our interrelatedness with everything through respect for country. The map included the neighbouring nations: Dharug to the west, Dharawal to the southwest, Guringai to the north. The ways in which crossing boundaries is acknowledged through protocols, and the ceremonies central to Songlines' continuation through country and across territories, were related to the protocols of code. The children needed to program their robots to track a coded course, which crossed through courtyard country and chalk-drawn nation boundaries.

Figure 2: Detail: A robot in action, navigating the chalk-drawn map. The map was composed of region boundaries with place-names (e.g. Dharug; Dharawal) written inside them, and also pictures of geographical features (e.g. mountains) Photo: Angie Abdilla, 2014

The map was also used for a derivation of a "starboard–port" running game substituting Indigenous Nations for the nautical coordinates. A simple explanation was given about the value and richness of Indigenous Knowledge in the domain of science and technology. We discussed how Western science is consistently readjusting facts accordingly to this knowledge base, as, for instance, in the growing acceptance of the multi-regional model of the origins of modern humans, which takes account of Australian Aboriginal people having evolved in Australia rather than in Africa, as Western science has historically claimed.

Card games depicting different robots in differing contexts were a way of introducing to the youth the different roles and locations of robots in society. These include domestic markets, the manufacturing industry, agriculture and other lesser-known areas. The card game was a simple matching game wherein images of robots are matched to their intended industry. Further to the acquisition of technical knowledge, this game has the future potential for a creative realigning or misaligning of roles to robots, in order to spark creativity and ingenuity in Indigenous youth regarding the design of future robots.

Scoreboards and awarding of stickers (featuring Indigenous animals) continued to inspire the cultural connection in the students. The prototype was concluded through an award ceremony where certificates, specifically designed to identify a range of STEM and attitudinal related award categories, were distributed.

Rich data were collected through evaluation mechanisms, creatively embedded throughout the prototype and post-course phases. Feedback was collated from mentors, teachers and the academic advisor. All feedback strongly attested to the outcome that the prototype workshop was highly successful. The group of children expressed a firm desire to return and continue with the robotics course.

The Indigenous Robotics Prototype Workshop allowed us to explore an example of how we could create meaning from an alternate knowledge base, Indigenous Knowledge Systems, through technology. Gaining support is a commitment to providing initiatives for Indigenous communities to engage and direct future economies within the digital sector. By analysing the key areas of current digital research and development, coding and programming has been identified as a core component of the future digital economies (Topsfield, 2014).

Executives [3] from major companies Intel, Google and IBM have told me that Equity and Diversity is not simply a corporate social responsibility, but is good for business (Bell, Baxter, Herbert and Dooley, in conversation with author, 2015). They are seeking divergent research methodologies, engineering insights and creative design innovations for and within their products and services. Edward Qualtrough interviews Intel's Rosalind Hudnell:

> The chipmaker [Intel] has started to make moves into wearables, Internet of Things, robotics, mobile devices and augmented reality markets; products are being tailored for different demographics, and "diverse experiences lead to different input, which leads to different engineering solutions". (Qualtrough, 2015, partially quoting Hudnell)

There is significant potential for Indigenous Robotics to enhance what we now consider to be mainstream robotics research and development, whether for creative, industrial, or consumer-related ends. As we will argue, Indigenous Pattern Thinking can lead to more effective design that considers the entire system lifecycle along with diverse environmental impacts. Indigenous Robotics would also inform the complex contextual relationships in multi-robot systems and human–robot interaction at the forefront of current scientific enquiry.

The success of the workshop in terms of student engagement is perhaps unsurprising given the history of robotics in promoting engaged enquiry and learning (Singh, Fitch and Williams, 2010). The main tangible outcome of the prototype workshop is more workshops, which build upon the Indigenous Knowledge base and Indigenous Digital Sovereignty framework established. But a deeper outcome is the opportunity to reflect more broadly on the significance of Indigenous robotics, which we explore in the remainder of this paper.

The initial inspiration for the Indigenous Robotics Prototype Workshop came from a desire to investigate how established Indigenous Knowledge Systems might contribute to, influence and impact our connection and experience with new digital technology. Further investigation has led to new questions, and in what follows we will ask how Pattern Thinking (a system for understanding the complex web of ontology, epistemology and interrelatedness within the Indigenous paradigm) might unearth new ways of engaging with digital technology.

Alternate Paradigms

> When paradigms change, the world itself changes with them. (Kuhn, 1996: 111)

In my own youth, there is no doubt that the idea of robots was epitomised by the Transformers of the 1980s. These Transformers also remind me of the superhuman Indigenous Creation Spirits such as Biame, who gave us our lore and culture, and formed the landscape, waterholes and rivers before returning back to the sky. This whimsical, pop culture image linkage – examined and presented in a socially and culturally responsive way – leads me to ask: how could such an adoption and adaptation of our culture through robotics and/or AI bridge the divide for our youth?

I want to compare Indigenous Knowledge Systems to the study of autonomous robots and other intelligent agents, where the agent's task is typically defined in terms of maximising a given objective (or utility) function. *The agent has access to perceptual information about the world, which is often incomplete and uncertain, and takes actions that are likely to increase its utility (task performance) over time, thereby maximising its chances of success. We will return to this idea later in the article.*

Indigenous Knowledge Systems (IKS) is a term I will use for the recognition of Indigenous Spirituality; Aboriginal Science; Philosophy; Cosmology; Kinship; Country; Culture; and The Dreaming, known as Lore (otherwise akin to "law"). Essentially, Indigenous Knowledge Systems is a term to make sense of all the components that a Western knowledge paradigm historically segregates.

Figure 3: Rock paintings at Ubirr, Kakadu National Park, Australia Photo: Rita Willaert, 2008, via Flickr, from the album

IKS is often mis/represented as mythology. But as Roland Barthes (1973: 188) points out, myth is language: 'Ancient or not, mythology can only have an historical foundation, for myth is a type of speech chosen by history: it cannot possibly evolve from the "nature" of things.' As Elder Wayne "Mukgrrngal" Armytage (in conversation with author, 2015) informs me, custodianship of Indigenous Knowledge is transmitted through strict, compressed oral lore, to ensure its veracity, reverence, relevance and ability to sustain and nurture all life. [4] This could be conceived as akin to code, to coding.

Ideas of the veracity, trust, and relevance of information have rich analogues in robotics. One primary challenge of modern robotics is how to deal with uncertainty in various forms, such as uncertainty in sensing, perception, localisation and control. Uncertainty is reduced by fusing immediate observations with mathematical models built from previous observations. Such models can also be shared among robots for mutual benefit. Trust and truthfulness of information (typically measured in terms of Shannon entropy) are therefore necessarily connected to (possibly shared) previous experience. Relevance of information is particularly important for systems of robots that must communicate with each other; one way of mitigating bandwidth limitations in wireless networks is to communicate only the information that is (mathematically) relevant to a certain robot at a certain time (Kassir, Fitch and Sukkarieh, 2015). These are deep concepts in robotics that can be quite naturally related to equally deep concepts in the custodianship and transmission of knowledge in Indigenous Knowledge Systems.Both place importance on a history of previous experience encoded such that it is trusted, timely, and relevant to the situation at hand. It seems that drawing this connection is useful both in engaging Indigenous students in learning about robotics problems, and also in possibly developing new approaches to these problems informed by Indigenous Knowledge Systems.

Songlines act as an oral map. Songlines impart (epistemological) knowledge while concurrently providing meaning and an ethical framework to all life and beings. The same song would be sung throughout one's life; the knowledge embedded through the Songline and the act of "singing up country" unlock the next "door" in one's consciousness. This could be conceived as a next-level intelligence. Australia is mapped by thousands of Songlines, intersecting and crossing at intervals, a network of routes for trade, initiation, seasonal hunting, birthing and death. Vicki Grieves explains:

> For Aboriginal people, each of the lines represents the law or knowledge that prescribes these connections and provides the blueprint for ensuring that they continue. (2009: 200)

IKS can nudge the existential compartmentalism of Western techno-science into another realm of interrelationship and interconnectedness; indeed, the current wave of "new materialisms" bears striking resemblance to, and could benefit from, *indyamarra*. [6] Mukgrrngal tells me that 'the rock over there does not exist until its sung into being' and adds that the power of matter interrelationship is such that 'if we stop caring for country, country dies, and we die'. [7] In Pattern Thinking, the rock has value, meaning and place, as do human beings and the animal, plant, cosmological and metaphysical worlds combined. All things create the complexity of the Pattern Thinking web in a nuanced relationship of being+knowing entwined.

Where once religion informed and influenced all aspects of Western society, now technologist corporations are increasingly informing and influencing our worldviews. The broad differences between Western and

Indigenous knowledges are summed up succinctly by Michael J. Christie:

> Aboriginal Science is a mode of knowledge production which has evolved to allow human beings to fit into, rather than outside of the ecology. It is a science in which all human dimensions, the social, economic, religious and political, are integrated and interpreted within, and in terms of, the rest of the physical universe. (Christie, 1990: 56-57)

IKS syndicates theology, philosophy, science, the arts, ethics and the law through Pattern Thinking: being+knowing is interconnection and interrelatedness. Pattern Thinking can regulate the delicate balance of all things synthetic and our relationship to them. It is an ethical intelligence and embodiment born from this land, giving meaning and relationship to everything. I take this system, evolved as a streamlined ecology, as the best chance of Australian humanity's maximising its chances of success.

Robotics can be viewed as in concert with Indigenous Knowledge in that it also involves the notion of autonomous agents [8] operating in synergy with their world, which roboticists refer to as the environment. A robot's environment can include terrain, objects, humans, animals and other robots. The scale of the robot's environmental representation, and the degree to which the robot's goals work for or against its environment, are matters of design. But questions of how the robot perceives its world and decides to act [9] are undoubtedly fundamental to the discipline (Thrun, Burgard and Fox, 2005), and these questions present a compelling opportunity to conceive of robots in a sense that is informed by Indigenous Knowledge. The setup and background story of the workshop's navigation exercise made an initial step towards drawing such a connection; obstacles and goals in the robotics sense were cast in terms of Indigenous ecology. The subfield of multi-robot systems [10] is concerned specifically with coordination, cooperation and collaboration, and is an excellent avenue to pursue in future workshops.

Being+Knowing Entwined

Indigenous philosophy can be seen as comprised by three components, all interlinked and informing the others: Physical World, Human World and Sacred World (Foley, 2003). Some cultural scholars (e.g. Haraway, 1988; Harding, 1993; Hartsock, 1974) adopt standpoint theory, an analysis of discourse that prioritises and explores the authority implicit in the experiential perspective of the individual (the individual standpoint). In Indigenous Standpoint Theory, the perspective of Indigenous peoples is prioritised in recognising and analysing the (co)construction of knowledge – this while acknowledging that all Indigenous experience is not the same (see e.g. Moreton-Robinson, 2013; Nakata, 2007; Tuhiwai Smith, 2014). Indigenous Standpoint Theory thus offers an ontological and epistemological framework for debunking the imperialism of Western knowledge; the framework supports 'emancipatory and liberatory epistemologies in their deconstruction process' (Foley, 2003: 45). Dennis Foley notes that this effort is guided by a vision that there is more than just one worldview and interpretation of what constitutes knowledge. Knowledge is rooted in, and determined by, the partial, embodied insight of multiple individuals, embedded in contexts of differential power, and inextricably affected by place and time.

In 2014, Twitter's Senior UX Designer Erin Moore gave a talk on the user's experience and construction of time when engaging with technology (Moore, 2014). She eloquently argued that Time and Experience become squishy and malleable and that, essentially, time stops when our engagement with technology is such that we are "at one" with it. She likened this technological "Ah-ha!" moment to our experiential connections with natural wonders, such as the sunset. Moore advocates for technologists and designers to go beyond creating technology for technology’s sake, and to reconsider how a typical contemporary focus on Time strives towards shaving fractions of seconds off activities in service of increasing productivity and time-efficiency, thus detracting from the potential social value of technology and meaning of it within our lives.

Time holds different meanings within Indigenous Knowledge Systems; it is encapsulated as multi-dimensional. As anthropologist William E.H. Stanner noted, '[a]lthough the dreaming conjures up the notion of a sacred, heroic time of the indefinitely remote past, such a time is also, in a sense, still part of the present. One cannot "fix" The Dreaming in time: it was, and is, everywhen...' (1979: 23-24).

Designers of new digital technology could use Indigenous Pattern Thinking, utilised as the basis of interactive and/or artificially intelligent systems, as a model by which to experiment with the psychology at the core of 'Ah-ha!' experiences. Perhaps in using this approach, which foregrounds absolute interrelatedness, we could avoid a scenario prefigured by Stephen Hawking in relation to AI: 'It would take off on its own, and re-design itself at an ever increasing rate … Humans, who are limited by slow biological evolution, couldn’t compete, and would be superseded' (Hawking et al., 2014).

Pattern Thinking: *the brain*. Pattern Thinking, considered post-structurally, is a construct. An active representation and differentiation can be seen through traditional paintings. When painted *true/proper way*, Pattern Thinking is created via an innate embodiment of pattern recognition.

Pattern Recognition: *the heart.* Intuitively known by us, Indigenous people. It is our profoundly ecological interrelatedness with everything and everyone. If you were to look at country from a distance, you would be able to see, as did the children in the Indigenous Robotics Workshop via their chalk maps, the complexity of the lines spanning it, representing different aspects of our society, culture, community, Nations: inanimate and animate objects, fauna and flora, sky and sea and country itself. We are all one and nothing is of more importance than, and or given precedence over, any other aspect. Pattern Recognition is a synchronous, intelligent system, a network in which all parts are equal in value, including humanity. It is multi-dimensional and includes the "lifeless", otherwise known as the metaphysic and the cosmic. It is being+knowing at once; epistemology+ontology; complex yet harmonious in its simplicity: it is the Indigenous central nervous system. Repetitiously sung up since time immemorial, the embodiment of Pattern Recognition surpasses knowing and knowledge, and becomes being on a cellular level. As Bruce Lipton writes in *Biology of Belief* (2005), our DNA is constructed in part from our belief systems. Pattern Recognition is the cellular membrane that translates experiences into sensations, which in turn informs DNA. Knowledge embedded via Pattern Recognition moves beyond philosophical, visceral and biological constructs by considering, for example, how does a sunset register with us on a cellular level? Indigenous peoples' Being+Knowing could be sought to assist technologists with more sophisticated registration of systems in their entirety.

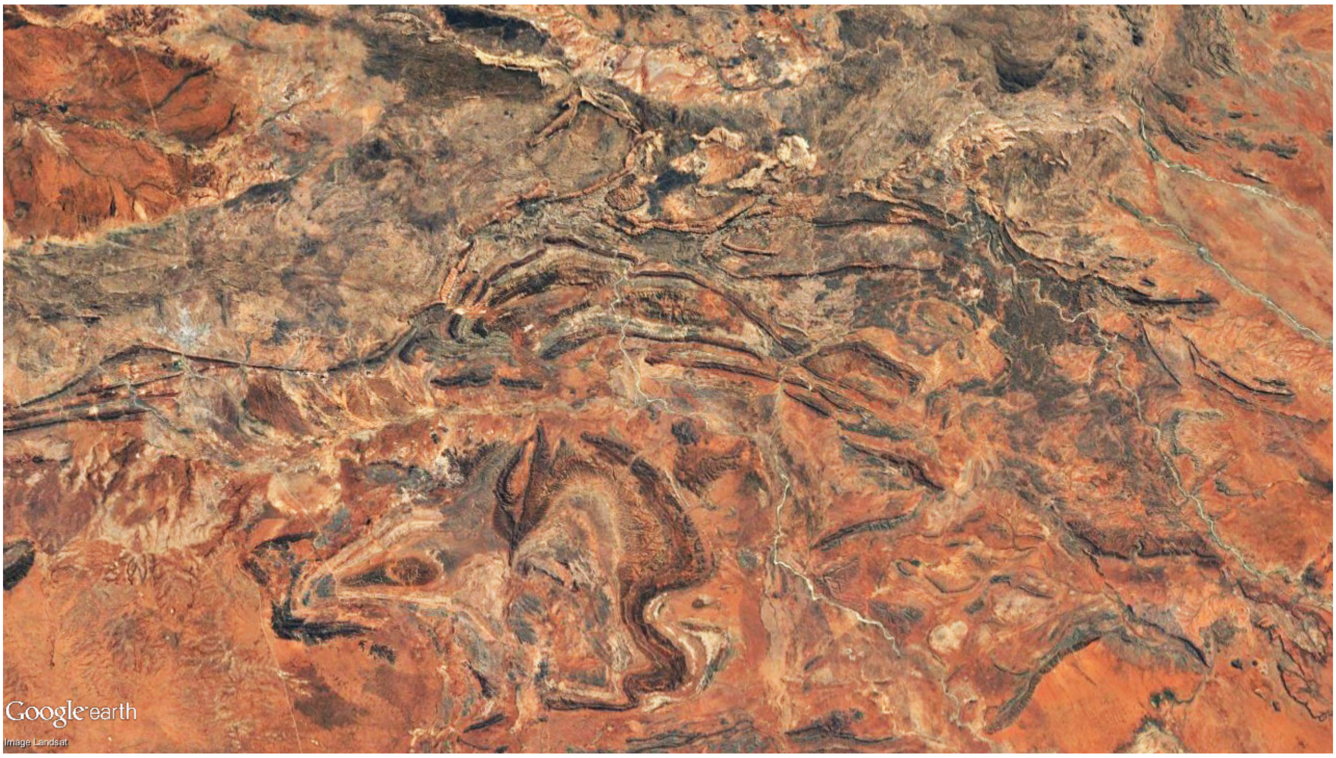

Figure 4: A view of country from a distance. The complexity of the lines represent aspects of society, culture and community when viewed through the lens of Pattern Thinking. Image data: Google, Landsat

An interesting opportunity to connect pattern thinking and recognition to robotics lies in the idea of systems of systems. Stated simply, a system of systems is one in which the whole is greater than the sum of its parts. The core of the idea is that the component systems act in synergy. This concept arises in robotics for large-scale applications such as agriculture and logistics, where robots themselves may be quite simple yet interact with many other processes for the common benefit of maximising the system's chance of success. Although component systems do have well-defined boundaries, systems of systems are a way to formally, yet creatively, consider the interactions between engineered, social and environmental components. This approach is critical for widespread adoption of robotic systems in industry and society, and thus it is important for future roboticists to think in this intersectional manner.

A related idea in systems engineering and design is the cradle to cradle approach, where manufactured objects are conceived as part of a larger ecosystem. When we consider the future proliferation of robots, particularly in areas such as agricultural robotics where the intent is to promote environmental stewardship through technology, cradle to cradle design is appealing in the sense that the lifecycle of the robots themselves should align with the overall goal of environmental sustainability.

Pattern Recognition is an ethical framework that has sustained and nourished Indigenous communities and country since the beginning of "time". Looking to the future, Pattern Recognition could be transformative for artificial intelligence and robotics researchers' quests to create innovative technology with a sense of humanity, awe and inspiration, disrupting the prevalence of clocked linear Time in our experience of technology. Furthermore, embracing Pattern Thinking negates the imperative to create "technology for technology's sake", providing an ethics framework of accountability and responsibility to a system "larger" than the sum of its parts.

Conclusion

The initial aim of the Indigenous Robotics Prototype Workshop was to engage Indigenous youth in STEM subjects in a culturally relevant manner through a novel adaptation of standard materials in robotics education. The workshop succeeded in satisfying its aims, but also compelled us to explore the idea of Indigenous robotics more broadly and to consider the potential for a deep symbiotic relationship between Indigenous Knowledge Systems and modern technological development. The implications of these ideas are profound, both for Indigenous as well as for technological advancement. Although Indigenous engagement in AI and robotics remains a nascent idea, it is exciting to consider its potential benefits for Indigenous communities in the long term. We can and should establish a platform for Indigenous leadership in the epoch of Digital Sovereignty — designed, inspired and informed by Pattern Thinking/Recognition. Indigenous advancement through self-sustaining digital industries and economies could result from this effort, cultivating the creatively produced "Ah-ha!" moments in the experimentations and human–technology interrelations of both children and adults.

Biographical Notes

Angie Abdilla is the Founder and CEO of Old Ways, New. Prior, she was Director of the Indigenous Digital Excellence, as part of the National Centre of Indigenous Excellence. As a United Nations Delegate, she has presented on the Ethical Digitisation of Indigenous Culture at the United Nations Permanent Forum on Indigenous Issues. Angie worked with the United Nations Development Programme for the protection of Indigenous Peoples' rights within world Climate Change negotiations as part of the Paris Agreement, and is part of the international United Nations Digital Rights Working Group. She has worked in digital product development, policy, strategy and research and is an acclaimed film director and producer for her immersive documentary film and cross-disciplinary arts works. Angie continues to utilise the craft of story-telling as the central component to all her work. http://www.oldwaysnew.com

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Notes

[1] The prototype workshop was co-developed and co-facilitated with Liam Ridgeway with advisory associates Kate Brennan, Allen Madden, and the second author. This prototype took place under the auspices of the National Centre for Indigenous Excellence (NCIE). The authors would like to confirm that the knowledge expressed in this article is their own and does not necessarily represent the views or perspectives of the NCIE. The body of knowledge developed within this article is by the authors and all intellectual property and copyright resides with the authors.

[2] Indigenous mentors included Trent Shields, Rebekkah Mooney, Eric Lesa and Michael Rome.

[3] The executives I interviewed are all women.

[4] Mukgrrngal is an initiated lore man, otherwise known as Wayne Armytage. He is by bloodline a Wiradjuri man. He is the "claimed one" by his traditional father, Peter Costelloe, and his traditional grandfathers Mukgrrngal George Musgrave and Tommy George. Mukgrrngal is the custodian of this traditional knowledge I am sharing, which is from a long line of Kuku Thypan Elders from Cape York, FNQ, going back to Mukgrrngal from its very beginning. I attribute this traditional knowledge to Mukgrrngal as my Elder throughout this article, if not otherwise noted.

[5] Mukgrrngal, in conversation with author, 2015.

[6] *Indyamarra* [from the Wiraduri language]: a sense of the sacred; to give honour to; show respect; and to do slowly. (Mukgrrngal, op. cit.)

[7] Mukgrrngal, op. cit.

[8] In robotics, "autonomous" refers to the ability to act independently (including both sensing and actuation) and outside the direct control of an operator. For example, a teleoperated ("joysticked") robot is not autonomous, but a robot that can move under its own command for the purpose of accomplishing some task is considered to be autonomous. Likewise, a "semi-autonomous" system is one that is teleoperated at some points in time and autonomous otherwise.

[9] In the context of robot autonomy, roboticists say that a robot "makes decisions" and "decides" to take an action.

[10] A good introduction to multi-robot systems can be found at http://multirobotsystems.org

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FCJ-210 Falling Robots

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Abstract: Falling is not usually viewed as a desirable act for humanoid robots, as it can lead to damage and injury of people, things and the robot itself. This article explores how falling can be viewed as an aesthetic, creative act, through positioning it within dance. Strategies for falling safely in dance are compared with engineering approaches to controlling falling for bipedal robots, through the language of automatic reflex, righting reaction and equilibrium response patterns in relation to gravity. By playing with parameters of movement as dancers and choreographers do, the act of falling by robots can go beyond safety-oriented motivations of avoidance and damage mitigation towards expressive behaviours that can be read on multiple levels of meaning for performance, entertainment and non-verbal communication between humans and machines.

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Falling is not usually viewed as a desirable act for humanoid robots, as it can lead to damage and injury of people, things and the robot itself. This article explores how falling can be viewed as an aesthetic, creative, and indeed desirable act, through positioning it within the disciplines of dance and choreography. Strategies for falling safely in dance are compared with engineering approaches to controlling falling for bipedal robots. By this comparison, the article identifies two main areas in which an aesthetic approach to movement might be used to extend falling strategies for humanoid robots. Studying and categorising reflexes used by dancers and humanoid robots in falling, the article proposes that particular reflexes be used as common ground in developing a more communicative language for moving, falling and performing robots. Then, by playing with parameters of movement as dancers and choreographers do, falling robots can go beyond safety-oriented motivations of avoidance and damage mitigation towards expressive behaviours that can be read on multiple levels of meaning for performance, entertainment and non-verbal communication between humans and machines.

Instability is at the core of human balance and movement. Movement scientists have observed the phenomenon of postural sway – the continuous, small amplitude, high frequency movement of a dynamic system. This was once discounted as noise, but in cybernetic theory these small movements are considered exploratory and provide informative feedback on the state of balance of the system (Goldfarb, 1993). This instability – a small continuous wobble – is a crucial mechanism for proprioception in the detection of where we are in space and the maintenance of balance. Lepecki (2000) takes this function of the vibrating body further by reframing it as a source of creative action for choreographic material. He works with the example of Steve Paxton’s "small dance" in standing, in which the dancer observes the micro movements of the body’s reflexes and righting reactions as it performs the act of standing without their conscious control (Lepecki, 2000). Attendance to the tremor, vibration or wobble inherent in the body can provide dancers with inspiration and material for movement, which they can choose to amplify and extend into pathways of movement.

Dance and choreography exploit the expressive potential in the tension between stability and instability, verticality and the surrender to gravity (Lepecki, 2006). A series of open moments exists in the execution of the fall, where the choreographed body can transition from one strategy to another or play with the aesthetic expression through varying the timing, duration, rhythm, speed, scale, tension and counter-tension of movement. At the moment of going off-centre and yielding to gravity, there is more than one possible pathway to the ground. When a specific pathway or strategy has been committed to in the descent, then other potential pathways open up in the first contact with the ground and the recovery of the fall. This same principle can be applied to robotic falling decisions. As will be shown, the initiation and recovery phases are the points at which there is currently the most divergence between the dancer’s and the humanoid robot’s repertoires of movement in falling; this is interpreted to indicate a promising area in which to extend the aesthetic communication and somatic scope of the robot. In opening up the initiation and recovery phases to experimental movement and improvisation, humanoid robots can fall more creatively, refining their reflexes and playing with the wobble.

Controlling Stability and Fall Prevention in Humanoid Robots

In emulating humans, robotics engineers who design humanoids are confronted with the complexity and mystery of the human body. Seemingly simple, everyday acts of standing and walking appear as complex, hard to solve problems of non-linear dynamical systems with unpredictable behaviours. The bipedal posture of both the human and the humanoid robot frees the upper limbs for tasks other than locomotion, yet simultaneously creates a crisis of balance: the ability to walk is intertwined with the possibility of falling.

In robotics research, much of the understanding and inspiration for how to create safe falling sequences for humanoid robots have come from the disciplines of biomechanics, human dynamics simulation, medical studies and martial arts (Fujiwara et al., 2002, 2003; Ruiz del Solar et al., 2009; Moya et al., 2015). Interestingly, dance is notably absent from this list even though in contemporary dance controlled falling is a common and essential movement pathway in transitioning into the ground. This can be traced back to the pioneering modern dance of Martha Graham in the early twentieth century and the relationship to space and gravity so central to her approach. [1]

Much like in humans, static stability in humanoid robots is more difficult to achieve in the sagittal than the lateral plane. True static stability requires at least three legs, or very large feet for two-legged robots (Bekey, 2005). Walking is statically unstable and dynamic stability is achieved through balancing inertial, frictional and gravitational forces (Bekey, 2005). Various methods for controlling stability have been developed, including active control of joints through sensors and actuators (Bekey, 2005), stepping in the direction of the fall (Pratt et al., 2006) and reflexes (Moya et al., 2015).

Fall prevention is not always successful, and when stability is compromised, strategies for controlling the fall safely are needed. If the robot falls as a dead weight, either accidentally or intentionally, much damage can be done to the electronic and mechanical parts. [2] As Ruiz del Solar et al. (2009) point out, robots differ from humans in the way that they absorb shock through their structure. In humans, impact forces are absorbed by the joints, skin and flesh, before reaching the more fragile bony skeleton. In contrast, robots generally absorb shock through sturdy frames and padding. It is their joints that are the most prone to damage, as the joints house the servomotors that actuate the joint movements.

A reflex, in robotic terminology, corresponds to a pre-calculated sequence of motions that requires the aborting of the current activity, for example, stopping walking or lowering the centre of mass by squatting (Moya et al., 2015). In a parallel way to the Paxton technique presented above (Lepecki, 2000), robots are continuously monitoring their internal state and attending to the moment-to-moment fluctuations. When a robot detects an unstable state, an aesthetic choice could be made in conjunction with the functional safety decision. Aesthetic pathways are available and can be integrated into the existing planning algorithms that seek to optimise the fall strategy for minimising damage. As part of this work, robotic researchers will also need to identify the envelope and lower threshold of acceptable falling manoeuvres, in order to expand the available set for aesthetic consideration.

In summary, going off-centre is the initiation of an aesthetic act in dance, but is an indicator of undesirable instability in humanoid robots. In what follows, the falling strategies for robots are recast in the aesthetic frames of dance performance and choreography, to open up perspectives on possibilities for creative innovation and expression.

Beyond Safety to Choreography

As stated, this article identifies the initiation and recovery phases of falling as the most fruitful areas in which to encourage robotic experimentation (all three phases – initiation, control and recovery – will be explained in detail below). Here, it presents some examples of ways of falling that might stimulate these experimentations. Depending on the specific robot embodiment (the shape, size, degrees of freedom, configuration of parts), more or less options for creative movement on the ground and in the vertical will be available.

Following Lepecki's (2006) thinking of dance as a challenge to verticality, conception of the ground can be freed from its being just a surface to stand and travel on; it becomes a territory to inhabit, with extra choreographic potential. The relational placement of the body in space and on the ground plane is a diagramming of action, offering multiple levels of meaning. In choreographer Trisha Brown's solo *It's a Draw/Line Feed* (2003), her first move from standing is a fall to the ground. The unexpected landing of the fall outside of the square surface designated for performance is significant to the political meaning of the work (Lepecki, 2006). A corresponding choreographic, or even political, decision regarding where to land and contact the ground could elevate the falling action of a robot from a pure function of safety to one engaging registers of expressive and symbolic meaning. Acts of falling can be expanded from being purely motivated by avoidance and damage mitigation to being laden with aesthetic and expressive power.

The recovery phase of the fall for humanoid robots is usually concerned with a fast recovery of the standing position (Moya et al., 2014), especially in robot soccer. In viewing the 2014 RoboCup SPL Grand Final, there is a great deal of accidental falling happening, apart from the intentional falling of the goalie. [3] It is a slow game! The knee-high robots slowly shuffle around the field, often gently colliding with each other with the net result of at least one of them falling over in what, it must be said, is a clumsy action. What is more impressive is the quick recovery action of getting up after falling down – a rapid series of articulated joint manoeuvres in the legs and torso. The ability to dynamically change body morphology is being explored in the area of self-reconfigurable robots (Stoy et al., 2010), but is yet to be successfully demonstrated as a mechanism for redirecting forces in falling strategies of humanoid robotics.

In contexts not dictated by gameplay, safety or social requirements, what takes place in the recovery phase after ground contact can be expanded well beyond simply transitioning to standing. The return to verticality can be resisted. In *It's a Draw/Line Feed* Trisha Brown resists the call to verticality by rolling, slithering and crawling on the ground. The horizontal and vertical planes become a playground for experimentation in moving and falling, built on the reflex, righting reaction and equilibrium response patterns (see below).

In the example of the Honda Asimo humanoid, a 2007 televised demonstration of the robot intends to show it walking up a small set of stairs. Unfortunately, it stumbles on the third step and falls backwards. This moment of public failure is heightened as a modesty screen is quickly placed in front of the fallen, motionless Asimo. However, considered under the rubric of experimental, theatrical choreography, the motionless figure of the robot after it falls backwards off the stairs could be recast in a performance frame as a "still-act". The employment of stillness as a legitimate element in choreography opens up a moment of presencing, an intensification of perception and affect between performer and audience (Lepecki, 2000). It can also be used to heighten or underscore what came before or what will follow. In De Quincey Co.'s 2005 performance *Dictionary of Atmospheres* in the dusty Mparntwe/Todd riverbed in Alice Springs, Central Australia, the use of fall-downs created an intense intimacy between performers and audience through the images of suspension and surrender embodied in their falling. The points of prostrate stillness correspond to the suspension of movement when standing and preparing to fall, and reverberate the impact of collapsing to the ground and remaining motionless before rising up again.

The shock and danger of a potential fall can be used for theatrical impact, keeping the audience on edge due to the risk-taking inherent in going off-balance. Falling can also be used to great comedic effect, as exemplified by 1920s physical comedian Buster Keaton with his particular style of slapstick involving physical stunts. One of the participants in the below-described study of dancers shared how he might experiment with interacting with a chair as part of stunt falling (Loke and Robertson, 2007, 2010). He discussed choices available for dramatising the action, through collapsing into the ground as the chair tips over versus walking over the top of the chair as it tilts to the ground. With the impending rise of robots for entertainment, the idea of clowning, dancing and stunt-performing robots that use falling as part of dramatic and comedic routines could be an interesting future direction in creative robotics.

Learning to Fall: Reflexes, Righting Reactions and Equilibrium Responses

The somatic body-mind centering (BMC) work of Bonnie Bainbridge Cohen on human developmental movement patterns provides a language of automatic movement patterns in relation to gravity that gives rise to intentional, expressive movements (Cohen, 1993). These patterns provide a language for linking the analyses of the falling strategies of dancers and humanoid robots. Falling strategies for robots are beginning to appear that deal with the direction and dissipation of forces through a limited application of human-like equilibrium responses. These strategies can be expanded by considering reflexes as producing expressive performance, using Cohen's schema and insights as a springboard.

Primitive reflexes, righting reactions and equilibrium responses are a continuum of automatic patterns of movement that underlie our volitional movement. These mechanisms begin to develop from birth and are mostly formed within the first year of life. This section outlines definitions from Cohen (1993) of the automatic patterns most pertinent to this article, prior to them being applied to select examples of dancers and robots falling.

- **Primitive Reflexes** (PR) are controlled by the spine and brain stem. For every reflex, there is an opposite reflex, which modulates it. One of the first reflexes to develop is the Tonic Labyrinthine Reflex. It is about bonding to the earth – it draws us towards the earth by increasing the postural tone of the muscles on the underside of the body. On the basis of this grounding, we can then leave the earth through righting reactions.
- **Righting Reactions** (RR) are controlled primarily by the mid-brain and are most dominant at 10–12 months of age. They are necessary for us to lift our heads, roll over, sit, crawl, creep, stand and walk. In pushing away from the earth towards the vertical, the three righting reactions (Head, Optical and Body Righting Acting on the Head) combine to draw us upwards. [4]
- **Equilibrium Responses** (ER) are automatic patterns of response for maintaining balance as a result of the shifting of one's centre of gravity and/or base of support through space, from lying to standing to flying. When we go off-balance or fall, there is a range of possible responses. (The first response is that of head righting (above), to protect the head from impacting the ground.) There are five types of ER; these will be used both in the analysis of the three stages of falling and in the discussion of published strategies for falling in humanoid robots.
    1. Navel-Yielding
    2. Protective Extension
    3. Spatial-Reaching
    4. Spatial-Turning
    5. Outer-Spatial

The *Navel-Yielding ER* is activated in the release of the body into the ground. It is gravity-oriented and yielding in nature, as the limbs are curled around the navel and the bodyweight is released sequentially. The *Protective Extension ER* occurs when we extend a limb and reach out in the direction of the fall, to extend the base of support. It includes *Protective Stepping* that underlies walking, and *Protective Hopping*.

In the *Spatial-Reaching ER*, instead of reaching for the ground with the limbs, the spine curves in the direction of the fall, whilst the limbs (arms/legs) reach away in the opposite direction to control the descent. In the *Spatial-Turning ER*, the head, spine and limbs shape into a rounded form around a central body axis, so that the body turns in space in order to either: a) reorient the body's position in space, as a last resort when a Spatial-Reaching ER has been unsuccessful; b) transition from an unsuccessful Spatial-Reaching ER to a gravity-oriented response; or c) transfer the falling forces or momentum into circular forces, for example in rolling.

The *Outer-Spatial ER* occurs when the focus is far beyond the personal kinesphere. The body is fully extended as it reaches for an object well beyond itself. An example is a soccer goalkeeper leaping or diving to catch a ball.

Dancers' Falling Strategies

The following section deploys my previous study of falling techniques by contemporary dancers from a range of backgrounds (Loke and Robertson, 2007, 2010) to analyse falling strategies using Cohen's set of reflex, righting reaction and equilibrium response patterns underpinning volitional movement. My previous performance research studied the act of falling as a means of making strange or defamiliarising everyday movement (Loke and Robertson, 2007, 2010). A study of dancers who are skilled movers adept at falling was conducted to understand how they performed and experienced the act of choreographed falling. A selection of falls from the study illustrates the variety of falling strategies employed by the dancers (Figure 1).

There are three distinct stages in the process of falling: (1) initiating the fall, (2) controlling the descent, and (3) resolving the fall, contacting the ground and recovering. This structure is useful for identifying opportunities for generating creative, expressive movement in the choice of available pathways for robotic falling strategies. Three examples of instances of dancers falling are presented and explained in terms of the involvement of the reflex and equilibrium response patterns. The study revealed the way dancers use their spatial imagination, both in mechanical and imagistic terms, to shape, support and direct the moving body and energy flow in the fall and recovery. In *mechanically-based* techniques, the focus and emphasis is on the order, organisation and sequencing of body parts in relation to each other and the environment as the movement unfolds, and the direction and dissipation of energy through the body. In *image-based* techniques, the focus and emphasis is on working strongly with the image to direct and inform the movement process and quality of movement. If one surrenders fully to the image, the body follows. There is less conscious attention given to specific body parts moving in a certain order, although the arrangement of limbs for minimising injury is worked out through training and experimentation.

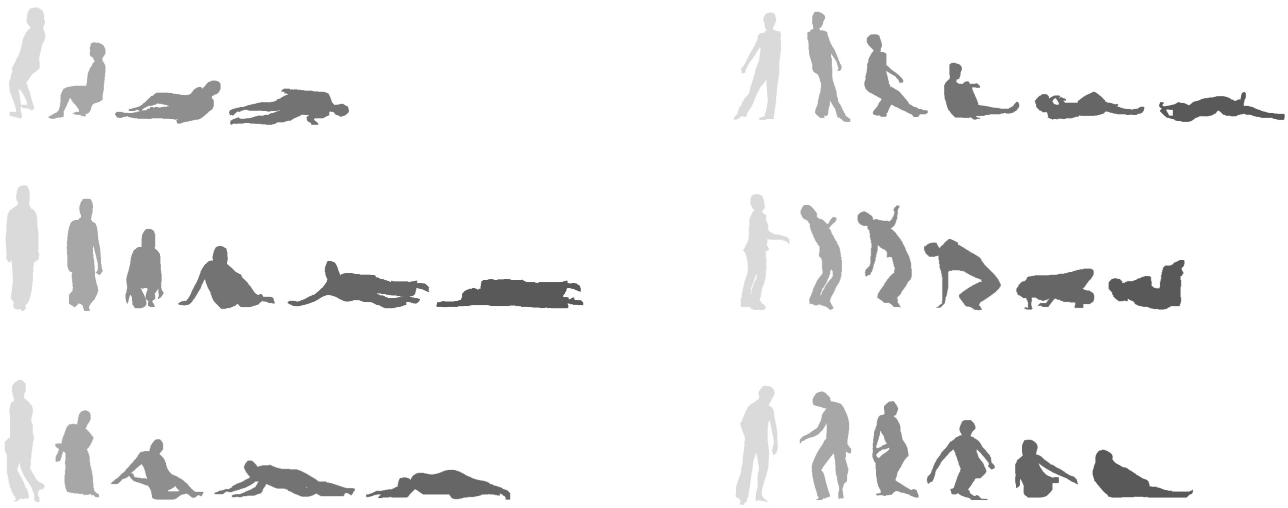

Figure 1: Visual silhouettes of falling strategies of dancers

Initiating the fall: finding triggers

Dancers demonstrated a range of strategies for initiating the fall, such as going off-centre, spiralling around the central axis or collapsing by degrees. Some dancers used specific qualities or images to help generate how the body experiences transitioning from being stable to off-balance and releasing to gravity, such as dissolving from a point of suspension or imagining being shot by a gun. Many of them spoke about the desire to surprise themselves with how the act of falling was initiated and how to find novel pathways down to the ground rather than repeating habitual patterns of movement.

Controlling the descent: the paradox of light/heavy

There is an inherent paradox in the controlled action of falling by dancers. Simultaneously the experience is one of buoyancy and lightness, combined with giving weight, a yielding to gravity. The Spatial-Reach or Navel-Yielding ER is predominant in this phase of the movement. The Tonic Lab Reflex is also present in the drawing down of the underside of the body towards earth. Playing with the opposing forces of these patterns, we can become accustomed to releasing our weight into the ground from all kinds of positions, including sitting, and on all fours. Dancers employ weight shifts, muscular tension and counter-tension to control the direction and momentum of releasing to gravity. They play with this dynamic to create different effects.

Resolving the fall: contacting the ground and recovering

The resolution of the fall, from the descent to contacting the ground, usually involves some form of Protective Extension ER such as stretching out an arm or leg to make ground contact. This then turns into a Navel-Yielding or Tonic Lab Reflex. An essential strategy for not causing injury is to soften and release any tension in the body. Another important strategy is to redistribute the impact forces through rolling, by curling the body into configurations that will protect the bony parts and enable the dancer to control the impact and recovery – this is the Spatial-Turning ER in action.

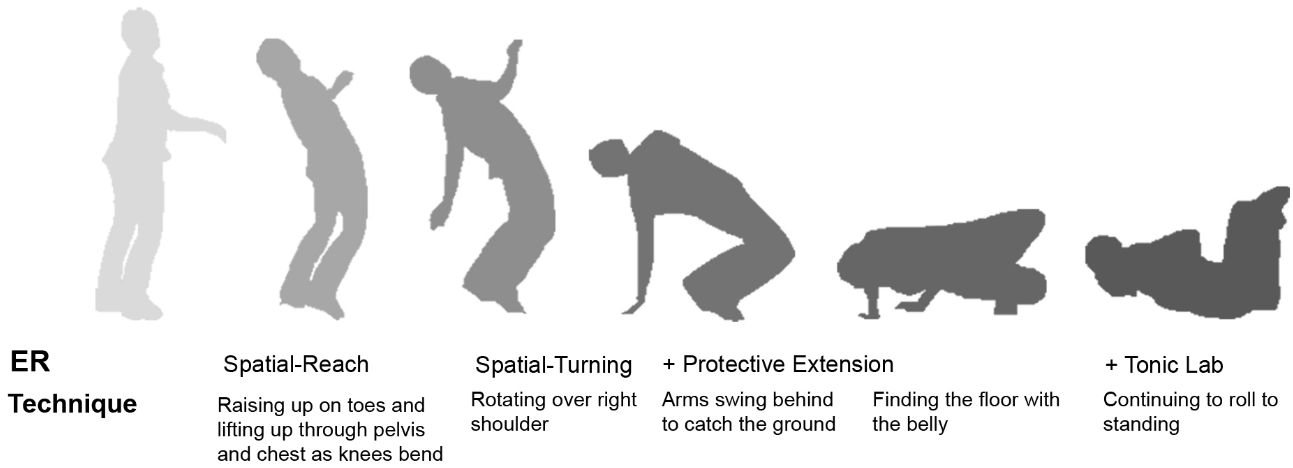

Figure 2: Detailed analysis of falling for participant 4

In Figure 2 participant 4 performs a hinge fall. This falling strategy begins with a variation of Spatial-Reach ER with the bent knees moving in the direction of the fall and the rest of the body moving in the opposite direction to control the momentum of the fall. The fall is resolved with the twist of the torso enabling the belly to seek the ground (the Spatial-Turning ER) and the hands to touch the ground and control the landing (Protective Extension ER). Upon the belly contacting the ground, there is an element of Tonic Lab Reflex, before the twisting motion is continued into a side roll (the Spatial-Turning ER continues). The recovery of the fall is a spiralling to stand. The dancer described her experience of the falling process predominantly as a feeling of lift and suspension, in working against gravity.

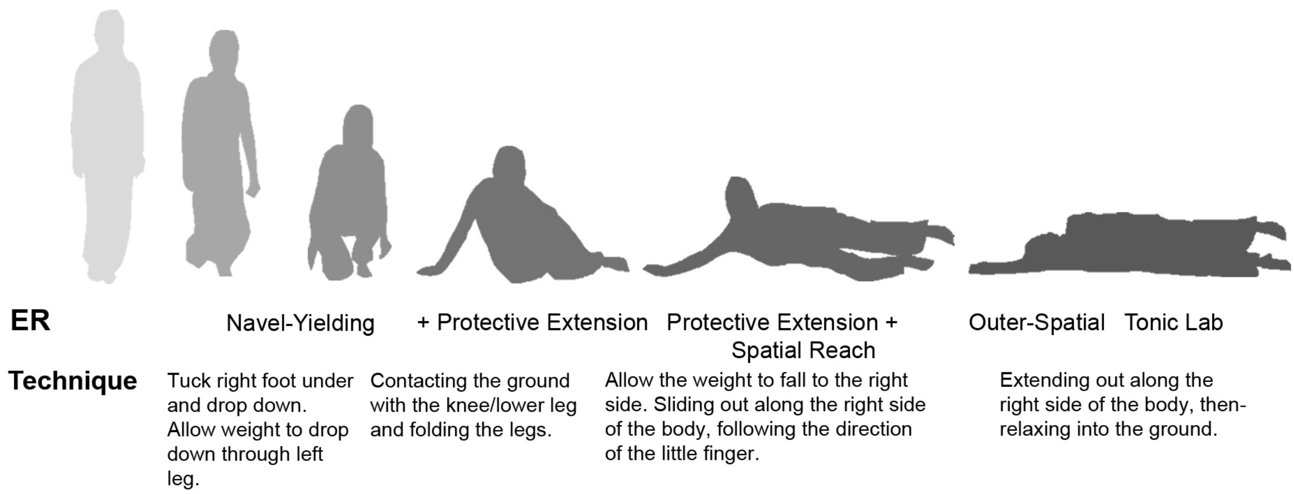

Figure 3: Detailed analysis of falling for participant 1

In Figure 3 participant 1 demonstrates a sideways fall, commonly used in contemporary dance. Distal initiation through the fingers takes the body out into the desired direction. The falling strategy begins with a form of Navel-Yielding ER as the dancer uses the momentum of vertically dropping down and then folds the limbs inward. The contact with the ground is made with the legs and little finger, as a Protective Extension ER. The Spatial-Reach/Outer-Spatial ER is activated as the dancer slides out to the side with the little finger leading and extends the body along the ground, followed by a softening into the ground (Tonic Lab Reflex). The dominant feeling in this fall was described as a sensation of shooting out.

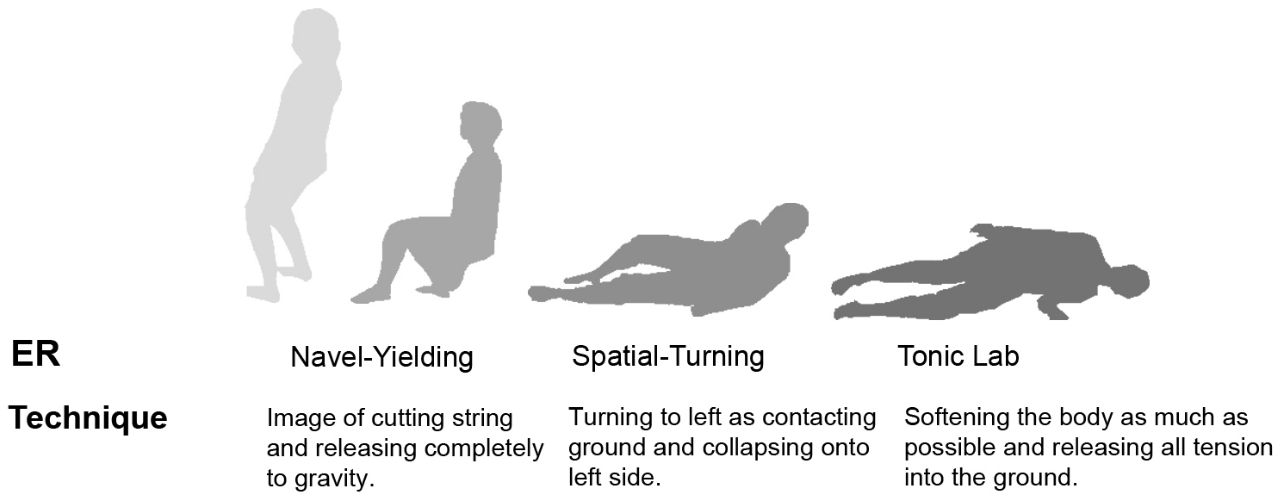

Figure 4: Detailed analysis of falling for participant 6

Compared to the above examples, which are mostly about the physics and mechanics of managing forces through the falling body, Figure 4 illustrates the use of imagery for doing fall-downs in the Bodyweather dance practice. In Tess de Quincey's words, 'the whole imperative of the fall-down exercise is the experience of emptiness, which is driven fundamentally by a philosophical relationship to and questioning of what it means to be human, what it means to stand upright'. [5] The image is in two parts: (1) the body is suspended by a string attached to the crown of the head into the sky, and (2) the string is cut, and the body is like a bag of bones, collapsing to the ground. Prior to the initiation of the fall, the body is heavy 'like a sack of potatoes' (dancer's description). Upon the image of the string being cut, the dancer releases all her weight into the ground. Here, this is a backwards fall that flows from a Navel-Yielding ER into a squat. As the dancer turns to one side in making contact with the ground, the Spatial-Turning ER is activated. This technique requires a large release of tension and softening into the ground, drawing on the Tonic Lab Reflex.

Table 1. Summary of dancers' falling strategies categorised into phases and reflex/equilibrium responses (modified from Loke and Robertson 2010)

	Initiating the Fall	**Controlling the Descent**	**Resolving the Fall**
Mechanically-based	Going off-centre Release from the centre Spiralling around central axis Momentum of dropping down Finding interesting configurations, that surprise me	*Body Righting Reaction:* Internal muscular lift to slow down Protective Extension *ER:* Distal initiation with hand *Spatial Reach ER:* Working in opposite direction to the fall Control by taking my weight to the opposite side *Navel Yielding ER:* Folding bones into alignment	*Protective Extension ER*: Distal initiation with hand Finding a way to support myself down, with your hand Let the legs and arms catch some aspect *Navel Yielding ER*: An unfolding … Letting my body roll into the ground Rolling down the body Making the contact with the ground take the greatest amount of time and cover the greatest surface area *Tonic Lab Reflex*: Release into the ground Relax and soften Absorbing it in the joints *Spatial-Reach/Outer-Spatial ER*: Little finger extends body out along the ground, legs moving in opposite direction *Spatial Turning ER*: Twisting/turning to redirect momentum and control which part of the body contacts the ground Fast falls need some kind of roll
Image-based	Collapsing Dissolving Toppling like a rock Image of extension and then release (like a string being cut) Imagine being pushed, an outside force Bang! Get shot and hit the ground	*Body Righting Reaction*: A sense of suspension *Navel Yielding ER*: Collapsing by degrees Crumpling Body is like a bag of bones	*Navel Yielding ER*: Work with multiple, simultaneous images, e.g. bag of bones and foetal

Extending Humanoid Robots' Falling Strategies

Turning to an examination of currently published strategies for falling in humanoid robots, the following will analyse examples of falling strategies for humanoid robots, using Cohen's set of reflex and equilibrium response patterns. The section first juxtaposes falling strategies of dancers and robots, and next presents a discussion of potential aesthetic strategies for falling humanoid robots.

A range of falling strategies for humanoid robots has been developed by several groups of robotics researchers. In abstract terms, these strategies involve actions like squatting to lower the centre of mass, extending the legs to redistribute the impact force, extending the arms in the direction of the fall, and turning the torso to redistribute the points of impact. These bear some similarity to the automatic reflexes, righting reactions and equilibrium responses underlying human movement and our relationship to gravity. When humanoid robots become unstable due to an external push or uneven terrain, the first reactive response often applied is a stepping strategy (Pratt et al., 2006). A step in the direction of the fall can often save the robot from falling and enable it to regain balance. This is equivalent to Cohen's Protective Stepping equilibrium response (Protective Extension ER). When stability is compromised and a fall is inevitable, fall controllers are activated to control the fall and minimise damage to the robot and its surrounding environment.

The design of safe falling motions for forward and backward falling has been explored by Fujiwara and colleagues (2002, 2003, 2007). They identified squatting as one strategy for reducing the potential energy and impact force (see Figure 4 for comparison). For falling over backwards, they were inspired by a martial art in the Judo Ukemi break fall technique (Fujiwara et al., 2002), however it is not clear how they understood the Ukemi technique and applied it to their model.

Landing speed is closely related to damage at impact. In Fujiwara et al. (2003), the aim was to minimise the landing speed through the leg extension force. (A Spatial Reach ER, with one leg moving in the opposite direction to the fall.) As illustrated in Figure 5, the backward falling strategy consists of five stages of *Squat—LegExtend1—Touchdown—LegExtend2—Finish*. This sequence can be reinterpreted as a chain of Cohen's ER responses: *Navel-Yielding (Squat)—Spatial-Reach (LegExtend1)—Navel-Yielding (Touchdown)—Spatial-Turning/Spatial-Reach (LegExtend2)—unclassified (Finish).* In other words, when a fall is detected the robot bends its knees to assume a squatting position and curls its neck, waist and arms into the landing posture. The hip becomes the first point of contact on landing. The extension of the legs before and after touchdown is calculated so that the optimum landing position for minimal impact is reached. During touchdown, the servomotors are temporarily turned off to minimise damage to the mechanical parts. The servomotors are turned on after touchdown to prevent the robot from rolling too far backwards and damaging the head.

Depending on the robot morphology and ability to rotate the head, it may be possible to extend this sequence by employing the shoulder roll performed by dancers. The shoulder roll is a technique for dealing with backward falls and is particularly useful when running backwards at high speeds, as the high momentum will need to be absorbed and redirected by a rolling action.

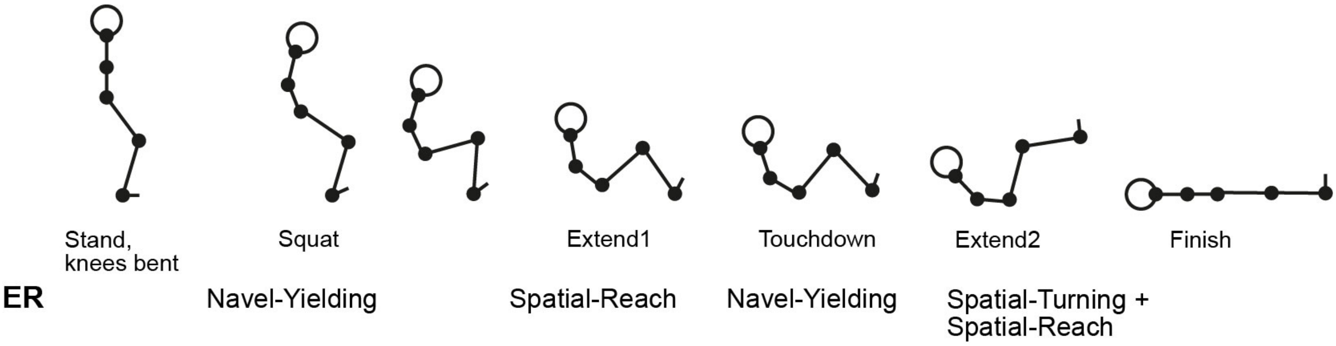

Figure 5: Detailed analysis of backward fall (after Figure 8, Fujiwara et al. (2003))

In Fujiwara's study (2007), the research team simplified the problem by designing a humanoid robot with a simpler shape and less degrees of freedom: it has only one wide leg, and its upper arms are driven by one servomotor as one link. The reduction to one leg means no stepping strategies can be applied and the robot will fall forward or backward when pushed. The researchers focus on the forward falling, modelling it as a quadruple inverted pendulum model. As illustrated in Figure 6, the forward falling strategy is *Squat—ArmExtend—Finish*; in Cohen's terms it is *Navel-Yielding (Squat)—Protective Extension (ArmExtend).* Apparently the padding (soft cushions at each joint) and protection (electronics and motors are inside the frame) are adequate in this set-up to minimise damage. Ha and Liu (2015) take this idea of distribution of forces over multiple contact points further with their planning algorithm that computes the optimal sequence of points to minimise the ground impact forces. Possible contact points in their system include feet, heel/toe, knees, hips, back, hands and head; the exact selection is dependent on the individual robot morphology.

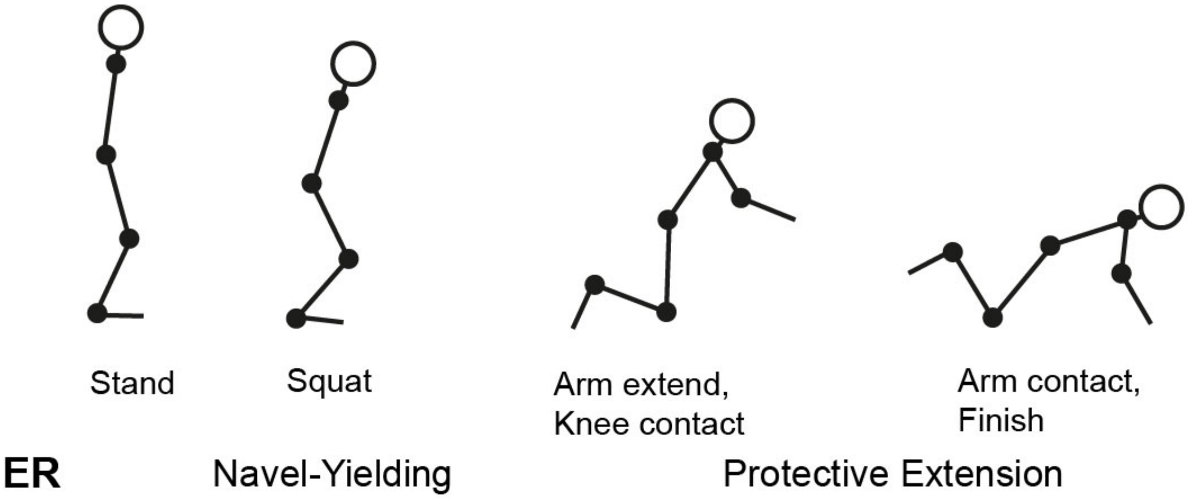

Figure 6: Detailed analysis of forward fall (after Figure 11, Fujiwara et al. (2007))

Human-size robots are heavy and can cause damage to people and objects upon impact. Some researchers (e.g. Yun et al., 2009) have tackled this problem by devising fall controllers that optimise the fall direction for minimal damage. The inertia-shaping technique recruits all the joints to control the composite rigid body (CRB) inertia (Lee and Goswami, 2007). It controls joint angles to produce a desired angular momentum, either towards a desired direction or away from a direction to be avoided. However, it is not clear how this changes the body configuration and influences the fall direction and landing posture. For Nagaran and Goswami (2010) the problem is expanded from a single object as obstacle to multiple objects in the environment. They propose a similar yet more generalised approach, changing the robot's support base geometry through stepping, and whole body inertia shaping techniques. They expand the set of strategies to include Lift a Leg and Partial Body Inertia Shaping. Simulations and experiments involving an Asimo-like humanoid robot (Aldebaran NAO H25, 57cm tall) have shown promising results for computing the optimal stepping location for the safest fall (Goswami et al., 2014). These techniques show potential for being rethought and applied for aesthetic, expressive and choreographic contexts. Instead of computing optimal paths for safe falling, the computational goal could be expanded to also include stepping and body inertia shaping choices that may result in interesting, aesthetic shapes, pathways and target locations.

Robot soccer is one of the few areas where falling is viewed in a positive light. In a human game of soccer, falling is a common occurrence triggered by sliding tackles, collisions, and extreme movements to kick and obstruct the ball. The goalkeeper is the one player who can touch the ball with her/his hands and thus is frequently involved in acts of diving and falling to catch or block the ball. In the work of Missura, Wilken and Behnke (2010), robot goalies perform a limited set of actions: stand, bent-knee halt posture, squat, jump, dive and walk. The dive is considered a high-risk option, due to the risk of mechanical damage and the time it takes for the goalie to recover and reposition itself in front of the goal. It is one of only a handful of examples in humanoid robots of a self-initiated intentional fall.

With reference to Figure 7, the dive motion is initiated by a sideways hip swing, using the hip and ankle joints to accelerate the torso towards the yielding leg – an action that leads to the Spatial-Reach ER. Then the yielding leg shortens and before the support leg loses ground contact, it is extended and moved inwards closer to the yielding leg – this has the effect of increasing the blocking distance. While the support leg is extending, the arms are also lifted high up above the head – this appears similar to the Outer-Spatial ER. This motion is being used in the RoboCup SPL games. The design work of Ruiz del Solar and colleagues (2009) and Moya and colleagues (2015) adds an important element of dissipating forces through the arms on landing, much like martial artists and dancers do. This is achieved by extending the arms in the direction of the fall (a Protective Extension ER) and by reducing the torques in the arms' motors to just above zero to minimise damage to the joint servo motors. Missura and colleagues (2010) also explored a FrontTurn frontal fall sequence where the robot turns its body before touching the ground – this action is like a Spatial-Turning ER, distributing the transfer of kinetic energy over several contact points and for a longer lapse of time (with the caveat of success limited to simulation due to the complexity of synchronisation).

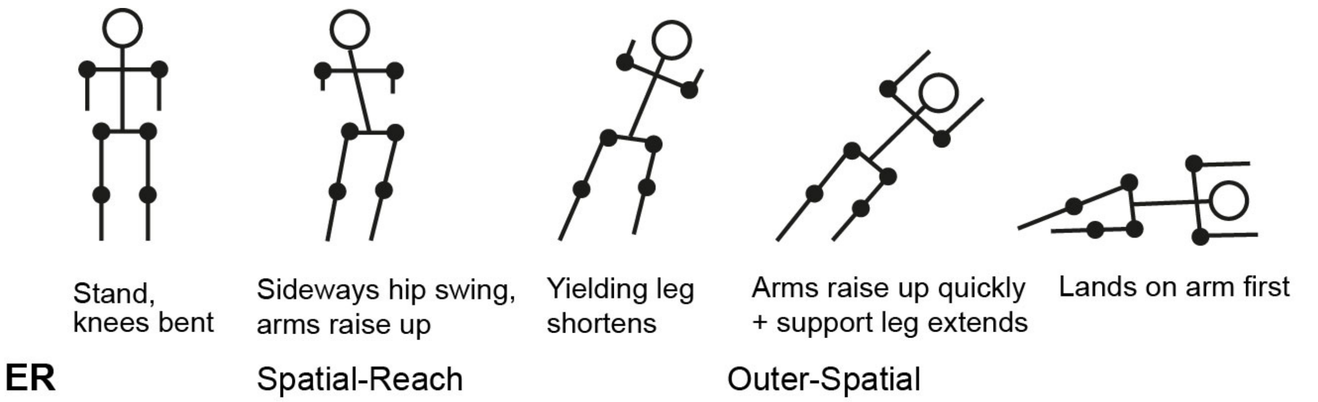

Figure 7: Detailed analysis of sideways dive fall (after Figure 4,Missura et al. (2010))

Table 2. Summary of humanoid falling strategies, categorised with Cohen’s reflex, righting reaction and equilibrium response patterns

Initiating the Fall	Controlling the Descent	Resolving the Fall
External force, e.g., push, collision, resulting in front, back or side fall Instability due to uneven terrain Internally generated, e.g., hip swing in desired sideways direction, leading to Outer-Spatial ER towards the ball	*Protective Stepping ER*: Stepping *Navel-Yielding ER*: Squatting Curling body and limbs *Protective Extension ER*: Extending arms or legs in direction of fall *Spatial-Reach ER*: Extending arms or legs in opposite direction to the fall *Combination*: Direction of fall controlled by stepping, foot placement and body inertia shaping	*Protective Extension ER*: Extending arms in direction of fall *Spatial-Reach ER*: Extend leg away from fall to minimise landing speed Turn joint motors on again after landing to control and stop the rolling action through extension of the joints to avoid damaging the head (*Head Righting Reaction*) *Spatial-Turning ER*: FrontTurn frontal fall – twisting torso to land on side *Unclassified*: Reduce or zero torque in joint motors to minimise damage Padding on likely contact points to absorb shock Springs joining body segments

Aesthetic Strategies for Falling Humanoid Robots

Comparisons

On comparing Table 1 and Table 2, the middle stage of controlling the descent is already quite similar for dancers and humanoid robots, probably due to this phase of the fall being the one least open to variation. Both dancers and robots demonstrated the common use of three equilibrium responses: Navel-Yielding, Protective Extension and Spatial-Reach.

However, in the other two stages (initiation and recovery) the richness and diversity of strategies for falling are evident for dancers, and the gaps revealed in robotic strategies for initiating and resolving the fall may indicate potential opportunities for extending their communicative and their falling repertoires through aesthetic, expressive approaches. In initiating the fall, the dancers have a more developed set of intentional triggers and strategies, expressed in interview as drawn from a desire to break habitual patterns of movement and find new and surprising ways of going off-centre and moving into the ground. The robots in comparison have a very limited set, comprising external pushes, collisions, instability caused by uneven terrain or internally generated hip swings to initiate a dive for soccer goalies. The use of images is an aesthetic approach to generating movement, for which there is no direct equivalent in robots. In contacting the ground, dancers used more variations of the Spatial-Turning ER with softening, rolling and redirecting of forces. Robots were limited to controlling impact forces through turning servo motors on/off, shock-absorbent padding, protective extension of the arms, spatial reach by extending one leg and some limited spatial turning actions.

Thus, the stages of falling most open to creative improvisation are initiating the fall and the recovery. By playing with parameters of movement such as scale, speed and direction in initiating the fall, roboticists can generate interesting qualities of movement using repetition and surprise as the evaluative criteria. In resolving the fall and recovering, the ground plane and transitioning to the vertical can become a playground for experimental movement, delaying or eschewing the transition to standing. The impetus for falling can come from an external force or an intentional, internal act. In general, external stimuli lead to reactive responses, whereas internally generated triggers are of a deliberate intent. Even with intentional falls, where the performer or robot is deliberately seeking off-balance moments, the registering of the actual effect of the trigger can result in surprise. This notion of surprise, or at least of unexpectedness, can be used to evaluate the aesthetic merit of the chain of movement sequences making up the fall trajectory. It can also be used to continuously improvise small shifts in instability, before committing to a descent. Instead of applying a Protective-Stepping action to avoid a fall and restabilise, the robot could play with the size, speed and direction of the step, or could choose to go with the impetus of the fall. This is a situation wherein, for example, the body inertia shaping technique could be applied to create interesting and unexpected falling trajectories.

Inspiration from the Falling Reflex in Non-Humanoid Robots

A reflex-based model for expressive acts of falling based on behaviour-based robotics could be another potential avenue for extending the falling strategies for humanoid robots. Behaviour-based approaches in robotics model a close link between a robot and its environment in terms of tight coupling between action and perception (Arkin, 1998). In Rodney Brooks' pioneering subsumption architecture, complex behaviours are built on top of low-level primitives (Brooks, 1986).

Watching insects walk over rough terrain, Brooks (2002) had the revolutionary insight that falling could be embraced in the act of walking. This was in opposition to the prevailing approach of attempting to maintain balance whilst walking. Brooks' fall prevention approach to walking could be summarised as 'catching oneself falling' and was first realised in robotics in the six-legged robot Genghis. Genghis develops its high-level behavioural performance of walking over rough terrain based on the lower-level behavioural layers of Standup, Simple walk, Force balancing, Leg lifting, Whiskers and Pitch stabilisation. The Pitch stabilisation layer could be interpreted as an equilibrium response (ER), as it is similar to the work of the spinal reflexes involved in maintaining human upright posture in the sagittal plane.

Boston Dynamics more recently demonstrated this approach with Big Dog. Big Dog is a four-legged robot, [6] intended for rough terrain locomotion (Raibert et al., 2008) and famous for demonstrations of recovering from near falls and regaining balance, for example walking and slipping on an icy surface. [7] A robotic creature with an inflexible spine and no head, it has been designed to absorb shocks and ground reaction forces in its four highly articulated, springy legs. Much like cats do when landing after a fall, Big Dog steps in the direction of the fall with some of the legs while simultaneously flexing its leg joints in order to absorb some of the shock as well as to generate an opposite force for recovery through extension of the legs. Big Dog's performance on ice is reminiscent of an antithetical, expressive performance *Exergie* (2000) by performance artist Melati Suryodarmo, [8] wherein she stood in high heels on a surface of butter and repeatedly gyrated, slipped and fell. The reflexes and equilibrium responses underlying Suryodarmo's falling include Head Righting and Protective Extension. Here the expressive power lies in the violence of the fall compared to the tension felt when observing Big Dog's ability to not fall completely to the ground despite the slippery conditions underfoot.

Conclusion: Reflexes and Expressive Potential

This article explored the idea of reflexes producing meaningful performance, and proposed that aesthetic and expressive approaches be used to extend falling strategies for humanoid robots. Dancers strive for the mechanics of falling to become automatic and thus available for creative use in performance. The trained body then knows by reflex the pathways and patterns for falling safely, allowing the motivation for movement to come from the choreographic intent provided by drama, action, interaction, feeling state or imagination. In Cohen's understanding of human developmental movement patterns, '[o]nce you have a reflex, you can use it as a "form" of expression' (Cohen, 1993: 131). In improvisation, dancers are able to play with movement parameters to discover layers of expression and meaning, whilst relying on the automatic movement patterns underlying volitional movement.

The majority of research into two-legged humanoid robots has focussed on the hard problem of locomotion, with the attendant issues of balance and instability, and the development of strategies for preventing falling. Loss of balance – falling – is an undesirable consequence in most circumstances, with the exception of robot soccer. A comparative analysis was conducted of the falling strategies of dancers and some humanoid robots, using the language of automatic movement patterns to identify areas in which we might extend current robotic falling strategies, allowing humanoid robots to be more expressive social communicators. Drawing on Cohen's insight that a reflex can be used as a form of expression in volitional movement, some initial propositions were presented for directions in which current robotic falling strategies can be extended and developed into a more expressive language for moving and falling, using choreographic approaches to generate expressive behaviours.

Roboticists have yet to turn to dance as a fertile source of inspiration for understanding falling as a creative act. By examining how dancers use falling as an intentional act for practical and aesthetic purposes, and also how they intercept sets of reflexes when falling whether or not the fall is intentional, we can begin to apply a choreographic language that enriches the mechanics of movement. Falling is no longer seen as something to avoid, but as an exploitation of instability as a creative resource in the generation of aesthetic, expressive performance. Falling can be used as a dramatic device, creating moments of heightened attention between robots and audience. The image of a falling robot presented through the lens of dance performance and choreography rethinks what it means to be a sociable robot and opens up new practices of creative expression for humans and machines.

Biographical Note

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Notes

[1] For Graham, falling was both a physical and a psychological act, to be used for dramatic and emotional effect. She developed a technique of contraction and release, mirroring the rhythm of breathing and built

around the relationship of the torso and spine (Benbow-Pfalzgraf, 1998). Her approach continues to be taught today in various forms, for example, in the Safety Release Technique, developed by B.J. Sullivan (USA). The Safety Release Technique can be found at http://performingarts.uncg.edu/bios/bj-sullivan

[2] The damage can also be of an emotional kind, such as embarrassment for the makers of the robot. See, for example, Honda's Asimo falling (2007): https://www.youtube.com/watch?v=ASoCJTYgYB0 Four years later a new demonstration reveals a more physically competent version of Asimo, able to walk up stairs and hop on one foot. Asimo jumping (2011): https://www.youtube.com/watch?v=Bmglbk_Op64

[3] 2014 RoboCup SPL Grand Final, https://youtu.be/dhooVgC_0eY

[4] The modulator of the Tonic Lab is the Landau RR, a total body extension pattern where the head, tail, arms and legs extend away from the earth like an aeroplane.

[5] Personal communication, Tess de Quincey (De Quincey Co.), Sydney, 4 February 2016.

[6] In their work on multi-locomotion robots, Fukada and colleagues (2014) also use a quadrupedal robot to explore strategies for fall prevention inspired by human and animal locomotion modes. Quadrupedal locomotion is inherently more stable than bipedal walking, since the base of support is distributed over four legs compared to two. The risk of falling is related to the relative stability of the robot in relation to the terrain. Fukada and colleagues combine models of stabilisation based on the robot's internal conditions with stabilisation based on external information from the environment. When the robot encounters rough terrain and the risk of falling is greater than 0.7, the strategy is to transition from a bipedal walking gait to a squat to a quadrupedal walking gait. The squat position lowers the centre of gravity and is an important intermediary action.

[7] Big Dog on slippery ice: https://youtu.be/cNZPRsrwumQ

[8] Documentation of *Exergie*: http://www.melatisuryodarmo.com/works_Exergie_Butter_Dance.html

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FCJ-211 Embodying a Future for the Future: Creative Robotics and Ecosophical Praxis

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Abstract: In recent years I have begun to integrate creative robotics into my ecosophical art practice, which I have long deployed to investigate, materialise and engage the thorny, ecological questions of the Anthropocene. I have been seeking to understand how this form of practice may promote the cultural conditions required to assure, rather than to degrade, our collective futures. When creative robotics and ecosophical practice combine forces in hybrid, strategic intervention, might this fusion further the central aim of ecosophy – to encourage cultural conditions required to assure a future for the future?

Many of us would instinctively conceive of robotics as an industrially driven endeavour, shaped by the pursuit of relentless efficiencies. Instead, I indicate through my practice that the field of creative robotics is emerging with radically different frames of intention. In other words, creative practitioners might still be able to shape mainstream experiences of robotic media that retain a healthy criticality towards such productivist lineages. Will this nascent form bring forward fresh new techniques and assemblages that better spark conversations around ecosophy and, if so, which of its many approaches present the greatest opportunities?

In this article I present a context for, and some examples of, prior work to give an overview of (my) ecosophical practice. I then detail the recent integration of creative robotics into the practice, and analyse achievements in relation to the work's broader aspirations in my installations *Night Rage* (2013), *Night Fall* (2013-14) and *Light of Extinction* (2014).

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Ecosophy

Norwegian philosopher Arne Næss (1995) defined ecosophy as a form of personal, relational and intersubjective philosophy, or a guiding series of principles, which he contrasted with the discipline(s) of ecophilosophy. Ecosophy was subsequently developed by a number of commentators, notably Félix Guattari (1995) who categorised it as a relational process that draws upon interconnected networks of mind, society and environment. My own synthesis, or ecosophical undertaking, is contexualised within the aegis of experimental arts practices, comingled over the past 22 years with diverse historical tendencies in new media arts and net art. In response to societal and environmental imperatives, I have evolved an approach to thinking and working that I call ecosophical, and that involves scoping out a relational, interactive, embodied and interdisciplinary series of interventions that interrogate cultural conditions.

This process has involved a broad swathe of media and approaches, and in recent years has increasingly, creatively, become entangled with robotics. This new engagement has allowed me to introduce a range of electromechanically controlled, physical forms into my mixed media works. Robotic forms present as complex socio-material assemblages and intersect with theoretical discourses such as anthropology and sociology. Petra Gemeinboeck and Rob Saunders (2013: 37) speak of their 'affective potential to materially intervene into our familiar, human-created environment, bringing about a strange force' and therefore performing material mesh-works of relationships that traverse the aesthetic, social and political. Understood this way, creative robotics presents significant potential for the ecosophical practitioner.

We live in a time of unprecedented environmental challenge that demands the urgent attention of all disciplines. Significant confusion exists around how to tackle the wicked problems of sustaining a future for those species that will follow us. We find ourselves routinely locked in unwinnable duels between the discourses of freedom and limitation that dog the Climate Change debate. We struggle to think, design, create and act in ways that acknowledge timescales longer than weeks, years or decades, repeatedly falling back upon patterns of short-term thinking even though we observe the closing down of possibilities for other species as well as our own. Despite living within the sixth great extinction event (Oreskes and Conway, 2014), we deny that we have precipitated an unstoppable catastrophe in the biosphere, cryosphere and atmosphere that will ripple forward for hundreds if not thousands of years, significantly pre-determining and limiting future options.

Our apparent inability (or unwillingness) to grasp the scope and reach of the problems of ecology that we collectively face is evidenced by today’s ever-worsening series of environmental indicators (Emmott, 2013). Not only do we cause the ecological problems that threaten us today, but we also have created cultures that innately limit our capacity to act sustainably. What we design for our world continues to design us (Fry, 2012). A world and a society founded on "de-futuring" principles cannot assure anyone or anything in it a future (Fry, 2011). If these problems we face stem from a failure of our cultures to evolve in ways that can fundamentally sustain us, then cultural practitioners must become front-line operatives in driving the requisite change.

Paradoxically, as understandings of the scale of our problem accrue, appropriate, broad-scale public and political responses appear to weaken (Foster, Clark and York, 2010). Both democratic and non-democratic political systems appear frozen in holding patterns that further undermine the collective futures of all species including our own (Oreskes and Conway, 2014). Sustaining what is left of the future remains a uniquely non-partisan necessity, even if short-term politics and vested interests have temporarily obfuscated this fact. It requires much more than a dab or two of 'Green Capitalism' (Foster, Clark and York, 2010) or a vague instilling of eco-sensitivities into the populace. In reality we need wholesale and profound reorganisation of contemporary society – physically, culturally and politically – in order to encompass root-and-branch sustainability. Commentators such as Tony Fry (2012) have named this project 'The Sustainment', which Fry asserts requires crafting new economic paradigms and modes of cultural production that align with new forms of political philosophy. Such a project effectively parallels the scope and ambition of the Enlightenment, which successfully precipitated modern society but failed to understand the need for significant limitations and boundaries. And so, a project of The Sustainment's scope must move us far away from normative understandings of *progr*ess and *development*, re-crafting us into new *types* of thinking and acting beings. Clearly this will require truly powerful forces in seeking solutions, and it is therefore within this space that practitioners committed to cultural change should focus their energies.

We have long known that sufficient information and the necessary technical capabilities are not, in themselves, sufficient forces to change our behaviour, especially given we humans do not have a history of deferring to simple logic (Brooks and Heyd, 2010). Indeed, anyone proposing broad cuts or limits in this brief phase of plenty (plenty at least for the rich portion of the world's population) is unlikely to be lauded. Slavoj Žižek (2007) (following Louis Althusser) describes how our ideologies (such as the capitalist assumption of endless growth in a finite world) have succeeded to date because they "interpellate" us into their value structures and correspondingly we want such systems of belief to succeed. Given its innate link with contemporary capitalism, unsustainability may appear to suit many of us now – but clearly it will serve us profoundly poorly into the future.

Even slowing such terrible momentum now requires our immense creativity and application. It asks us to re-understand and re-imagine our relationships to social, biophysical, cultural, synthetic and psychological ecologies (within which we are all profoundly enmeshed). It asks us to precipitate new kinds of conversations that we are yet to conceive. It requires us to promote and model the cultural conditions within which enhanced comprehension can emerge, encouraging us towards new forms of navigation, mitigation, long-range thinking and conception. We must learn to craft cultural strategies that can assist us to break into, and ultimately out of, the wrench of ecological destruction, re-imagining ourselves as new kinds of profoundly embedded, differential, socio-environmental subjects (i.e. new kinds of citizens).

Ecosophical Praxis

Two decades ago I named my contribution to the above project "ecosophical praxis" – a synthesis of media-based, experimental arts that draws upon approaches such as embodiment, relationality, interactivity and distribution of movement (all of which innately relate to the robotic domain). A foundational component of the word *ecosophy* is the Greek *sophia* which equates to *wisdom* – a somewhat intangible idea that suggests care, learned knowledge, and measured and equitable response. Its praxis in the arts requires an evolving methodology that seeks to engage all conceptions of ecologies, but primarily philosophical ecologies. Ecosophical praxis resonates with the idea that:

> … there is no such thing as individual life because organisms cannot by themselves sustain life. … Without … support by a community of the living and non-living, the individual organism simply has no existence. (Ophuls, 2011: 34)

Being non-didactic, and thus more akin to pure research, the core objective is to ask foundational questions about the very meanings of ecology, highlighting how we overlook, misunderstand or obfuscate this problematic. The outcomes of its projects are process-based, and seek to create *conversational experiences* that speak to and/or shed light on such definitive schema.

Cultural theorists such as Timothy Morton have advanced a 'critical ecology' by ascribing to it characteristics such as omniscience, entanglement, 'mesh', and freedom from any 'central position that might privilege any one form of being over others' (Morton, 2010: 38). Morton's idea of ecologies defies conventional notions of boundaries (such as flesh, air or fences) and routinely accepted ideas of *insides* and *outsides*. He stresses that our long-held conception of nature as separate and different from us, and as being there to sustain us, is an inherently false and dangerous conception at the very core of the ecological problem. He calls for an 'ecology without nature' (2007: 1) fused with humanity in a way that 'permits no distance' (2010: 39). This central tenet of inseparability leads Morton to the idea of 'dark ecologies', which, he suggests, leaves 'no neutral theoretical ground on which to articulate ecological claims' (2010: 16). When ecologies are understood as innate inseparabilities, then we, in relationship to the worlds we are creating, embody the crisis.

Ecosophical Foci in My Work

Building upon these understandings, ecosophical praxis drives a particular range of tendencies in my work that aligns with both Morton's and Guattari's assertions that aesthetic activities can and must be deployed as part of our ethico-aesthetic response to the problem of ecology. Indeed, Guattari (2000) speaks eloquently to the value of participating within aesthetic experiences that, when carefully construed, may have transformative power – provoking us to understand the need to raise our sheer ambition in the face of today's challenges and thus move cultural disciplines beyond the limits of how they are conventionally understood and practiced. This suggests that transformative conversational experiences might be effectively fostered via artistic works.

To illustrate this thinking I will first touch briefly upon a major, historic project that pre-dates my recent investigations into creative robotics: the dual-site work *Intimate Transactions* (Armstrong, O'Neill and Webster, 2005-08), now in the permanent collection of ZKM Media Art History Museum in Karlsruhe, Germany. This work shares commonalities with my more recent investigations into robotics. Whilst it was not conceived specifically as a robotic form, its dissemination exhibited some of the characteristics that I am attracted to within that form – particularly the cultivation of embodied relationship between participants and the work; believable suggestions of living forms; and the capacity to playfully sense an order of things whilst also exploring the continuum between flourishing and collapse.

Intimate Transactions was a telepresence-based installation that allowed two people in geographically separate spaces to interact in real time via avatar, using only their bodies to operate the interface. (For substantive details see Lone Bertelsen (2012) and Keith Armstrong (2005).) Participants interacted using a physical interface called a "bodyshelf" and wore a sound vibration transmission device around their necks called a "haptic pendant". By gently moving their bodies on this "smart furniture", they were able to instigate "intimate transactions", which influenced an evolving "world" created from digital imagery, multichannel sound and tactile feedback. The interactivity was designed as transactional and conversational, in its formal properties, in the participant-initiation processes, and in the organised parallel events, each of which broadly contextualised possible actions and framed reflection around ecosophical principles.

The interactive structures were ambiguous in their narrative framing, engendering open-ended conversations between pairs of participants. This was enhanced by placing each player's avatar within a world of apparently life-like, animated creatures that were themselves programmatically dependent upon a generative *atmosphere* that could be either degraded or maintained depending on the chosen actions of both participants. The ecospohical focus was cemented through foregrounding simple, playful ecological rule-sets and simple game-like procedures. This engaged participants in a tangible experimental scenario, comprising the gathering and exchanging of responses across the network via haptic feedback, and the distinct physical materiality of the work's bodyshelf interface, which required feet, back and shoulders to operate. The work used sensuous interest as a foil for speaking to deep entanglement between forms and re-directing attention towards the ecologically unnoticed and disregarded.

Figure 1: Intimate Transactions, Bodyshelf(2005). Img. Keith Armstrong)

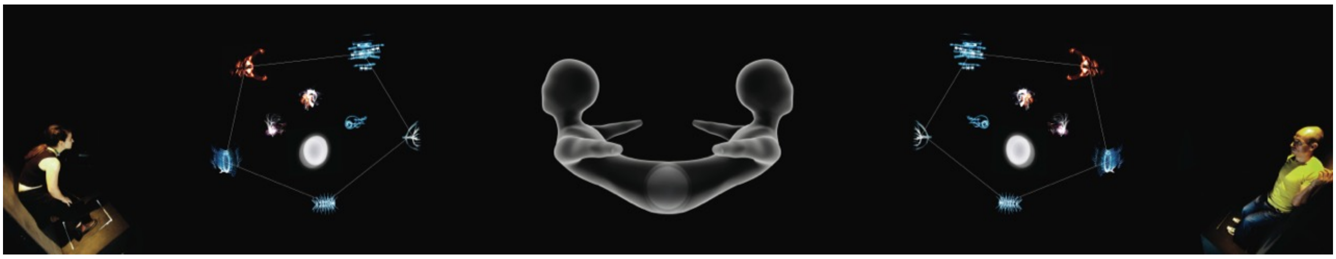

Figure 2: Intimate Transactions, (2005). Img. Keith Armstrong

In all of these ways *Intimate Transactions* sought to establish clearing/focusing spaces capable of fostering conversations that dealt macroscopically with the requisite cultural conditions for improved ecological futures, and more immediately with the powerful experiences of a kinesthetic, transactional exchange across remote sites. Ecosophical praxis requires practitioners and participants to take temporal, creative journeys that maintain consistency with Næss' rejection of the person *in* an environment in favour of 'a relational total field image' (cited in Hay, 2002: 43). Such an embodied approach became in *Intimate Transactions* a potent tactic for confronting our increasing inability to perceive the *time of everything* and thus *give time back* to others and to the future.

Integration of Creative Robotics: What Might Be Life?

The subsequent integration of robotics into my work developed more by stealth than by planning. It arose from particular artistic collaborations and the evolution of my studio practices. I was now moving away from the directly embodied human-to-human engagement of *Intimate Transactions* and the innate complexities of its realisation, and looking for logistically manageable formats for exhibition spaces. I began shifting the works' emphases to exploring the kinetic potential of robotic forms. The consequent robotically infused projects include *Night Rage* (Armstrong, English and Lickfold, 2013; ISEA 2013, Powerhouse Museum Sydney) and *Night Fall* (Armstrong, English and Lickfold, 2014; Queensland Museum).

For *Night Rage* I developed a large-scale visualisation device based on the Pepper's Ghost technique. This approach allowed me to visually "float" and control a lit form (in combination with other simple, fibre optically lit cloth forms) in inky darkness, achieving a somewhat ethereal sensibility of flotation, 3D volume and, most importantly, life. Animation was achieved firstly through the simple ingress of air into flexible cloth objects, and subsequently via a full four-axis robotic motion control assembly, through which I was able to achieve a creatural/life-like form with relative simplicity once the technical hurdles had been overcome. This led me to ask what *conversations* would become conceivable and possible, when robotic actors became mixed and coupled with diverse media actors, materials and ecological thematics.

Figure 3: Night Rage (2013). Photo: Alex Wisser

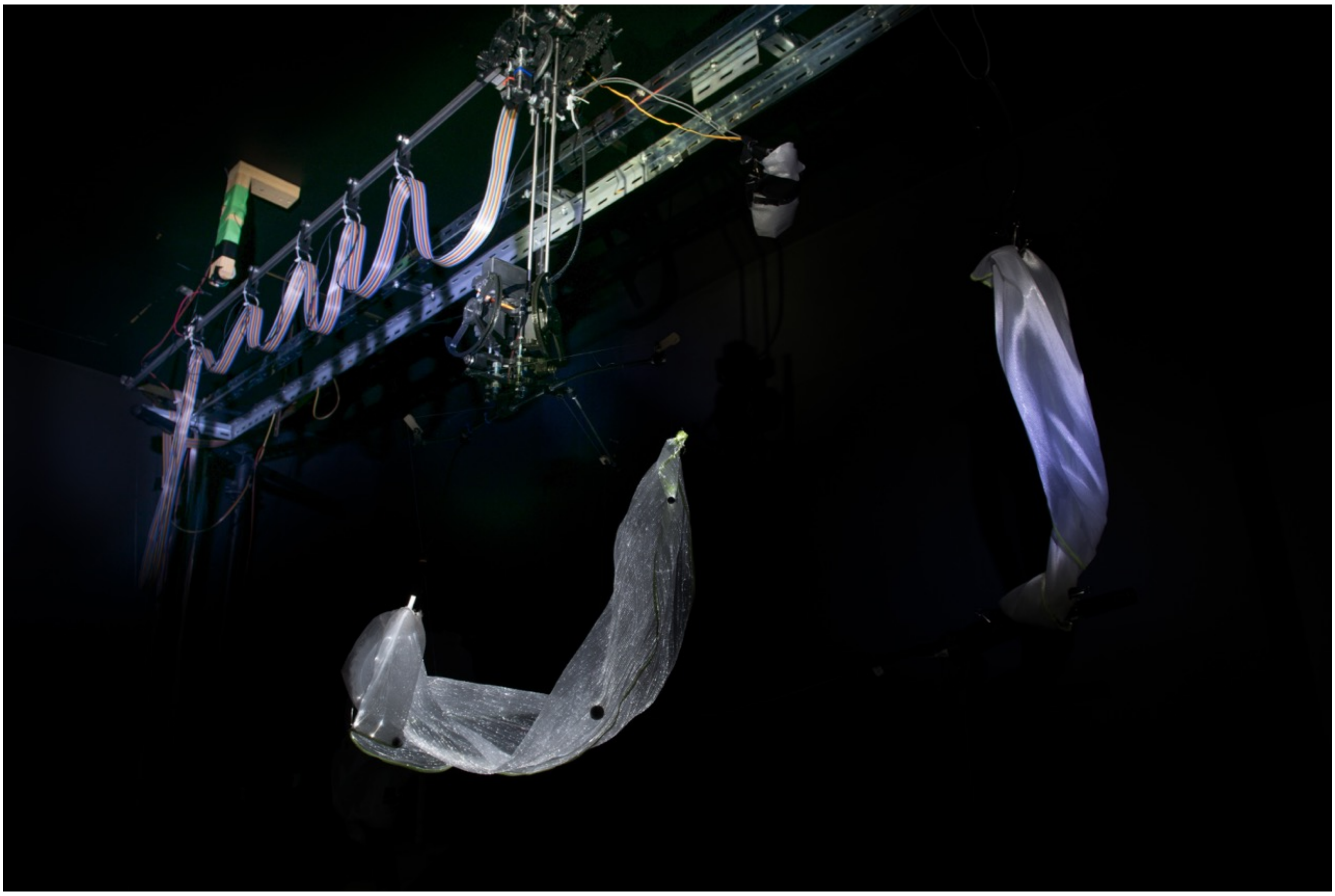

Figure 4: Night Rage (2013). Photo: Alex Wisser

The perception of a life-like modality emanating from the electromechanic puppetry of *Night Rage's* lit cloth forms evoked a more naïve engagement with the robotic form, and particularly, I suspect, with the fantasies portrayed in popular movies and comics. Many of us have longstanding, curious habits of imagining life-like features of the *other* in a robot. Simon Penny developed his early robotic work *Petit Mal* (which he called a 'embodied cultural agent') to explore 'how much can be left out in the construction of such an "agent", and yet still give the impression of sentience' (Penny, 1997). To this end *Petit Mal* pointed up an 'interaction which takes place in the space of the body, in which kinesthetic intelligences, rather than "literary-imagistic" intelligences play a major part' (1997). Creative works playing on our tendencies to believe in the unpredictable, life-like power of robotic forms range from wind-responsive works such as Theo Jansen's *Strandbeest* series, to humanoid forms such as Mari Velonaki's *Diamandini*, to the architecturally responsive installations by Gemeinboeck and Saunders. This ability to connote senses of *life* within a machinic work is not in itself remarkable, considering that a definitive set of physical properties common to living things (that excludes everything we might routinely think of as inanimate) has to date eluded us (Penny, 1997). Indeed, even the most simple of apparently randomised behaviors may, in certain contexts, be enough to flick the switch of "life" believability.

Whilst robotic artworks exhibit different levels of technical complexity, they often possess a powerful ability to sway the public. Gemeinboeck and Saunders' *Zwischenräume* created devious, machine-vision capable robots programmed to break through a gallery wall, rendering machines and audiences strange embodied objects of each others' curiosity. Edward Ihnatowicz's *Senster* (cited in Zivanovic, nd) was said to have behaved like a 'wild animal' (Rieser, 2002: 88), whilst Ken Rinaldo's robotic assemblage *Autopoesis* successfully developed collective animalesque behaviours through sensing the bodies of the audiences and of their fellow robot forms. Several examples of robotic/dance collaborations (e.g. Chunky Move's *Mortal*

Engine and ADT's *Devolution*) manifest the uncertain, the multiple and the entangled realities of human and robotic entities entwining within the mesh, rendering them necessarily or temporally strange. Such distinctly embodied renderings recall the user experiences of *Intimate Transactions*, wherein a parallel kinesthetic sense of agency became the currency for negotiating spaces of ecologically inscribed transaction and exchange.

Penny (1997) suggests that creative robotic forms' significant potential is in challenging audiences to consider their personal limits of perception and comprehension (as occurred in *Intimate Transactions*), particularly in relation to the strangeness of an impending ecology without nature. Similarly, Ingeborg Reichle (2009: 11) observes that artistic experimentation with robotic forms is often motivated by the desire to develop interactions between machinic actors and humans premised upon 'open, non-determined modes'. I began to wonder whether the potential of robotic forms to creatively evoke living sensibilities might also correspondingly have capacities to evoke *interactive kinesthetic intelligences* within audiences, and thus subtly enhance audience members' interactions with the works within the domains of their own bodies. I set out to re-invent a process that I had discovered to be so powerful in *Intimate Transactions*. I saw this as a particularly valuable link for maintaining senses of presence and subtle activation within my new works, given my focus at that time upon on non-live installation practices. Seen this way, creative robotics appeared to introduce an embodied, sensate driver into these new works, and therefore to help tilt audiences into conversational experiences with the work's underpinning ecosopohical narratives.

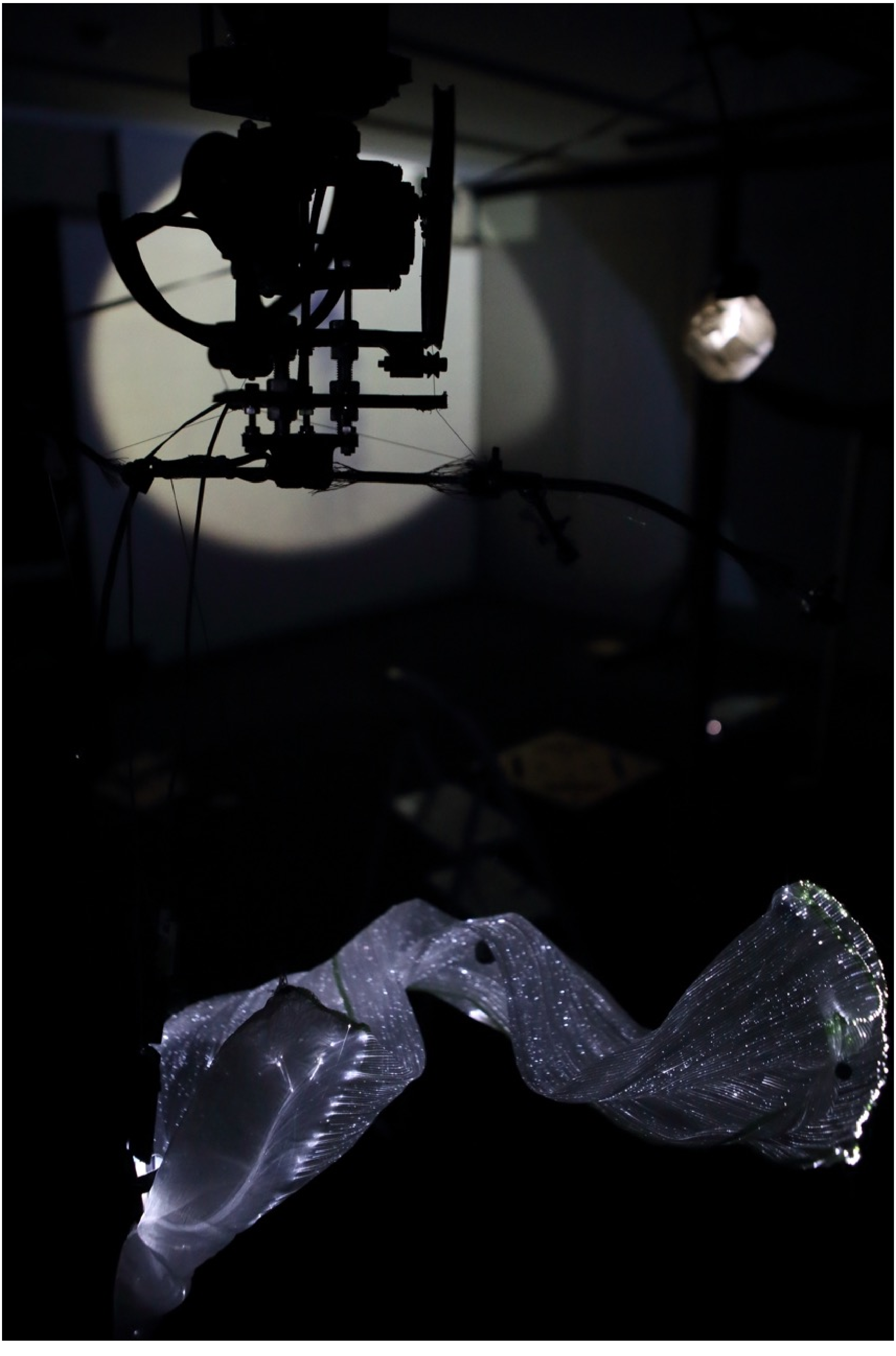

Figure 5: Night Fall (2013-14). Imgs. Bryan Spencer

Figure 6: Night Fall (2013-14). Photo: Bryan Spencer

Buoyed by this possibility, I began to experiment with incorporating robotic forms into my installation works 2013-15, which include *Dark Cartographies* (Armstrong, English and Lickfold, 2013-14; Centre for Contemporary Art, Cairns), *Black Nectar* (Armstrong, English and Lickfold, 2014; Bundanon's *Siteworks* Festival), *Light of Extinction* (Armstrong, English and Lickfold, 2014; *Media Art China* , National Gallery of China) and *Temporal* (Armstrong, English and Lickfold, 2015; Bundaberg Gallery). Each of these works involved an art–science collaboration with behavioural ecologist Dr Peggy Eby, assisted by GIS ecologist Heidi Millington, and was created in collaboration with sound artists Lawrence English and Luke Lickfold. They all drew upon overt or subtle techniques set within creative robotics and combined with ultra low-level, controllable illuminations of materials, which were physically manipulated in real time through multiple dimensions. Technically this was achieved through the application of controlling computers, embedded microcontrollers and series of controllable mechanical arms, pulleys, wheels and strings, as well as crane and gantry mechanisms. This resulted in robotically controlled, faintly glowing objects designed to engender certain and differing senses of aliveness when viewed from particular audience viewpoints.

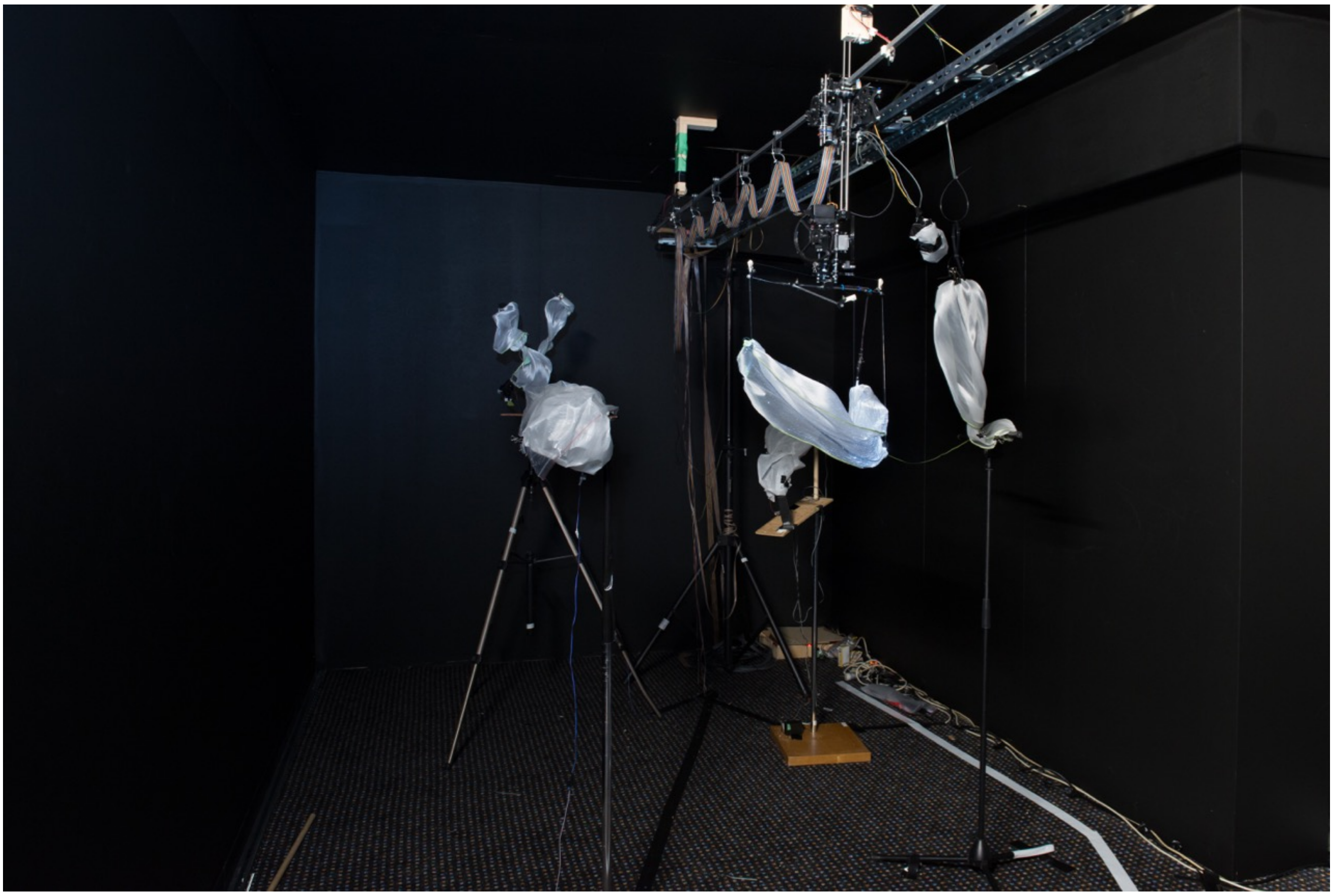

Figure 7: Night Rage (2013). Photo: Alex Wisser

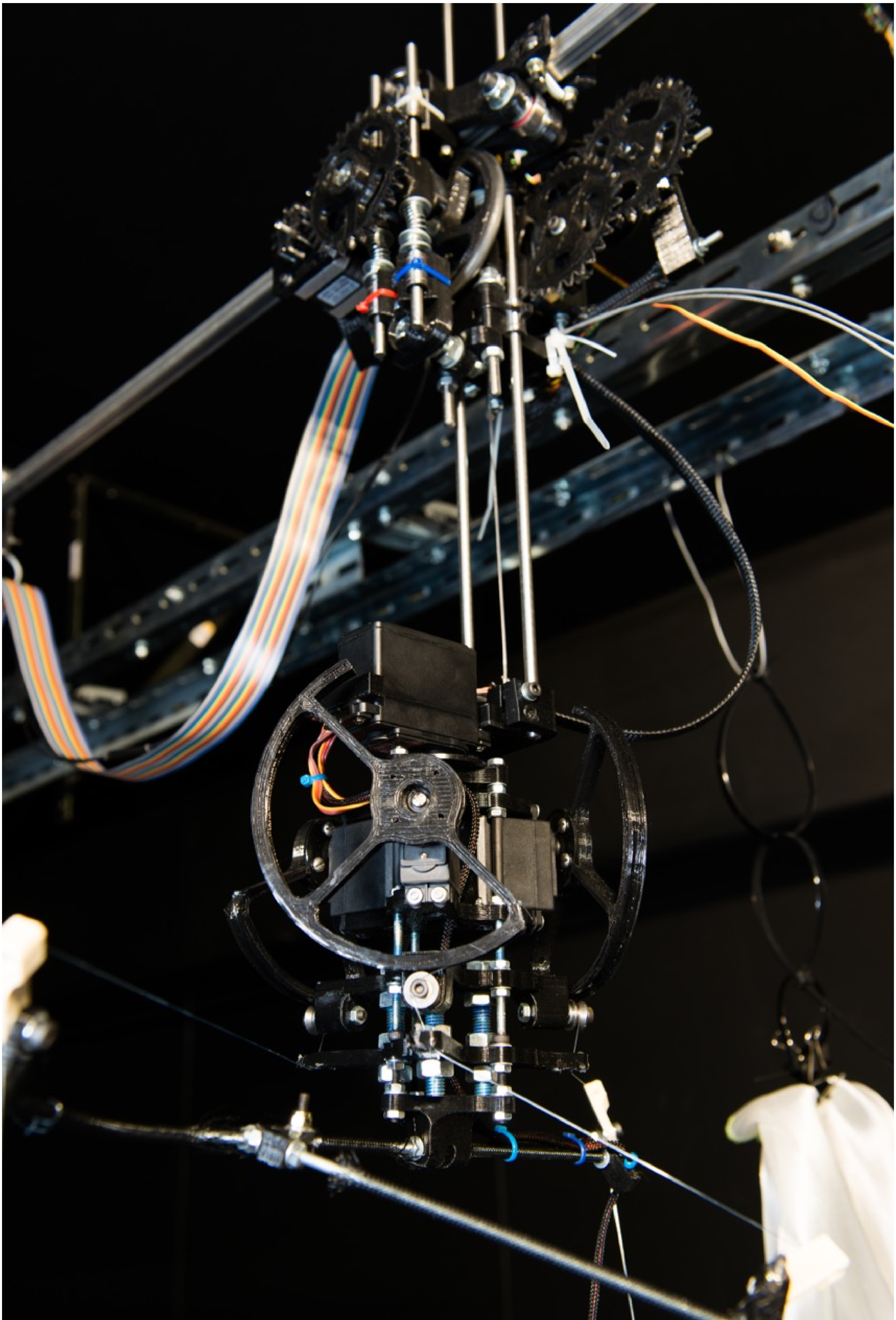

Figure 8: Night Rage (2013). Photo: Alex Wisser

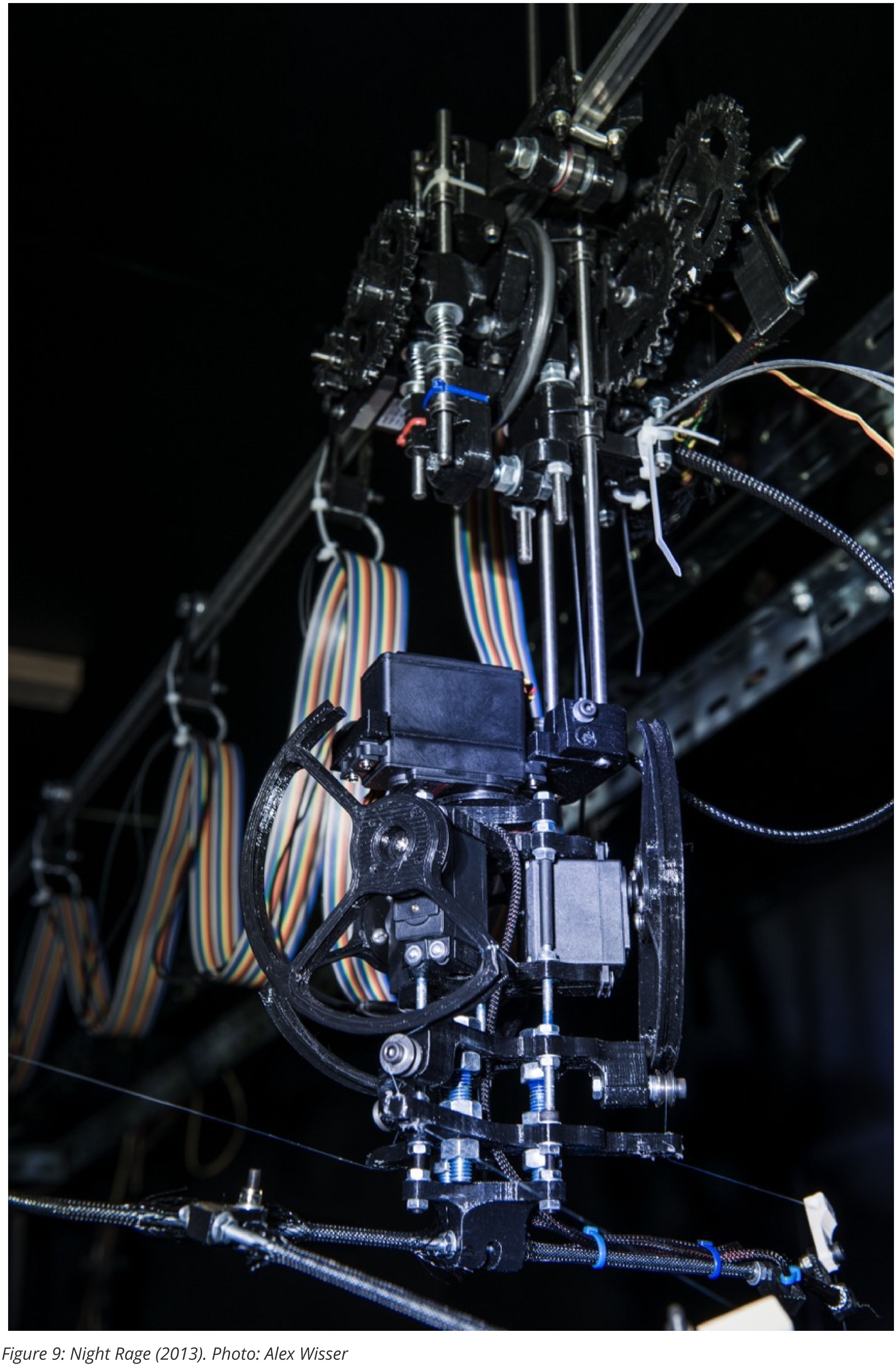

Figure 9: Night Rage (2013). Photo: Alex Wisser

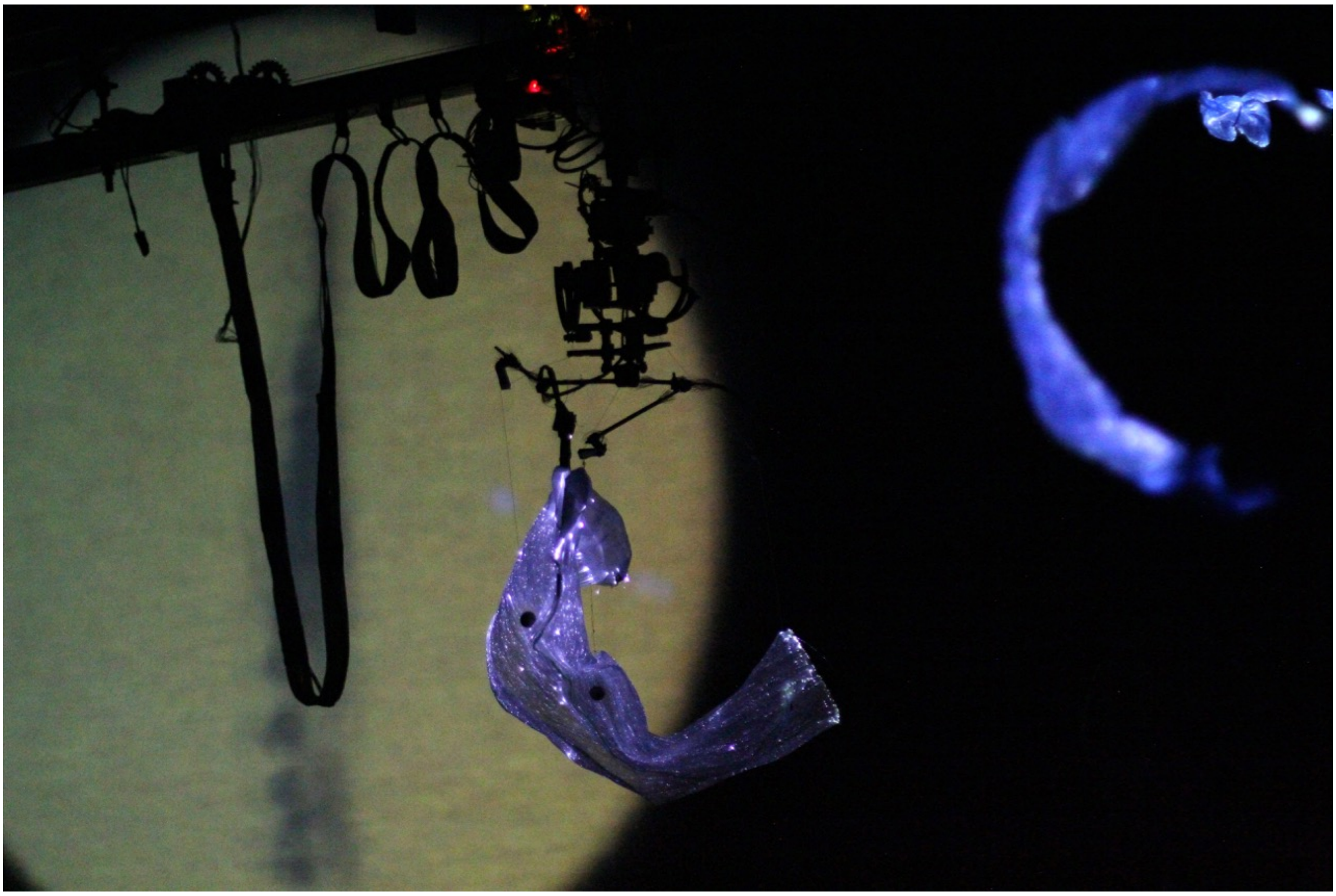

Figure 10: Light of Extinction (2014). Photo: Keith Armstrong

The exemplar work of this kind, *Light of Extinction*, evolved from presentations of *Night Rage* and *Night Fall* and involved sophisticated implementation of a gantry-driven robotic system that ultimately allowed fibre optically lit cloths to be manipulated and contorted along all dimensions and moved back and forth and up and down. The system used a series of motors, servos and mechanical linkages to move lit objects within a plane of view. These works were thematically linked by ideas of the *seasonal* in order to cast a different perspective upon my consistent questioning of ecological relationalities. Through the work, I argued that processes of seasonal change affect human existence within the mesh-work, and that correspondingly our embodied presence affects seasonal progression in increasingly significant precipitations of climate chaos (Oreskes and Conway, 2014). The work also foregrounded how our lived experiences of being embodied and embedded in place and time are increasingly being lost – the so-called 'extinction of human experience' (Miller, 2005) that concurs in broad outline with John Thackara's assertion that:

> We miss phenomena that are invisible, such as energy; We are unaware of things that are somewhere else, such as resource flows; We miss all sorts of natural phenomena because we use so few of our senses; And, because of our education, we fail to experience the planet as a living system of which we are a part. (2013: np)

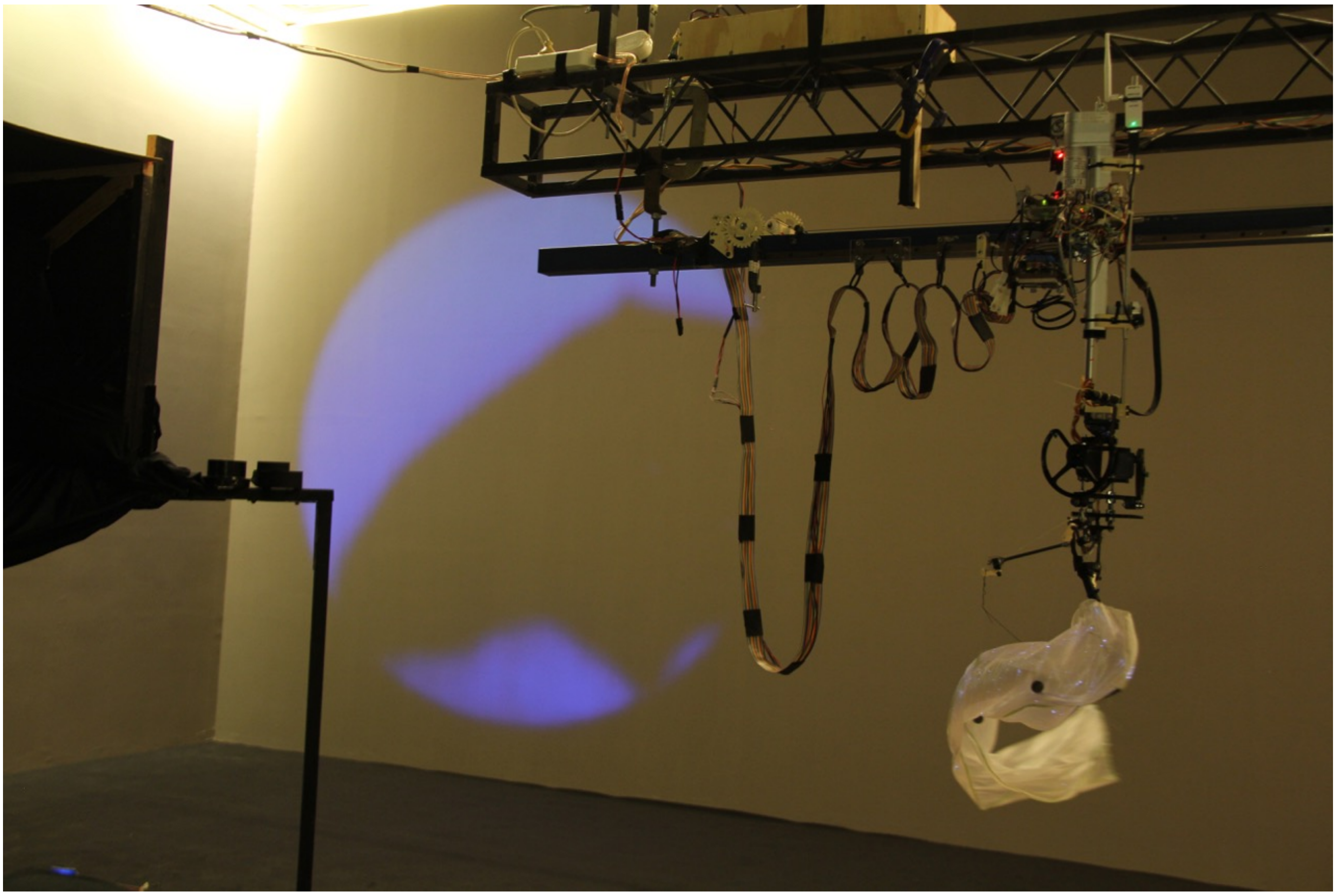

Figure 11: Light of Extinction , Back End (2014). Photo: Keith Armstrong

I created for *Light of Extinction* two distinctly differing viewpoints into the work. I constructed a series of physical corridors that used darkness and scale to encourage slowness of approach. Audiences initially entered into the *back end* of the work to be confronted by the first viewpoint, which exposed much of the robotic mechanism and the physical nature of the manipulable cloth forms. I refer to these forms as a "semi-autonomous gaggle of robotic actants". Audiences then moved through into the work's second viewing space, or *front end*, where they were now obliged to view the same robotically manipulated objects through a restricted aperture (again using the Pepper's Ghost technique). Here, what they witnessed appeared to coordinate into a deep-field choreography, floating lusciously within inky landscapes of media, noise and embodied sound suggesting a privileged view into the "life" of non-human entities whose experience remains outside of our knowing.

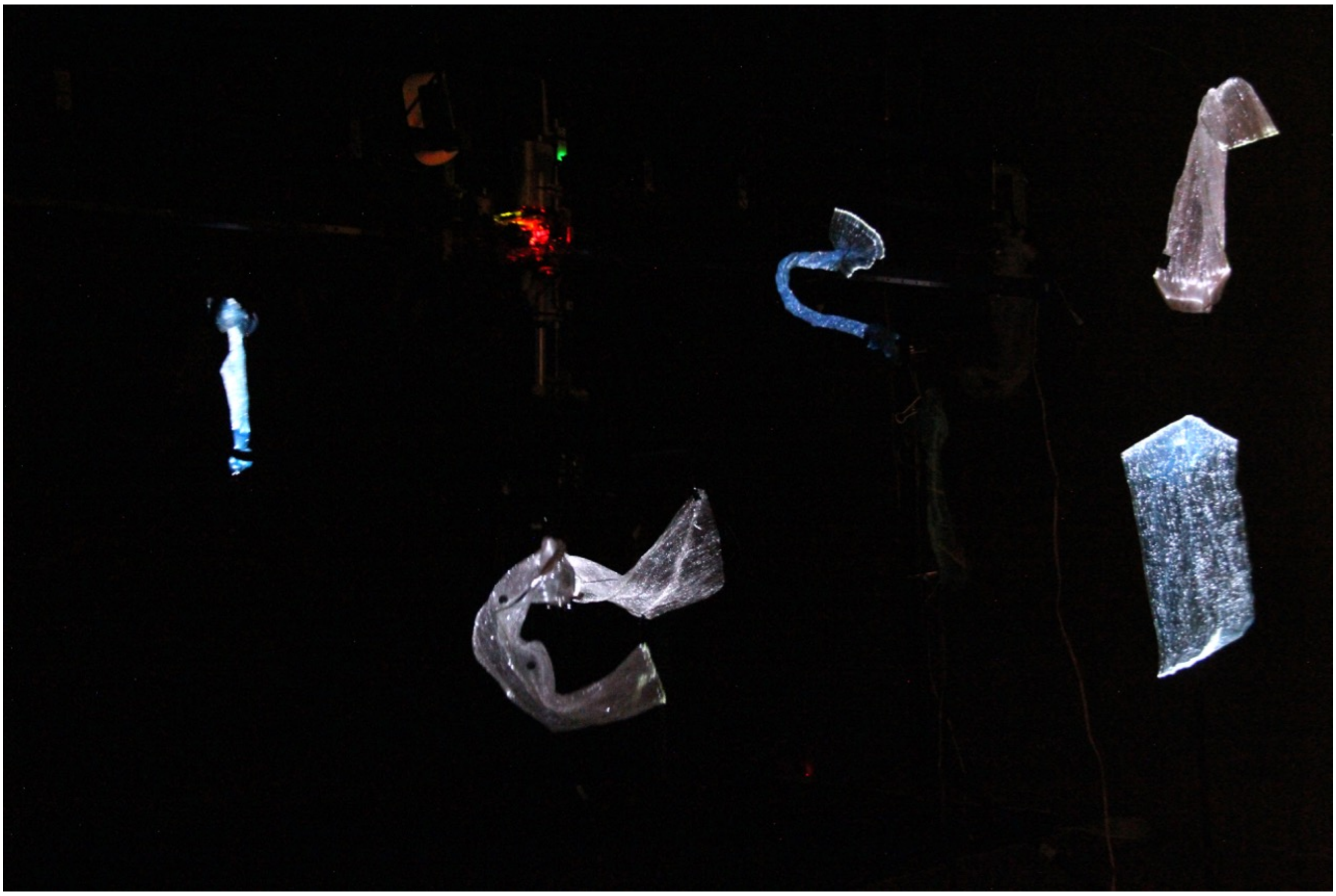

Figure 12: Light of Extinction , Back End (2014). Photo: Keith Armstrong

Together these two perspectives remained sensitive to notions of ecologies alluded to by Morton in his 'mesh' (2010) and expanded 'hyperobject' (2013) theses. Building on the idea that something as small, simple and trite as a manipulable series of hanging cloths could ultimately allow one to sense the vibrancy of something living, maybe even as embodied sensation, *Light of Extinction* provided a momentary disbelief giving way to 'a relieving celebration of the imagined birth of "things" – without need for staples such as conventional light or the harmonious lullabies of long-extinguished sounds' (Armstrong, 2014: np). This suggestion of a coming into life was premised upon the potential of embodied connection being germane to this application of creative robotics. The inclusion of robotics in *Light of Extinction* appears to amplify its catalytic ecosophical potential through the direct intimation of embodied experience. It draws attention to our increasingly diminished sense of emplacement, of *belonging* or of being *at home* – given that the unfamiliarity of ecologies still confounds us.

Figure 13: Light of Extinction , Front End (2014). Photo: Alex Wisser

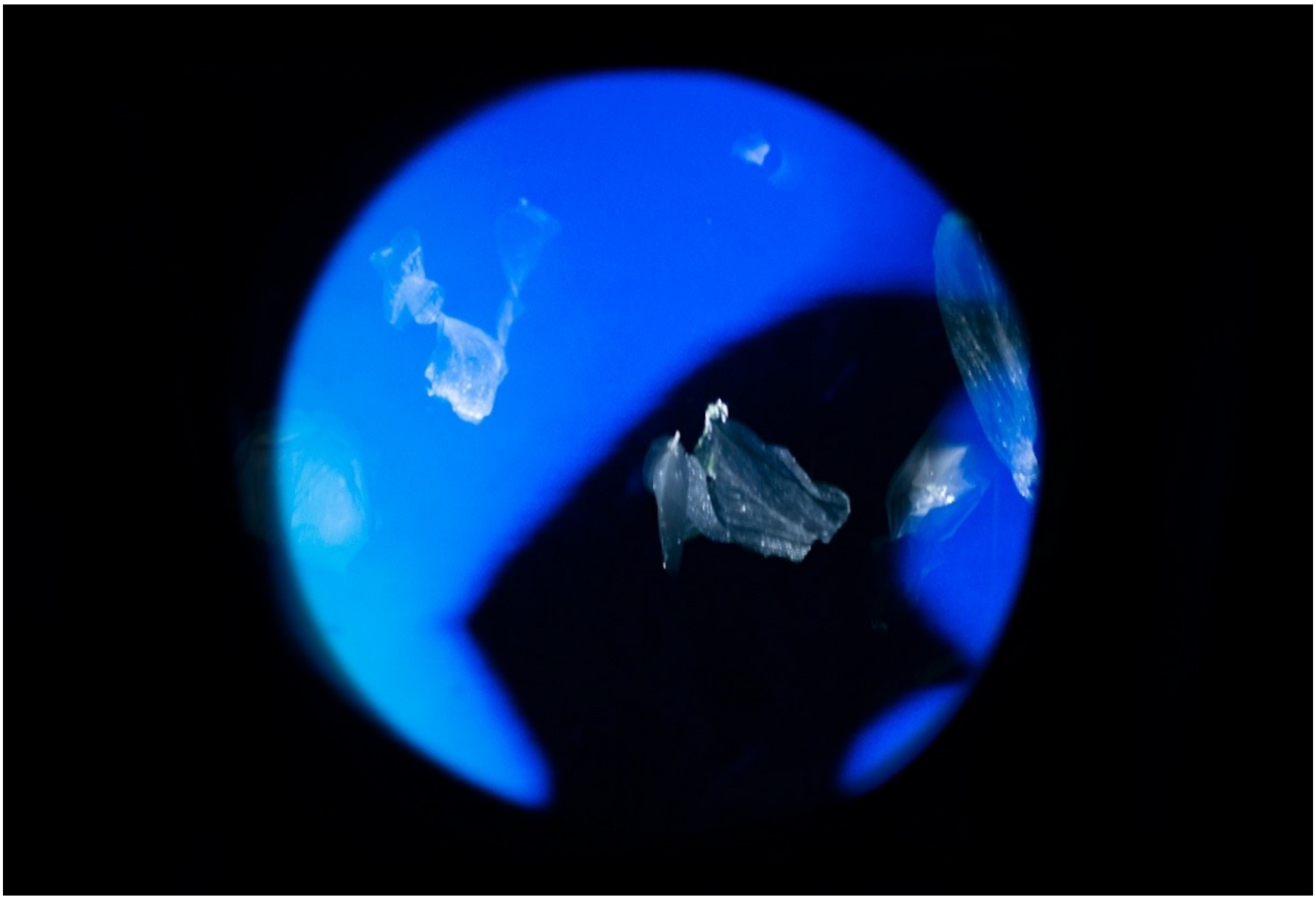

Figure 14: Light of Extinction, Front End (2014). Photo: Alex Wisser

Figure 15: Light of Extinction, Back End (2014). Photo: Bryan Spencer

Light of Extinction built upon ideas from *Night Rage* and *Night Fall* of systemic breakdown, failure and the increasingly tenuous grapple with ecologies that eschew almost all contemporary understandings. In a kind of anthropomorphic lament, these works strip back the complexity of *Intimate Transactions* and other prior works to focus on a loss of our experience as once biodiverse worlds crash or fade into darkness. Indeed, as Thackara (2013: np) suggests, we would gain much should we choose to 'focus attention on the positive qualities of the often small, humble … things that surround us'. Correspondingly we might move towards a more rounded inclusion, within any ecological picture, of human-created forms. The ironic playfulness of *Light of Extinction's* "both-ways" approach proposes a conceptual re-positioning even in the face of unbearable loss. If creative robotic practices can invoke an interaction which takes place in and expands our sense of the space of the body, then the form will resonate powerfully with a mature ecosophical praxis – serving to propel degrees of sensuous engagement that might better redirect attention toward urgent questions of the Anthropocene.

Biographical Note

Keith Armstrong has specialised for 22 years in collaborative, hybrid, new media works with an emphasis on innovative performance forms, site-specific electronic arts, networked interactive installations, alternative interfaces, public arts practices and art-science collaborations. His ongoing research focuses on how scientific and philosophical ecologies can both influence and direct the design and conception of networked, interactive media artworks. Keith's artworks have been shown and profiled extensively both in Australia and overseas and he has been the recipient of numerous grants from the public and private sectors. He was formerly an Australia Council New Media Arts Fellow, a Doctoral and Postdoctoral New Media Fellow at QUT's Creative Industries Faculty and a lead researcher at the ACID Australasian

Cooperative Research Centre for Interaction Design. He is currently part-time Senior Research Fellow at QUT, author of numerous chapters and papers, and an actively practicing freelance new media artist. (http://www.embodiedmedia.com)

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