Research Article

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Sensual Environmental Robots: Entanglements of *Speculative Realist* Ideas with Design Theory and Practice

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Abstract: In response to this issue's theme of *Can robots be sensual?* two propositions are discussed from a design researcher's perspective. Four devices across two speculative projects *Habitat Robots* and *Soil Protector Robots* are presented. *Speculative Realist* ideas provide reasoning for design approaches to metaphorise sensed environmental data into multi-sensorial performances that the devices embody. Facilitated through the projects are philosophy of design concerns, such as asymmetrical relations, the nature of data, and language about the devices prefiguring sensorial expectations. The performative behaviours of these multi-sensorial robots evoke a *sense of things* by removing the *truthiness* of data and thereby emancipating language from privilege and expertise, subverting expectations of technology, and notions of urban Nature. Through Harman's *Quadruple Object*, we speculate on asymmetricality within object relations, including between the devices and the practices of design itself. Thereby, allowing *ontological design* implications to be reviewed – where acts of designing in turn design us; design processes are not only entwined prefiguratively, but are companion output artefacts of these technological ecology interfaces. The devices bring together and physicalise questions of contextual boundaries and politics between humans, technology, and Nature.

Keywords: sensorial design, Speculative Realism, data abstraction, Object-Oriented Ontology, Quadruple Object, philosophy of design, more-than-human, environmental robots, design praxis, ontological design

1 Introduction

In this article, we introduce a novel approach to design theory and practice, based on *Speculative Realist* ideas, which has been developed through the creation of a series of unconventional multi-sensorial environmental robots. Through design praxis, the creation of these robots has become a profound domain of enquiry and discovery for new types of human–machine interactions – and even, perhaps, more-than-human–machine interactions. To conceptually approach the contextual complexities of these devices, we rely on a range of concepts of *Speculative Realist* thought to reason design decisions and, in turn, discover the opportunities of those philosophies for design. Through two practice projects, *Habitat Robots* and *Soil Protector Robots*, two propositions are put forward in this article which have emerged from the creative and epistemological discoveries made through the design stages of the presented sensual environmental robots. The first proposition under consideration is the emancipated communicative possibilities across human and nonhuman audiences from the devices themselves, as the devices' performances depart from the privileged languages of

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typical data visualisations or expressions. The second is for the benefit of design praxis itself; as it is through the required interdisciplinary collaborations and imaginations in order to develop these exploratory ecosystem interfaces – where there is a prerequisite for diverse and applied nonanthropocentric thinking – which in turn assist in evolving design theory-making.

To discuss these two propositions, the article has been structured to first introduce an overview and context of the research, followed by a section to establish a number of essential *Speculative Realist* philosophical ideas and the research's interpretations of them; after which a deeper contextualisation of the design research and a description of the devices themselves is presented. Language about the devices is an important aspect of experience, so a discussion is offered, as viewed through the philosophic ideas introduced, on how language surrounding the devices can be utilised to prefigure experience; through Graham Harman's *Quadruple Object*, we discuss how these robots embody their unique sensualities, and provide an overview of the design considerations for the artefacts through that framing. A reflection is offered on this new approach and its implications for design thinking and practice brought about by *Speculative Realist* ideas and philosophy of technology viewpoints applied to the domain of sensual environmental robots. We conclude with further research considerations and questions if these sensorial devices were brought into their full functionality in the world and provide details of their current hardware and software components, and the in-field tests of the prototypes.

This article is written from a design researcher's perspective. A perspective founded upon a developing *Speculative Realist (SR) Design* theory and an *Object-Oriented Metaphorism* design methodology. As such, this article is designed to demonstrate how *Speculative Realist* ideas have established a foundation for a design praxis through the creation of multi-sensorial environmental robots, and therefore this article may be of interest to philosophers as a demonstration of how philosophic concepts have been translated for design contexts, and to design theorists interested in how *Speculative Realist* thought has been brought in to influence design thinking and praxis. By drawing on ideas from *Speculative Realism* for a philosophy of design we can begin considering many important aspects of design from nonanthropocentric viewpoints, including what is designed and for whom, and its potential resultant impacts beyond typical anthropocentric considerations.

The *SR Design* theory that this article describes, attunes design praxis to a more-than-human mindset. This nonanthropocentric framing has been vital for innovative conceptualisation and development of the presented speculative, multi-sensorial technological devices, and of the design reasoning which underpin the creation of the experimental data experiences more generally. More-than-human ideas aren't new and have been discussed by a range of thinkers across ecological, social, and political domains, such as Donna Haraway,[1] who discussed her idea on the *Chthulucene* as opposed to the Anthropocene, "I imagine chthonic ones as replete with tentacles, feelers, digits, cords, whiptails, spider legs, and very unruly hair" – an incidentally close description of the resultant robotic devices in my research; also Jane Bennett[2] whose *Vital Materialism* rebalances "human narcissism" with other nonhuman agentic entities; and Bruno Latour[3] and his *Parliament of Things* "rejoining" the privileged human-object with Nature are just a small sample of the variations for more-than-human thinking. However, there is a lack of genuine follow-through of these ideas applied in design praxis. What I mean by "genuine" for more-than-human approaches in design, are those practices that talk of more-than-human or of an equalisation of the human with Nature, or even of symbioses, but default back to human-centric hegemony and viewpoints, one such example is EcoLogic's Bio.Tech HUT,[4] which is "a prototype dwelling that encapsulates the office's innovation for the integration of advanced biotechnology in the build [sic] environment." While seeming to present as a symbiosis between human and algae, it nevertheless is a return to viewing Nature as a resource, as a tool, and as a means for humans to improve living space. This is not necessarily a criticism of the project; rather, it is a criticism of defaulting to human centrism in design

1 Aarhus University, "Donna Haraway, "Anthropocene, Capitalocene, Chthulucene: Staying with the Trouble," 5/9/14"; Haraway, *Staying with the Trouble*," 2.
2 Bennett, *Vibrant Matter*, xvi.
3 Latour, *We Have Never Been Modern*, 142–5.
4 "Bio.Tech Hut."

praxis. This human exceptionalism is further revealed in the following statement from the project, "where new species of micro-organisms are domesticated and engineered into artificial cultivars [...]." As a design practitioner concerned with the defaulted, defuturing, approaches of human-centred design,[5] the opportunities for investigations to re-entangle the human with nonhuman are present in object-oriented philosophies for genuine approaches to a more-than-human design praxis.

The domains of *design* and of *philosophy of design* discussed here are entwined with theory-making and creative practice research, but with a more-than-human mindset; in other words, my approach to design praxis is not necessarily specific to a discipline of design, such as communication or industrial design, and so my practice is atypical of design practices and therefore my thinking and writing of design may well be read as unconventional too. There are many differing definitions of *design*[6] and *designing*. In this article, *design* can be understood in a broad sense of design, being not particular to any discipline of design other than it being infused with my own historical familiarity of interaction design underpinning the research. Some key design terms which are used in this article are "design research" which refers to the research as a whole across design theory and practice. "Creative practice research" is research conducted through each of the practice projects from which each process can act back to deepen and refine theoretical ideas of the broader research. The term "design praxis" is the embodiment or enactments of the theories in practice. The last design term to be defined here is "ontological design" which – in the context of this research – is concerned with the acknowledgement that we are "designed by our designing and by that which we have designed"[7] – and that it is too easily forgotten that designed objects and systems design back upon us affecting how we understand the world; and for this research we use this "designing back" to deconstruct the embedded bias and the privileging of data translations in order to engage with the nature of data itself and to investigate nonanthropocentric design processes.

Through various *Speculative Realist* ideas, this design research has developed a design theory and methodology which provides a genuine, reasoned move away from human-centrism in design. I've borrowed the label of "Speculative Realism" as an umbrella-term to group ideas and attitudes which I have assessed as speculating on realities outside of direct human access; whether or not the originators of those ideas ought to be considered as *Speculative Realists*. The research interprets and applies concepts from these various *Speculative Realist* thinkers to speculate on the asymmetricality of object–object relations, nonhuman spatio-temporal scales, context boundaries, language forms, concepts of charm, on intersubjectivity, and phenomenal experiences, and beyond to imagine and conceive of performative technological ecology interfaces. The history of my own practice stems from interaction design – which spans many forms of interface development and user experiences between a digital platform and human users; from the fading years of the 1990s through to the mid-teens of this century, much of my professional design practice was experimenting with and applying HCI designs and controls – a practice of experimenting with data translations which has flowed into this research. This research therefore is situated as an extension of that practice, investigating new types of interfaces between Nature, humans, and technologies – hence the resulting multi-sensorial devices. Through the various methods to create these robot artefacts, it was found that ontological implications of design are revealed – that is, design praxis itself was necessarily modified through the acts of designing the robots with a *genuine* more-than-human mindset founded on *Speculative Realist* ideas.

2 A Brief Introduction to Key Concepts from Speculative Realism, Object-Oriented Ontology, and the Quadruple Object

While it is beyond the scope of this article to attempt to summarise all Harman's work on *Object-Oriented Ontology*, it is necessary to draw out some key ideas and offer our applied interpretations of them. Of particular

5 Norman, "Human-Centered Design Considered Harmful."
6 Redström, *Making Design Theory*, 6.
7 Willis, "Ontological Designing," 70.

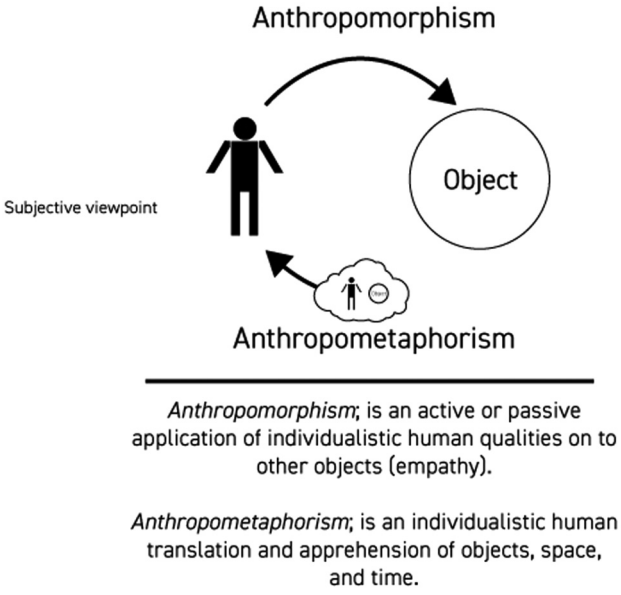

Figure 1: Anthropomorphism and Anthropometaphorism.

importance to this research are the books, *Object-Oriented Ontology: A New Theory of Everything,*[8] *The Quadruple Object,*[9] and *Art and Objects.*[10]

First, we can situate *Object-Oriented Ontology* and other contributing ideas to this research as being *Speculative Realist* in nature. The essential premise of *Speculative Realist* thought is fairly straightforward in our interpretation of it. We consider that while there is a reality outside of ourselves, and indeed "outside" of everything else, no one object has any direct access to an objective "true" reality. Rather each object has access to a reality which is non-direct, filtered, translated, and understood through its physiology, its materiality, and its mere existence. This translation and understanding do not imply that objects have qualities of some type of animism or panpsychism, and we're certainly not encouraging a casting of thoughtless anthropomorphic qualities on objects. Instead, objects should be considered as having some capability, likely quite alien to human understanding, to translate their being-in-the-world as they travel on the journey of entropy; whether this translation is through their changes in physicality, changes in essential qualities, or even some form of change in the realms of our imagination for non-physical objects. These object-oriented translations of reality could be further apprehended through their senses or cognition – if those abilities are available for those objects. Because these translated realities are outside of ourselves and everything else, then the only way we can approach any apprehension of these object realities is through speculation, imagination, research, and poetics. Hence, the term *Speculative Realism* is suited to this premise of seeing realities as pluriversal, multiversal, and uniquely individualistic.

A key insight from applying *Speculative Realist* philosophy in this research is the awareness and acknowledgement that we, as humans and in generalised terms, are constrained by a continuous anthropo-*metaphorisis* of reality (Figure 1) – which can be said to be a natural translation of reality through human physiology and senses of spatiotemporal scales – but we need to move beyond this generalisation. We noted above that objects translate their realities on individualistic terms, so we can say that, if I myself am in an *i-metaphorisis* of my reality – which is translating/interpreting/relating to what is outside of myself into terms suitable to my unique physiological capabilities and life experiences – then you are in a *you-metaphorisis* of your reality. And there may be many overlaps between our translations because of shared physiological

8 Harman, *Object-Oriented Ontology*.
9 Harman, *The Quadruple Object*.
10 Harman, *Art and Objects*.

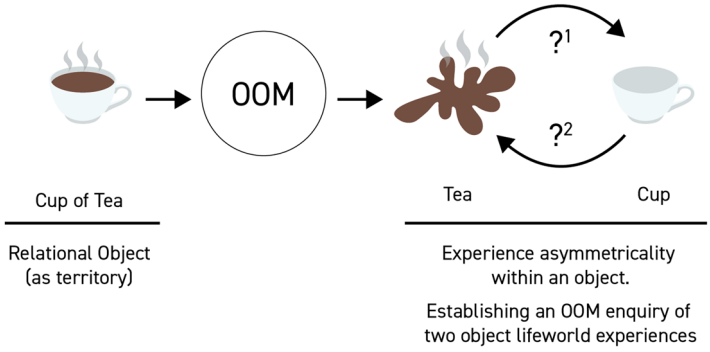

Figure 2: Cup of tea context, considered through OOM, to query the tea's and the cup's unique metaphoristic worldviews.

attributes, but they will necessarily be different. Even my worldview apprehension from yesterday will be different today because I have moved on in time, in space, on my own entropic journey. Hence, for object-oriented speculations, we speculate on object-*metaphoristic* translations of their unique realities, and we can do this with the assistance and reasoning found in *Speculative Realist* ideas. Through design praxis, the acts to research, materialise, and reflect on these object-*metaphoristic* worlds we have called *Object-Oriented Metaphorism* (OOM). This notion of object-metaphorism is important, as we are setting up to create devices that reveal a *metaphorisis* of alien, uncanny, situations between Nature, technology, and humans, while attempting to be equally respectful to each entity's reality – and we can set about these acts of design with the assistance and reasoning offered by *Speculative Realist* ideas.

Object-Oriented Ontology (OOO) is, in the views set out above, a *Speculative Realist* philosophy. However, OOO reinforces the idea that these speculations on object lifeworlds are to be object-oriented and to depart from our habitual reflexive anthropocentric anthropomorphism (which is the *giving* of human qualities to nonhuman objects based on human priorities – Figure 1). For OOO, it is vital to remember that objects are any unified entity[11] from an event, a corporation, an assemblage, an idea, a human, to a planet. It is not enough, as a simple example, to speculate on a cup's lifeworld through a human perspective (Figure 2). We must extend our imaginative and research nous to speculate on how tea, for example, may experience the cup (thinking about the cup through a *tea-metaphoristic* worldview) – and in turn how the cup experiences the tea (from a *cup-metaphoristic* worldview). Even with this simple example, we can begin to see that the tea's experience of the cup will be vastly different to the cup's experience of the tea. This difference between relational experiences and their subjective translations within this context is an example of *asymmetricality*, even though we can assign the cup-of-tea as being a single object – a relational object, with a *cup-of-tea-metaphoristic* worldview. Suddenly, it may seem that we have a complexity of objects and experiences emerging. The relational object – the cup-of-tea – which is our context, our assemblage, our territory in this example, and within this cup-of-tea context there is a cup-object experiencing the tea-object and the tea-object experiencing a cup-object. To help us think through these object-oriented experiences and the myriad shifting tensions between them, Harman provides us with the concept of the *Quadruple Object*.

Graham Harman describes the *Quadruple Object* as a fourfold structure which defines for any object its "basic structural features. This structure is shared by all objects"[12] – defining their individualised and unique ontological presence.[13] The *Quadruple Object* is a valuable concept for establishing a more-than-human mindset for design contexts, as it helps orient speculations in object–object relations. The *Quadruple Object* concept is made of four parts. The phenomenological object, which is what other objects experience of this object, and which Harman calls the *sensual object* (SO). The SO is in tension with its momentary surface *sensual qualities* (SQ) and its hidden imbued *real qualities* (RQ). The SQ are momentary qualities of an object. If

11 Harman, *The Quadruple Object*, 7.
12 Harman, "On Vicarious Causation," 204.
13 Harman, *Object-Oriented Ontology*, 150–7.

we use an example of a wooden boat moored offshore, the SQ would account for its blue paint, its scratches and dents, the salty and diesel smells emanating from it, the clanking sounds of ropes against its railing, and so on. If we would repaint the boat with a different colour, tie down the ropes to stop the sounds, or let the boat fall into disrepair in some distant paddock, it would remain the same boat. The RQ on the other hand are aspects of the boat we don't directly perceive but we imbue the boat with the qualities that we expect the boat to have, such as there being a hull for it to float, a rudder for it to be steered, and a propeller for its propulsion. However, if we've never encountered boats or even the idea of boats before, then imbuing these hidden real qualities is going to be difficult and will be difficult for the observer's own innate imagination to allocate what is unseen. On the other hand, if the *real qualities* of the boat exceed our expectations – such as we are informed that instead of the expected unseen hull keeping the boat afloat it's actually supported by a gigantic turtle – then we can be surprised by the boat's *real qualities*, we are confronted by the boat's unexpected qualities, and therefore, the sensation of dissonance with the object occurs as we try and rationalise our expectations with our experiences. This brief outline of the phenomenal SO which is in tension with both *sensual qualities* (SQ) and *real qualities* (RQ) are, for this research, the easiest to describe, because these aspects of objects can be based on observation, experience, and reflection. The last of the four *Quadruple Object* aspects, the *real object* (RO), however, is more difficult because the concept remains abstracted.

In the *Quadruple Object*, the withheld aspect of objects, the object's Being, is accounted for in the RO, the *real object* – which is always withheld from (or in excess of) direct access but can be alluded to through speculation and artistic practices. The *Quadruple Object* allows for object-object relations: When an object comes into relation with another object, this relational object is an object in its own right, which could be referred to as a *context* or an *assemblage*, and has its own emergent *Quadruple Object*. When two objects come into a relation then the subject becomes the RO with the other object contributing the SO–SQ–RQ structure. This state of affairs reveals that a relation between two objects is not only vicarious (there can be no direct RO-RO tensions),[14] but also reveals the asymmetrical nature of relations – as the relational understanding is dependent on which object in the relation takes the subjective (RO) viewpoint. In OOO, the essence of objects is said to emerge in the RO-RQ tension. So if we follow the logic, then we can see that relational objects have the subjective RO forming essence with the other object's RQ.[15]

We can determine this changing subjective viewpoint within relational objects because we have an acknowledged and privileged viewpoint outside of this relationship. This external viewpoint allows us to speculate on the differing subjective points of view – we can turn relations around and inside out within contexts as we speculate on object lifeworlds. This directionality is a key finding which arose through the design research into the application of *Speculative Realist* ideas and from which the proposed *Object-Oriented Metaphorism* design methodology was developed – and therefore how this research conceptualised these sensual environmental robots (Figures 3 and 4).

3 Two Practice Projects, *Habitat Robots* and *Soil Protector Robots*

It should be noted that the robots from these projects exist as a collection of design artefacts such as hardware and software prototypes, animatics, 3D visualisations and animations, communication designs, and hand-crafted and 3D printed models. The devices as such exist between theory and actuality. With current knowledge and technology, the robots as displayed could be brought into full real-world functional realisations, and installed at suitable locations; using knowledge from disciplines such as soft robotics,[16] 3D printing, and so on. As a collection of artefacts however, human beholders are required to take part in the theatrics of the projects, and imagine their experiences with the devices being in the world and their relationality to data and Nature.

14 Davies, "The Problem of Causality in Object-Oriented Ontology," 100; Harman, *Object-Oriented Ontology*, 162–7.

15 Harman, *The Quadruple Object*, 75.

16 Fras et al., "Bio-Inspired Octopus Robot Based on Novel Soft Fluidic Actuator."

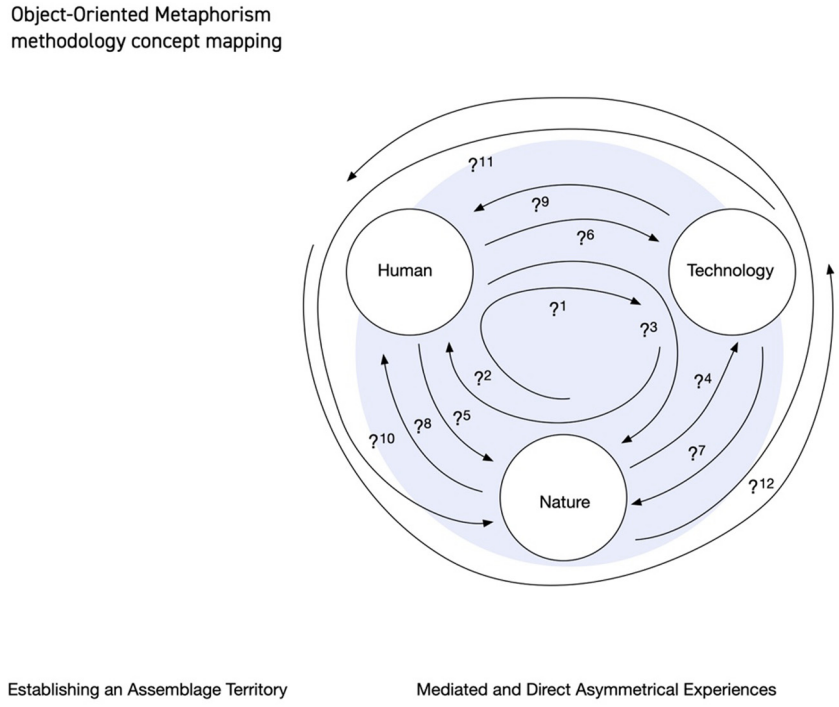

Figure 3: Mapping relation asymmetricality.

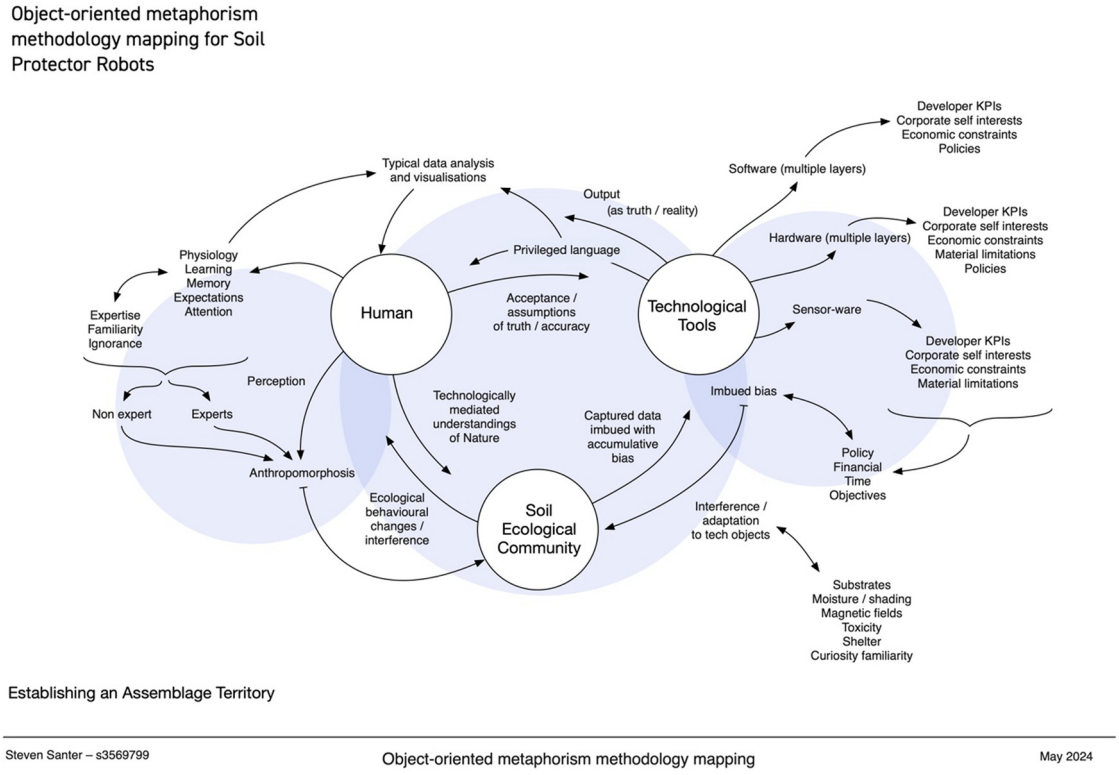

Figure 4: Mapping relation asymmetricality and context boundaries.

Collectively, the artefacts demonstrate how the devices communicate translations of environmental sensor data through various performances. They are ecosystem interface designs; performative interfaces between Nature and humans and technology while being humble and careful of their entwined natural contexts. Another way to understand the design premise of the robot behaviours is that they perform metaphors to map data translations, such as up is good, down is bad, being the most simple.

To approach this issue's theme, let's first define the usage of the term *sensual* as being interchangeable with *sensorial* or *multi-sensorial*, and the label of *robot* as a technological device which physically performs in response to translations of sensed data inputs. The presented creative practice research projects are various environmental robots, specifically created to elicit sensual arousal through their performative abstractions of environmental sensor data. Therefore, sensuality is an embodied multi-modal and multi-sensorial communication, experienced through the devices' performative and surface qualities which react to environmental sensor data. In turn, the (human or nonhuman) beholder's sensorial sensations are caused by the devices' forms, surface qualities, behaviours, and contextual strangeness to stir innate knowledge and awareness via the generation of phenomenal oddness, of stepping into moments of surreality via experiencing these technological beings. These projects explore the potential of simultaneous arousal of multiple senses from interfaces with Nature, via both active and passive experiences; providing subtle and poetic fulfilments, a satiation of curiosity of the world; of a satisfaction or, perhaps, of a disgust from the touch of varicosed surface textures and stiffnesses, the impulsive emotive and physical responses from odours, such as recoiling from the smell of rotten matter or the tilt of the head to maximise intake of perfumes from fresh blooms, to the closing of our eyes to heighten our hearing of technologies interacting with their surrounds – not the noise of gears or pneumatics, but of intentional mechanical designs to replicate sounds of gurgling, sighing, dripping, as if we are listening to wind in the trees or to lapping ripples on a lake shore – all as part of possible technological sensorial communications to humans and nonhumans alike. The underlying applied object-oriented philosophies for these convergences of multi-sensorial stimulation elicited from these strange technological devices are discussed below. However, before delving in too deep, a description of the four robots is required; there are two robots from the *Habitat Robots* project and two from the *Soil Protector Robot* series.

The first robot ("Robot 1" in Figure 5) from the *Habitat Robots* project stands approximately 60 cm high. It is asymmetrical, with three leg-like tentacles which provide a covering of the long sensor cabling. The tentacle legs wind their way outward from an elevated pot-bellied triangular body. The lower part of the legs are flexible allowing for placement in the environment and the subsequent burying of the sensor cables down to 60 cm below the surface soils. The device's body houses the technologies it needs; a chargeable power-bank, the cabling carrying the arriving sensor data, the microcomputer with custom software to translate the data and send variables to the actuators which push and pull the flexible pneumatics which subsequently control

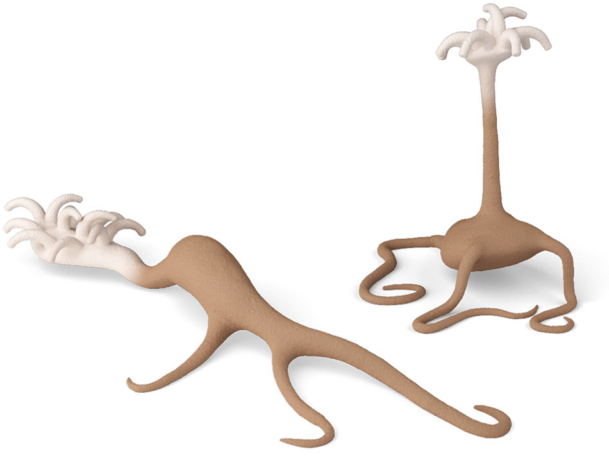

Figure 5: Habitat Robots screen capture of data controlled animatic composite. Robot 2 (left) and Robot 1 (right).

Figure 6: Still frame from Entropic: Soil Protector Robot animation.

the feelers. Arising from the middle of the round body of "Robot 1" is a disproportionately long slender neck upon which sits a bulbous head. The neck conceals flexible pneumatic tubes, while the head holds a blossom of 11 feeler-like protuberances measuring about 4.5 cm in length. The head and feelers hint at – but not-quite – flower qualities, perhaps closer to having qualities of crawling fingers. The feelers are the performative parts of the robot, they arc up and droop down in response to pneumatic pressures which are driven by the translations of the environmental sensor data. The computed translations are contextualised by a configuration text file – meaning that each robot can be specialised by expertise to "correctly" interpret the environment in which it is measuring. (See "Further Research" section below for a more detailed technical description.) The surface of the legs, body, and neck are tan in colour and gently stratified with a rough rock-like texture which is designed to slow rainwater as it falls down and to provide a substrate for spores. The head area including the feelers is a warm white, making the communicative parts of the device more visible from a distance. The second robot ("Robot 2") is also weirding in its asymmetricality. Its surface is the same as "Robot 1," tan and white, and sandstone rough. However, where the first robot is tall, "Robot 2" stretches its long narrow body over the ground, measuring 90 cm in length. Its legs are splayed wide to balance its disproportionate body – its mid-section balloons oddly, like a snake that has just eaten an almost over-large animal. The body arches up off the ground. Its head is held up, just off the ground, where it seems to awkwardly rest its contorted neck. These two robots are siblings and they are designed to communicate a general health status, a sense of health, of a given ecological community. They share the same traits and language despite the forms differing between horizontal and vertical formats.

Meanwhile, the two robots from the *Soil Protector Robot* series are not siblings. They are entirely different from one another. These robots however carry the same purpose, which is to engage with and signify soil health as informed by expertise. The "Entropic Robot"[17] (Figures 6 and 7) resembles a combined mix of a landed octopus or jellyfish, a colony of sea-squirts, and perhaps something from the Alien movie franchise. This robot's main body-mass size is approximately 25 cm long × 25 cm wide × 6 cm high. It has four flexible tree-like roots or tentacles which cover the sensor cabling. The flexibility of the entire robot is one of its key differentiators – it being able to be installed in and over complex terrain – minimising disturbances to the surrounding ecological community. This robot has misshapen pustule nodes across the top of its body mass.

17 See the "Entropic Robot" Technical Overview poster (Figure 7). See Fras et al. "Fluidical Bending Actuator Designed for Soft Octopus Robot Tentacle" for technical examples of soft robotics, which has informed the mechanical design approach of *Habitat Robots* and the "Entropic Robot."

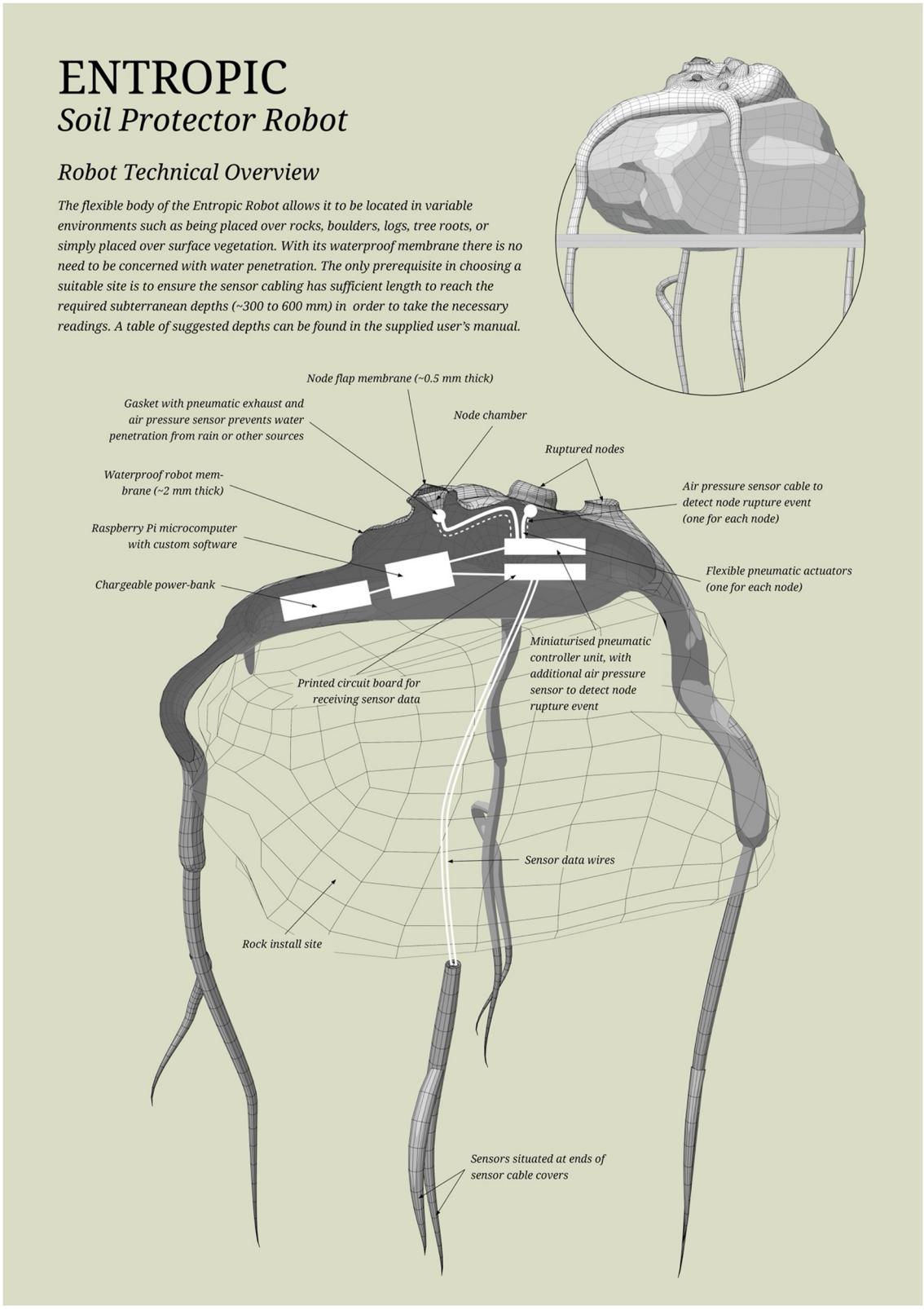

Figure 7: Technical poster for Entropic: Soil Protector Robot.

Figure 8: Still frame from Coral Spawn: Soil Protector Robot animation.

The nodes are this robot's performative features. When a criticality point is measured from the streaming soil sensor data, the software will select an available node, which it will quickly fill with air from connected pneumatics, until the node bursts open – revealing a luminous green internal lining; once broken, the software registers this node is no longer available for future eruptions – limiting and entwining the robot's life to that which it measures. The "Entropic Robot" has a glossy-wet, sweaty surface. The sheen highlights its rough textured surface which is coloured like poorly mixed green and brown paints. The blotchy surface is broken up by varicosed light-brown veins bulging here and there across its surface. It's an unpleasant device to look at. It looks diseased. It acts diseased. It pants, gasping. But we should only judge it by the nodes which have been burst open and the ones that remain – as this indicates the health of the ecological community it is measuring and the remaining lifespan of the device.

The second robot from the *Soil Protector Robot* project is the "Coral Spawn" robot (Figure 8). A strange name for a terrestrial device. But its form and behaviour reflect the name. The body, which is approximately 46 cm in height, is like a small collection of tube corals which are reaching up from a body-mass, which is supported by its very long sensor cabling tendrils. The length of these supports allows the device to measure an area up to 16 m^2. Reaching upward from the body are three main coral-like tubes with much smaller tubes branching outward. This device's form and surface qualities seem to allude that it exists between the worlds of plants and robots. When this robot translates that a criticality point has been reached, it spews forth a foul odorous orange fume.

4 On Theory and Language

As introduced, the research implements the term *robot* as being synonymous with a technological device which physically performs in reaction to computed translations of sensed data. Let's dwell for a moment on how this research has considered the semantics of the label *robot* for these un-robot-like devices. The impact of how the research discusses the *Habitat Robots* and *Soil Protector Robots* projects has been purposefully considered – as language is how humans instruct imagination,[18] co-create intersubjective experiences of

18 Dor, "From Experience to Imagination."

objects, and reflect on objects.[19] Therefore, we have used expected imaginings and language about robots to jar human phenomenal experiences of these devices. As a simple thought experiment of this premise, if you were presented with an electric vehicle and you were told it was a robot, this immediately sets up a confrontation with the car-object in front of you, and you would attempt, within your bounds of conceivability, of belief, of hope, to theorise hidden but possible expected robot qualities of that vehicle – you would theorise that there are robotic qualities contained in the car by attempts of rationalising transferrable aspects of whatever you may know of robots into the phenomenal vehicle in front of you, without any change occurring to the car-object itself – instead *you* have changed because language has set up intentional aspects of the object. Victoria Escandell-Vidal referring to social interactions discusses expectations as "[…] the cognitive, internalised image of … what we perceive as normal,"[20] and these devices (as robots) confront that internal normalisation. In other words, what the applied language does for our interactions with the projects' devices is to entangle […]

> [t]he subject's previous knowledge (of robots) [feeding] back to modulate basic perceptual processing in sensory cortices (of the phenomenal devices). [W]here prior knowledge guides the interpretation[…].[21]

The research claims that the *Habitat* and *Soil Protector Robot* artefacts, so labelled as robots, is a purposeful provocation, a Heideggerian breaking of the internal normalised object, in order to jar the human beholder's confrontation and thereby bringing their awareness closer to the devices' contexts and materialities. If we had named the devices *Critical Ecological Representations*, such a title would be entirely new and is, therefore, empty of any prefiguration, an empty SO-SQ-RQ structure awaits fulfilment and so no breaking of some normalised robotic aspects can occur; in other words, the human beholder would be pre-prepared for some new experience. Holding to the *robot* designation, however, generates dissonance by having pre-filled an intentional SO-SQ-RQ structure with robotic concepts which sits in contrast to what is physically presented – particularly in challenge to the prefigured and/or intersubjective aesthetic assumptions of some sort of shiny metallic humanoid, which is largely informed by myriad sci-fi visions,[22] or assumptions informed by imagery of assembly line robotics. Enhancing that provocation to our internalised image of robots is a compounding weirding – these technological objects attempt to communicate with our innate natural knowledge (such as our knowing when a plant is dead despite us not having ecological expertise) and to engage our morbid curiosity (such as when one is confronted by the strange biological and cybernetic enmeshments in H.R. Giger's work).[23] We can examine the resultant dissonance caused by the robot designation and the phenomenal object through the *Quadruple Object*.

Earlier, when we introduced the *Quadruple Object*, we referred to essence as forming between the subjective RO with an object's RQ. However, when this tension is malformed or broken, the sensation of dissonance occurs (where the subjective RO – in this case is a human, and the RQ – which are the hidden imbued qualities of the relational human–robot–object).[24] The research proposes that dissonance is established by creating disharmonies between two concurrently experienced (SO) robot objects; the prefigured, ideal, intentional robot in the mind (informed by subjective expectations of "robot") which sets up experiences of incongruency from the characteristics of the phenomenal robot artefact, and in return the exceeded qualities of the phenomenal robot challenge our prefigured robot in the mind. The two robot RQs which should be commensurate, according to a priori expectations, aren't – the theory (SO-RQ) tension shudders out of phase.[25] Both phenomenal robot and the expected intentional robot have seemingly little RQ equivalency and a harmonised or reconciled essence can't be achieved with the human beholder's RO – yet we hold to what we think is normal, and continue to attempt to make sense of our sensations in confrontation with an eerie

19 Krawczak and Mickiewicz, "Review of Jordan Zlatev, Timothy P. Racine, Chris Sinha, and Esa Itkonen (Eds.). The Shared Mind," 289.

20 Escandell-Vidal, "Expectations in Interaction," 494.

21 Ibid., 497. with author's additions in parentheses.

22 Auger, "Why Robot? Speculative Design, the Domestication of Technology and the Considered Future," 33–8.

23 "HR Giger ARh+."

24 Harman, *Object-Oriented Ontology*, 159–61; Harman, *The Quadruple Object*, Figure 7 on 107, Figure 8 on 114, 116.

25 Harman, *The Quadruple Object*, 104.

technological-organic form.[26] This continues until we loosen the hold of (change) our normalised prefigured expectations – which may be momentary or unending. Therefore, the research contends that merely the label of these devices as robots is a useful provocation to sensorial sensations. However, we can claim that these devices are in fact robots, because while there is a generally understood idea of what a robot is – and hence the provocation – there's no real consensus, so we borrow from James Auger's broad definition:

> for a thing to be considered a "robot" it should be able to sense and interpret in some fashion its environment, compute decisions based on that sensory information, and then act on those decisions in some mechanical way.[27]

Therefore, the project devices, being defined as robots within that definition, force not only the tension between expectation and actuality, but also allow the robots to embody tensions between seemingly organic, anti-literal performances and expectations of typical articulate robotic performances.

Following the above reasoning offered by *Quadruple Object* logics, we have established how language sets up theoretical expectations ahead of phenomenological experience. We have argued that language prepares the way for emotional and sensorial experiences a priori. Since, it can now be said that expectations are prefiguring experiences with the robots, the boundaries of the robots' context has therefore extended beyond the material and the physical. The application of *Quadruple Object* logic has shown how the prefiguration of beliefs, hopes, fears, etc. come to bear on experiences of the multi-sensorial devices.

5 How Can Robots be Sensual?

In this section, to understand how robots can be multi-sensorial, the research's applied interpretation of *Speculative Realist* concepts is explained. To begin considering the philosophic applications for the presented sensual robots let's first consider their forms. The design rationale took the stance that the forms, when perceived from a distance, must "break into consciousness"[28] and become near at hand.[29] This breaking is akin to Heidegger's tool analysis of the broken hammer which forces an awareness of the tool's presence, its materiality, and its contexts. But for our purposes, what breaks is our assumptions of the assemblage of urban Nature; suddenly there is an ill-fitting form infiltrating our foreshadowed expectations of an urban Nature context. Here, Harman's position is taken, that this breaking is the break into consciousness,[30] we become aware of the object. This is why the *Habitat Robot* and *Soil Protector Robot* forms are purposefully unexpected, in a surreal, uncanny sense; they are designed to initiate the breaking of the context's evanescence. Furthermore, the forms are dramatically asymmetrical in an effort to prevent easy relatability through our continual anthropomorphic conceptions of the world and to encourage surveillance of the object and its context.[31] That is, the asymmetrical forms provide unexpected Husserlian *adumbrations* and "serves as sensual "stimulus" by "instinctively driving" the perceiver to attend to it unwillingly" Beyer quoting from *Husserliana Mat.*,[32] "[…] in which case the subject enters "the first main stage of the striving for knowledge […]"."[33] Once a human beholder is actively aware of the environmental robot, the robot's performative actions can now engender charm and enchantment, inviting time to be spent in the presence of the alluring device as it harmonises or disharmonises with our physiological receptors and expectations. In Harman's *Quadruple Object*, the sense of charm from objects is said to arise from the tensions between SO-SQ, the tension between the phenomenological object with its changing surface qualities. Because we can control the devices' repeating

26 Harman, *Object-Oriented Ontology*, Figure 3 on 184.
27 Auger, "Why Robot? Speculative Design, the Domestication of Technology and the Considered Future," 37.
28 Harman, *Object-Oriented Ontology*, 152–3.
29 Harman, "Technology, Objects and Things in Heidegger," 21.
30 Harman, *The Quadruple Object*, 38–9; Harman, "Technology, Objects and Things in Heidegger," 20.
31 Harman, *Object-Oriented Ontology*, 155.
32 Beyer, "Edmund Husserl," Part 7. Passivity vs activity.
33 Beyer quoting Wu Beyer, "Edmund Husserl," Part 7. Passivity vs activity.

and anticipatory changes over time[34] charm can be induced with the device through rhythmic patterns. Once charm and/or curiosity has been established, and thereby a conscious awareness of the devices, the robots' performances can now attempt to convey meaning through our natural knowledge of living things.

We generally understand that plants and ecological communities exhibit their health status through their physicality, and part of this understanding stems from us receiving multi-sensorial sensations. These subtle communications of nonhuman lifeworlds that we receive contribute to our enchantment with natural environments; perfumes of budding blossoms, unfolding waxy new foliage, fungi-covered decaying logs emitting sweet woody fragrances, a deadened bough dryly creaking, and so on. For many plants, we can gauge their general health status at a glance, with our innate, natural knowledge filling the gaps. Therefore, without any expertise we understand. There are multi-modal and multi-sensorial sensations indicating a plant's health; smells of stagnant rot or flourishing perfumes, visual indications of withering or burgeoning foliage, the repulsive feel of slimy residues or the pleasing feel of shiny polished waxes. It is this type of accessibility to our innate knowledge that the device-artefacts have been designed to activate – as an escape from privileged data experiences (i.e. typical treatments and access to data mapping).[35] This avenue for robotic designs enables technological devices to convey to humans (and humbly to nonhumans), the connected ecological communities' status, through emancipated physical languages. These physical languages are situated as a range of anti-literalist translations of the gathered sensed data, and performed through multi-modal multi-sensorial channels.

It is this paradigm of sensual robots that the design research has examined to grasp the thinking and processes required for a more-than-human design praxis; where robots perform as interfaces between Nature-objects, technology-objects, and human-objects, communicating via multi-modal multi-sensorial capacities (Figure 4). With the premise that, as the ubiquity and potential of robots and devices increase for an increasingly at-risk natural environment, so too must their accessibility increase across not only human–machine interactions but also nonhuman–machine interactions. Let's first consider the robots from the *Habitat Robots* project, which both perform perhaps the most simple of data mapping metaphors – up is good, down is bad – which is exhibited in a collective blossom of feeler-like protuberances stemming from their bulbous head-like forms. The performance is the result of the *Habitat Robots'* translations being programmatically computed of the streaming ecological community's and environmental sensor data – it could be argued that the resultant movements are barely more than what plants indicate through a general premise of upward is life, downward is sickness or death; however, these robots *anthropometaphorise ecological time* – a move from ecological timescales to human timescales.

The *Habitat Robots'* feelers' movements en masse are tuned to our human-timescales, they echo the movements of sea anemones softly flexing and bowing with hidden ocean currents. The robot feelers similarly flow in their response to flows of hidden data streams (Figure 9) – hypnotic-constrained arrhythmic movements. Despite the RO–RQ dissonance from their forms, which captured our attention, the SO–SQ rhythmic tension allows us to meditate with the object and its connected context – we become warmly entangled. Plant movements similarly move to corresponding environmental conditions, yet do not so enthral us as they move in plant-time not in our rushed human-time, and therefore the rhythm between the phenomenological plant and its surface changes is too stretched for satisfying human enchantment. With the outlier of course if one has trained to *see* in plant-time such as a passionate gardener may. The *Habitat Robots*, therefore, are designed especially as anthropometaphorises of plant-time; allowing us to access the environmental conditions in human-suitable timescales that offer us a rhythm betwixt the phenomenological robot and its changing sensual qualities. The *Habitat Robots*' data mapping performances are to elicit a contemplative attitude toward the robots and the connected ecological community; akin to watching a gentle burning fire or listening to waves gently rasp and sigh over sand – these natural phenomena can enchant us in our human timescales.

34 Harman, *The Quadruple Object*, Figure 8 on 114.

35 Willis, "The Ontological Designing of Mapping."

Figure 9: Still frame from data controlled animatic showing a close-up of "blossom" of Robot 1's feelers from the Habitat Robots project.

The *Habitat Robots* are literally entwined in and entwining their contexts in the mode of Haraway's *tentacular*.[36] If one wanted, one could reach out and feel the feelers move in response to their sensed contexts, as embedded pneumatics increase and decrease pressure within the silicone skins of the robot-feelers. Beyond the movement of the *Habitat Robots'* feelers, are the surfaces of their body mass which are made of ceramic and are gently stratified to encourage lichen and fungi to find purchase, and in the longer term mosses and grasses and invertebrates. The artefacts' material and surface qualities encourage symbioses between technological objects and Nature. The symbioses form because the growth and collections of ecological communities, enabled by the robots' surface, expand the communicative possibilities of the robots; time, space, environmental health, and biodiversity are shown by the accumulation of Natural companions. Technological objects such as these use Nature in a humble, symbiotic manner; offering substrates and habitat opportunities and thereby gaining new communication channels across sight, sound, touch, smell, and even perhaps taste. However, this will only work successfully if technological forms and material choices are purposefully designed for such symbioses, and not rely on accidental opportunities. This last point refers us back to the argued benefits of designing multi-sensorial environmental robots as an interdisciplinary research field for the betterment of design praxis and of contributing knowledge domains.

Let's now consider the "Entropic Robot" from the *Soil Protector Series* (Figures 6 and 7), which appears to be the most "successful" concept because it performs strongest in its weirding and its ability to connect to human observers via charm, and then breaking that charming connection. It mimics breathing. It pants rhythmically, by pneumatically inflating and deflating its blistered pustule-like nodes. Its gasping cycles within predetermined patterns of faster and slower, allowing for a harmonising pulse with our phenomenological expectations of the object with its surface qualities. Then, when environmental conditions trigger a performative reaction, "breathing" subtly quickens and the device selects a blistered node and forces air into it until its covering flap of skin bursts. Bursting breaks the rhythm of charm and we are confronted with the object;[37] we become aware, again, in a Heideggerian sense,[38] of our relation with device's context and materiality. The breathing then slows, placating the rhythmic break, returning to a sense of SO–SQ harmony, while echoes and evidence of past disharmony keep us enthralled with the device, the context slides back into the background, as we await the next break in the rhythm.

Conversely, the "Coral Spawn" robot of the *Soil Protector Robot* series (Figure 8) lacks this charming breathing performance. Instead, this environmental robot spouts various volumes of an odorous dense orange

36 Haraway, "Tentacular Thinking: Anthropocene, Capitalocene, Chthulucene."
37 Harman, *The Quadruple Object*, 103.
38 Heidegger, *Being and Time*, 105.

fume which impermanently stains the immediate vicinity. The orange smoke smells of decay and cautions humans and other animals to remain away, while its nutrient ingredients support fragile botanical communities. The SO–SQ tension is seemingly static; any obvious rhythm is absent for us to harmonise with the "Coral Spawn" phenomenological object (SO) to its momentary surface qualities (SQ). Only the oddness and the asymmetricality of the form invite sensual stimulus as we try to imbue suitable hidden *theoretical* qualities (RQ) into the strange artefact.[39] The oddness encourages human observers to circumvent the object to gain understandings of this unexpected form and its context, to touch the form's undulating surface that resembles both organic and technological growths and extensions – a Giger-esque device. Only hints of the underlying potential of purpose and action are phenomenologically available, our theory of it remains lacking for now, but our uncertainty of its physical presence offers temporary allure. We now notice an orange residue staining the nearby ground and plants which encircle this robotic-being. The orange staining is shadowed by the robot's form, we deduce we are seeing evidence of past eruptions emitted from this form, with residue strewn stickily across its immediate vicinity – now our attention has sensed past time with the robot and the immediate environment, and we develop a state of suspense in anticipation for witnessing the next event – like waiting for the right wave to trigger a blowhole's spouting, while the surrounding moist rock surfaces provide us with a cautionary telltale of how long we may have to wait and – certainly – where not to stand.

Developing the sensorial robot design decisions with the *Quadruple Object* and other object-oriented philosophical concepts has provided a depth of reasoning and critique for such decisions which could not have been achieved without them. The philosophical ideas that I have grouped under the borrowed term of *Speculative Realism* fulfil the descriptor of speculating on lifeworlds and realities beyond any direct access – crucial for a design praxis to maintain a genuine more-than-human framing. It has been found that *Speculative Realist* ideas applied in design praxis exhibit what Harman wrote as series editor in DeLanda's book *Assemblage Theory*;

> [...] Speculative Realism defends the autonomy of the world from human access, but in a spirit of imaginative audacity.[40]

However, I would amend the statement to end with "[...] in a spirit of imaginative audacity, joy, and a sense of enchantment." The ideas of *Speculative Realism* which have been implemented in this research succeed as a foundation for a philosophy of design which can reason more-than-human approaches – providing both a platform of reasoning for design decisions, critique, and, crucially, an imaginative space for research approaches. Having both investigated and applied interpretations of these philosophic ideas, the research is now in a position to advocate for an object-oriented turn in design praxis while further refining its own *SR Design* theory through the finalisation of these sensual environmental robots.

6 Ontological Design Considerations for Sensual Robots

As introduced, through the *Habitat Robots* and the *Soil Protector Robots* practice projects, we can put forward two propositions for the practices in designing sensual robots, particularly for environmental contexts. The first, as discussed above, is the emancipated communicative possibilities for human and nonhuman sensorial experiences of the resultant artefacts themselves – that is the liberation of the languages of environmental data through the devices' anti-literal performances. The second is for the benefit of design praxis and contributions to the associated knowledge and practice domains – as the knowledge domains which are required for designing such robotic devices force, not only a nonanthropocentric research design approach which encapsulates technological and Natural lifeworlds and our societal entanglements among them, but requires investigations across differing knowledge silos. For instance, throughout the stages of ideation and prototyping, research of ecology, philosophy, software development, electronics, art theory, and so on, was

39 Harman, *The Quadruple Object*, 104.
40 DeLanda, *Assemblage Theory*, Prior to Imprint Page.

necessary to inform the design directions of the devices, as they each embody the acknowledgements of the enmeshed asymmetricality of human, technology and Nature relationships among their intended contexts.

The ontological design argument, therefore, is based on the epistemological value for design praxis through investigating the convergence of sensoriality and technological devices, and the work in materialising object-oriented metaphorisms. Ontological design refers to the feedback loop from the acts of designing and the resultant design artefacts affecting in turn design practitioners and practices – Willis phrases this far more eloquently as; "we are designed by our designing and by that which we have designed"[41] (see also Fry).[42] The research has found that the designing of environmental sensual robots, which are to communicate among myriad human and nonhuman sensorial channels, is genuinely achieved through humble, object-oriented perspectives and interdisciplinary expertise in order for the devices to exude a sincere, tentacular, enmeshed presence. The context of sensual robot designing not only provides opportunities for interdisciplinarity – and thereby transcend knowledge domain boundaries – but there is a prerequisite for interdisciplinary collaborations[43] and imaginations. Without this interdisciplinarity, understandings of the entwining human and nonhuman lifeworlds would likely remain disingenuous – leaving understandings founded on speculative, artistic explorations. Furthermore, the collaborations enforce an openness to serendipitous moments in research and practice as well as the development of a common shared language through diverse points of view. The melding of knowledge domains along with the needed imaginative contortions, create a conducive environment for the design of plausible technological physical behavioural translations (i.e. the mapping of data to abstract physical performances). The complexity of sensuality in environmental robots, as experienced through this research, has shown that a design practice does not become bedded-down into familiar tropes nor does one become an expert in the design of abstracting sensor data through a mere handful of projects; rather, this field of practice is to be considered an on-going dedication of investigation and experimentation into new forms of interfaces between humans, Nature, and technologies. The object-oriented framing of the creative practice research, therefore, takes design praxis itself along on this journey, undergoing iterative improvements – one can imagine this journeying of improvements with Bennett's commentary on evolutionary spiralling pathways[44] – where, as we cycle through iterations, we always end up somewhere new. Therefore, the acts of design required to create multi-sensorial robotic artefacts involved the purposeful refinement of design processes *as a practice of design* in its own right. Because the design processes remained in flux, they remained active participants in the acts of designing. We can summarise this scenario somewhat by reversing the expected design relationships – instead of design processes designing a sensorial robot, we can establish that design processes are themselves outputs of designing *with* sensorial robots; this, Haraway may call a "curious practice,"[45] but here it is entangled with the assemblages of design practice itself, as well as the technological, the cultural, and the Natural. It has been found that both the completed sensual robot artefacts and the required design processes and collaborations to create them have provided opportunities for design thinking to be re-connected and re-enchanted with the amazements, the mysteries, the "*beatitude*" of the world.[46]

7 Discussion: On New Forms of Design Theory and Practice for the Creation of Novel Ecology Interfaces

A number of findings from the research have been through the opportunity to expound on the complexity of a design practice's role in creating plausible yet speculative human–machine/nonhuman–machine interactions.

41 Willis, "Ontological Designing," 70.
42 Fry, "The Origin of the Work of Design," 18.
43 Choi and Pak, "Multidisciplinarity, Interdisciplinarity and Transdisciplinarity in Health Research, Services, Education and Policy."
44 Bennett, *The Enchantment of Modern Life*, 38–9.
45 Haraway, "A Curious Practice."
46 Bennett, *The Enchantment of Modern Life*, 169.

The complexity emerges because of the remit in taking a more-than-human viewpoint requires a letting-go of familiar design trajectories – there is no central human user or key audience as such, but a context with objects coming and going. And within that context, there may be humans (or not) at any particular moment, along with the installed devices and the ecological community and environmental elements. To be genuinely more-than-human in practice, not only must we allow for the nonanthropocentric entanglements of Natural nonhuman lifeworlds, but we must also allow for the enmeshments of technological lifeworlds; from a device's concept, production, and use, to its disposal – these allowances are not specific decision points as such, but an on-going process of research and reflection, and is indebted to *Speculative Realist* philosophical positions for orienting the required thinking for speculating on these alien lifeworld journeys and relations.

An illustration of this journeying, as one follows the threads of technological enmeshments, myriad imbued biases can be postulated (through the tension of theorising SO–RQ), which can be so easily overlooked in technological systems.[47] And, for this research's focus of urban Nature, these biases find their way into mediating how we understand Nature (Figures 3 and 4). Audio recording equipment, as an example, may have sub-optimal materials for the desired purpose in its wiring, having been selected as a cost–to-benefit decision by the scientist or manufacturer. A given microphone then, may be selected for terrestrial field recordings because of budget constraints[48] or personal preferences such as logistics, consistency, or familiarity. Furthermore, the placement of microphones in the field may be selected because of physical accessibility, park policies limiting duration or areas of access, or of the technical requirements of the recording equipment. These choices all lead to certain data[49] being collected that stands in for actuality, in turn contributing to analysis findings, reporting, and policy decisions. Therefore, we can say that seemingly innocuous devices like the microphone have moral significance.[50] This is not declaring one way or another that technological devices have morality embedded, but devices are "morally charged"[51] and likely to have "non-intended functions" which affect moral outcomes.[52] The scientist accesses and assesses the microphone's functionality quite differently from the organisation that manufactured it or marketed it – the scientist imbues their expertise and needs upon the device (RQ). This questioning of data's "truthiness," of data-as-reality, is an impetus for the research to create artefacts which embody data as anti-literalist manifestations. Performative and multi-sensorial. Abstraction of data in this way forces the human observer to always take part in the interpretation of the theatrics of nonliteral data mappings, which will always be signified by a level of uncertainty. Because the interface performances are anti-literal the data doesn't stand in for actuality but rather for a *sense of things*. The simple scenario of a microphone being used for in-field audio recordings begins to unveil the complexities in understanding urban Nature mediated though more-than-human lenses, and why the subject of multi-sensorial environmental robots provides such a fertile ground for philosophy, design theory, and creative practice research development.

Typical anthropocentric design approaches remain "grounded in market-based perspectives,"[53] and the emergence of decolonial design remains human-centric despite a leaning away from market outcomes.[54] Human-centrism remains a key issue for this research, and while the research is not a reaction against human-centred design (HCD), it is conscious of the issues HCD can embed.[55] If we consider the familiar anthropocentric design approaches, they are likely to avoid inherent uncertainties laying beyond human concern, yet they will also deny or overlook research into the uniqueness and potential for new, alien, asymmetrical types of nonhuman relations and experiences; with the relative certainty offered by HCD, it

47 VanderLeest, "The Built-in Bias of Technology," Part. 2.
48 Lamont et al., "Hydromoth," 363.
49 Ibid., 369 and 372.
50 Verbeek, "Some Misunderstandings About the Moral Significance of Technology," 77.
51 Ibid., 78.
52 Heyndels, "Technology and Neutrality," 1, 11, 17, 19.
53 Taboada et al., "Decolonial Design in Practice," 142.
54 Ibid., 143.
55 Thomas et al., "The Limits of HCD," 85.

will likely be the preferred pathway in the field of science communications and collaborations.[56] In contrast to HCD, more-than-human allowances within design processes invite non-conventional and non-tested ideas. The inherent uncertainty of more-than-human approaches as part of design processes will encourage a return to the default HCD practices where, as VanderLeest writes, "designers may miss better solutions simply because they are innovative."[57] It has been through identifying and speculating on forms of object lifeworlds through *Speculative Realist* approaches,[58] nonhuman spatiotemporal scales,[59] and the alien asymmetrical relations[60] through the *Quadruple Object*, within the overlaps of technologies, humans, and Nature, that the complexities and benefits of more-than-human design praxis are fully realised. A key, and at times what can be an overwhelming consideration for the research, however, is how can a design praxis reign in this complexity and remain pragmatic? As any given context is so entangled that arguably one could, given sufficient time, rationalise the involvement of the entire cosmos. And so, a *research design* decision on what defines the boundaries of a research context needs to be agreed upon at the outset. But what terms are suitable to define the boundaries of the given contexts? When writing observations during the early research stage for *Habitat Robots*, the context was restricted by boundaries of time (60 min of writing) and space (observable from a fixed position) and limiting the layers/depths of relations to a maximum of secondary levels to limit assumptions. (For example, a dead tree in a park offering bees a habitable location for their hive was an observed primary relationship, with bees propagating plants in the park were taken as secondary relations because though it is a known or assumed relationship, the relationship wasn't directly observed from my fixed position at that time.) It is noted that decisions on how contexts are to be bounded are laced with bias, but are an acknowledged limitation for the approach to remain pragmatic. A positive outcome, however, was being able to replicate those constraints across different sites, which allowed for differing contexts to be comparable. The broader research asserts that the combined processes required to achieve these informed, though speculative, interpretations of human/nonhuman relations and their contextual boundaries, teach us about our own manner of being in the world in new ways,[61] and as such it can be attested that the processes of research and design of sensorial environmental robots can be at the forefront of a type of more-than-human worldbuilding paradigm.

Of course, and this has been discovered in the research journey, people will be all too quick to remind us of the inherent paradox in more-than-human, object-oriented, and nonanthropocentric thinking avenues;[62] in that we are always stuck within ourselves. In fact, if we go back to the *Quadruple Object*, if any object–object relation forms its own unique Being in the world, with its own *Quadruple Object* – then any speculations one has of that object, will have one's own RO along with it! This is a permanent individualised viewpoint, and thereby casting an individualised essence and meaning across all – and hence, as discussed earlier, we find that individualistic anthropometaphorism is a permanent fixture. But this acknowledged constraint should not preclude efforts of stepping outside our human-centric selves, our self-limiting RO, and take the leap with "imaginative audacity" as Harman said of *Speculative Realism*,[63] and humbly, ethically, even poetically, reveal hidden worlds through multi-sensorial data experiences. These efforts will generate not only artefacts of curiosity and embody an emancipated language for data mappings from those languages of expertise or privilege, but emerging from the research processes themselves will be avenues to reconnect humans to nonhuman worlds, and "[cultivate] an ethic of generosity toward others."[64] Therefore, we can situate design practices that take on the domain of sensual robot design, even speculatively, are forums for a form of pedagogical praxis, the projects provide a locus for applied learning and experimentation, of bringing together

56 Norman et al., "Assessing the Application of Human-Centered Design to Translational Research."
57 VanderLeest, "The Built-in Bias of Technology," Part. 6.
58 Bogost, *Alien Phenomenology, or What It's Like to Be a Thing*, 5 and 14.
59 Morton, "Hyperobjects."
60 Harman, *Object-Oriented Ontology*, 86–7.
61 Haraway, "Tentacular Thinking: Anthropocene, Capitalocene, Chthulucene," 2, 7–10.
62 Bennett, *Vibrant Matter*, 18; Bogost, *Alien Phenomenology, or What It's Like to Be a Thing*, 106–9; Harman, *The Quadruple Object*, 120–1; Shaviro, "Panpsychism."
63 DeLanda, *Assemblage Theory*, Prior to Imprint Page.
64 Bennett, *The Enchantment of Modern Life*, 11.

Figure 10: Successful in-field test of robot translation software and hardware in Melbourne Royal Botanic Gardens. The two servos responding correctly to humidity (moisture) and temperature fluctuations.

and sharing key expertise to reveal new language and knowledge. In many ways, as has been discovered through the development of these environmental robots, the resultant artefacts are not only objects fulfilling their intended purposes but also objects of philosophy, objects of design theory, and objects of epistemology; in their making, they bring together and physicalise questions of boundaries between humans, technology, and Nature, while consolidating languages in which to discuss their concurrently emerging contexts.

8 Further Research

There is an entirely feasible opportunity for final versions of these robots being developed for the real-world. The robots can be made, as they have been designed as extensions of or utilise current technologies across domains of soft robotics,[65] 3D printing, and model making, software programming, and so on. To begin, the forms of the devices have been designed to accommodate within their body cavities the necessary power-bank, microcomputers, cabling, and so on. A range of software and hardware prototypes have already been completed demonstrating real-time translations of environmental sensor data (Figures 10 and 11). The set up in the prototype pictured uses a text-based configuration file, a Python script to write raw sensor data to a local text

65 Fras et al., "Bio-Inspired Octopus Robot Based on Novel Soft Fluidic Actuator."

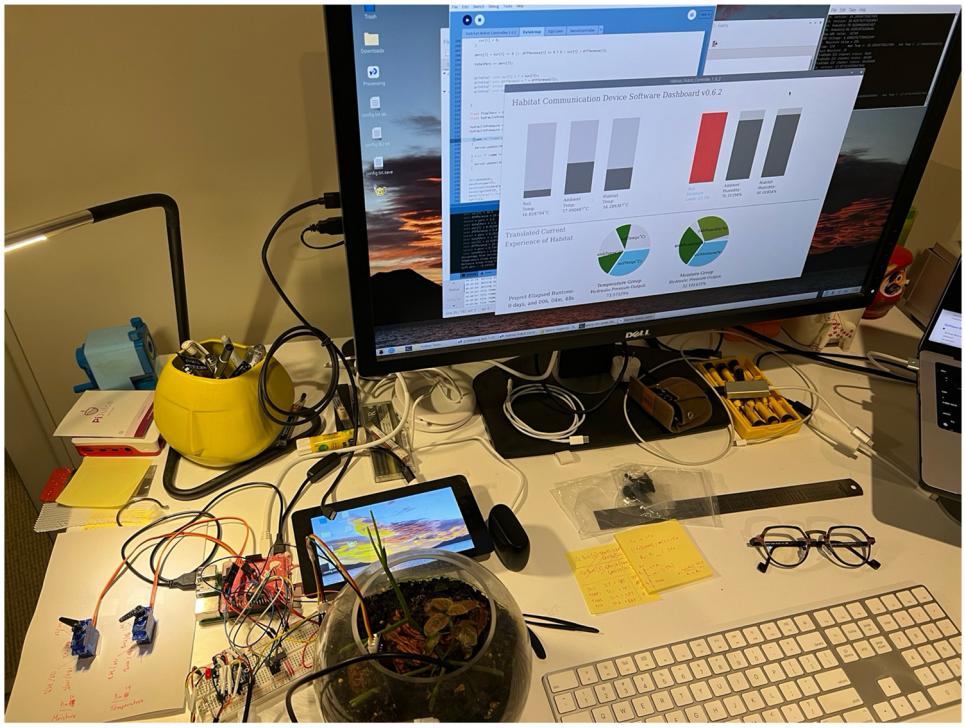

Figure 11: Desk-based tests of software and hardware running of Raspberry Pi micro-computer.

file which is then read in by a Java application running off a Raspberry Pi 4 microcomputer. This set up has succeeded in translating live sensor data from 6 sensors; ambient air temperature and humidity, habitat air temperature and humidity, and soil temperature and moisture. These six data streams are gathered into two groups – moisture and temperature. The configuration text file has three pairs of numbers for each sensor; optimal, tolerant, and critical values. The numbers for each sensor would be set or informed by someone with relevant ecology expertise to inform what are suitable ranges for each of the sensed aspects of the specific ecological community's needs. For instance, one sensor may be for ambient air temperature and, like the other sensors, would have the three pairs of numbers (in degrees Celsius); 15, 20, 10, 30, 5, 35. This translates to optimal air temperature being 15–20, a tolerant range of 10–30, and if temperatures fall below 5 or go above 35, then this would be a critical reading and could cause the ecological community to be irrecoverable (Figure 12). This being only one sensor, however, does mean that other sensor readings are taken into account before causing the resultant percentage to be a 0% reading for that group. The final translation for each of the two groups is then sent its respective servos. The servos in the prototype have successfully performed and correctly translated the sensor data into percentage values. This percentage value would then to be used to drive actuators such as pneumatics or hydraulics which in turn would drive the feeler parts of the *Habitat Robots*, or trigger a nutrient-imbued smoke canister of the *Coral Spawn Robot*, or cause sufficient air into a pustule-like node to burst on the *Entropic Robot*. Of course, these sensors are for prototype purposes only, and more sophisticated or expensive sensors to determine specific toxins, vibrations, or radiation could be used.

While substantial theoretical research can continue investigating the implications of *Speculative Realist* thought for establishing more-than-human design praxis via designing speculative devices and their contexts and subsequent worldbuilding narratives, there does remain an intriguing design practice-based investigation to be undertaken, and that is finalising these multi-sensorial robots for a subsequent real-world installation, testing, and observation of the devices in the field. Questions could then be answered, such as how do human and nonhuman audiences interact and interpret the devices? How do human experts and non-experts interact and interpret the multi-sensorial devices differently? How have natural entities accepted or confronted the

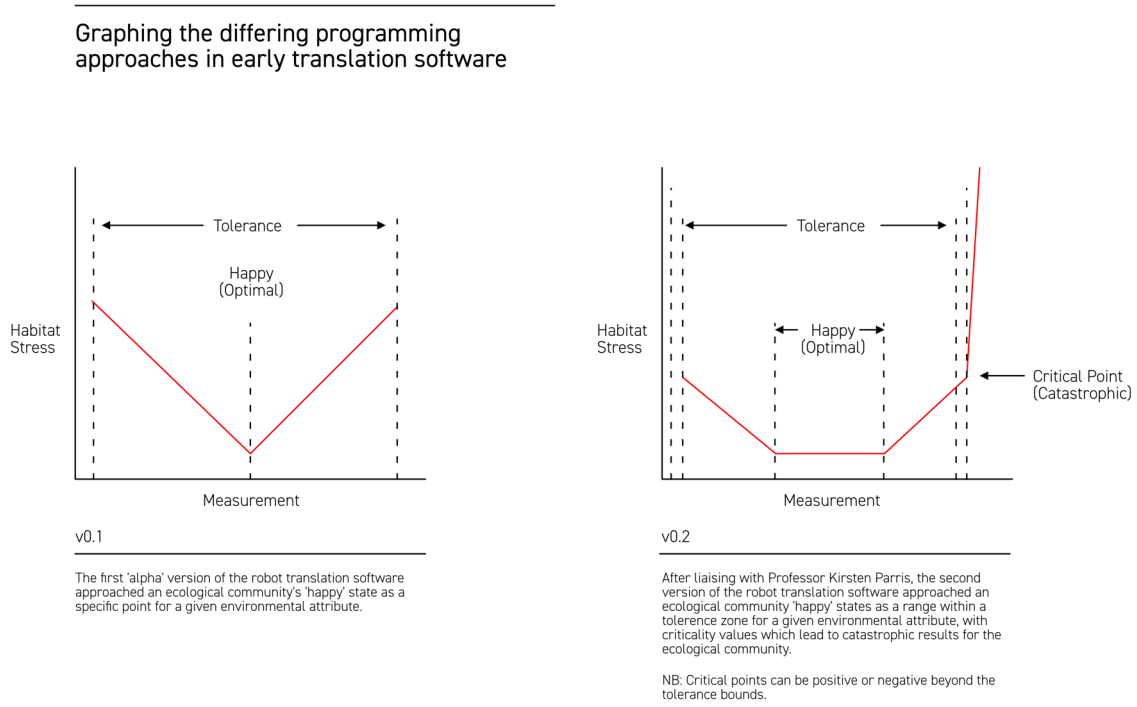

Figure 12: Software approaches to translating sensor data. The first version (left) was based on simple assumptions the second iteration (right) was improved via discussions with ecology expertise.

devices? And have the real-world devices performed as the philosophical concepts foreshadowed in facilitating new narratives about urban Nature conditions?

Deploying the devices into real-world contexts would provide a crucial step in being able to have empirical evidence of the successes or short-comings of the applied *SR Design* theory in real-world and science-based contexts and its application in creating multi-sensorial robots for complex environments.

9 Conclusion

In this article, two affirmative propositions have been outlined which have emerged from the development of multi-sensorial technological ecology interfaces. The propositions have stipulated why sensual robots that communicate multi-modally and multi-sensorily should be a pursued endeavour when opportunities arise – even as purely speculative exercises. The design research has demonstrated that these undertakings hone design processes, engendering "imaginative audacity," as well as generate epistemological discoveries as we learn about human and nonhuman sensorial capacities and craft their suitable metaphoric physical translations, while design praxis itself undergoes iterative refinements.

It can be seen by the references in this article, the diversity of knowledge drawn upon to discuss and create these sensual robots; with knowledge domains crossing from soft robotics, linguistics, design theory, art theory, philosophy, and ecology conservation. In the creation of the presented environmental robots, design thinking was supported by *Speculative Realist* philosophies oriented to understand the asymmetrical nature and politics of technologies themselves, particularly the nature of data and its mediating significance, and the enchanting realms of observations and speculations for mapping data as theatrical, abstract, physical performances in order to trigger our innate, natural knowledge.

These projects have shown immense value in designing this category of environmental robot; as not only have they provided opportunities for examining new types of devices which are aesthetically, materially, and performatively responsible for their intended ecological contexts, but their embodiment of sensoriality as key

communicative qualities for humans and for nonhumans emancipates language from expertise and privilege, and perhaps even from our own species. This freeing of privileged access to environmental data requires a genuine nonanthropocentric approach to their design and an understanding of asymmetrical relationships. These discoveries have only been attained through ideas provided by *Speculative Realism* while spending time with urban Nature, experimenting with technologies, and from interdisciplinary discussions with urban ecology expertise, and imagination focussed on the boundaries and enmeshments of humans, Nature, and technological lifeworlds. And lastly, the sensorial robots have reflected back and provided opportunities to interrogate design methodologies to be nonanthropocentric in reasoned applied practice and not just in hopeful ideology.

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